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Duxbury

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[54] **REMOTE CONTROLLED MULTI-STATION IRRIGATION SYSTEM WITH DTMF TRANSMITTER**

[76] Inventor: **Jonathan W. Duxbury**, 3673 Citronella, Simi Valley, Calif. 93063

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[58] **Field of Search** 364/146, 400, 420, 510; 137/15; 239/68, 70, 69; 455/95-100

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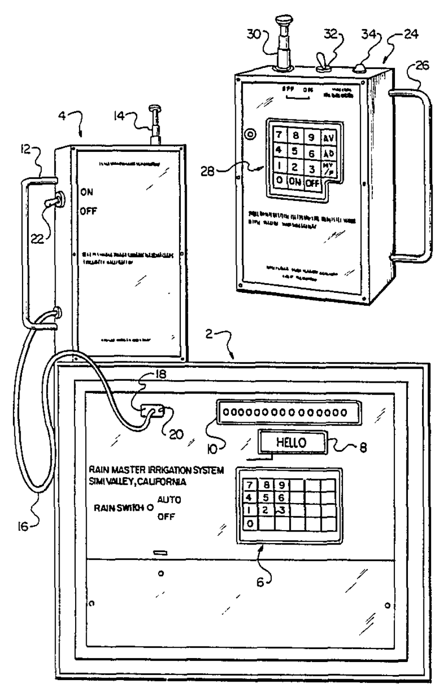
Primary Examiner—Jerry Smith
Assistant Examiner—Allen MacDonald
Attorney, Agent, or Firm—Koppel & Jacobs

[57] **ABSTRACT**

A remote controlled multi-station irrigation system in which discrete radio signals are transmitted from a remote location for each different function to be performed. The system includes a controller with a central processor, individual station actuator circuits, and interface circuitry; a transmitter which preferably transmits in an FM dual tone multi-frequency format, and a receiver which decodes the transmitted signal to hexadecimal data. The controller is automatically converted from a local to a remote operating mode by the insertion of a connecting cable from the receiver. The controller can be operated in real time or programmed for future operation from a remote location. The receiver can also be adapted for conventional controllers by adding field actuator circuitry which is connected directly to the field wires, bypassing the controller during remote operation.

20 Claims, No Drawings



REMOTE CONTROLLED MULTI-STATION IRRIGATION SYSTEM WITH DTMF TRANSMITTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to irrigation control systems, and more particularly to a system in which a multi-station controller can be operated from a remote location.

2. Description of the Prior Art

There are many large irrigation systems which employ a large number of widely separated valves to irrigate an extended area. Examples of such installations include farms, golf courses and large real estate development projects, in which a large number of stations may be employed. These systems generally employ a master controller which communicates with the various station valve by means of wire or radio. The controller can typically be programmed to operate each of the valves at desired intervals and for desired periods of time.

One of the principal problems in servicing such systems is that the maintenance person must do a lot of walking back and forth between the various stations and the central controller to turn one station at a time on and off for observation and servicing. In large systems the great majority of service time is often spent just walking (or driving if a suitable vehicle is available), rather than actually servicing the irrigation hardware. This waste of time is both costly and inefficient.

In an attempt to reduce the servicing time wasted in travelling back and forth between the controller and valves, a remote control device has been developed which permits the service person to exercise the controller and turn the valves on and off from a remote location, generally at or near a valve. The system is disclosed in U.S. Pat. No. 4,185,650 to Neves et al. Initially, the central controller is programmed to cycle through a predetermined sequence of stations for normal operation. Thus, each station is turned on and off in turn in the predetermined sequence, until the entire area has been watered. The service person is provided with a radio transmitter, which communicates with a corresponding receiver at the central controller. The transmitter can transmit on two different frequencies, one for advancing the controller through its station cycle to the desired station, and the other for turning the station on and off. To exercise any particular valve, the service person must first transmit at the station cycling frequency to advance the controller through its cycle, one station at a time. When the desired station has been reached, he then switches to the second frequency to turn it on.

While the system disclosed in the Neves patent is an improvement over the prior technique of physically travelling back and forth between the master controller and the various stations, its mode of operation is limited and can be somewhat inefficient. For example, if the central controller is set to the tenth station in a thirty-six station irrigation system and it is desired to operate the ninth station, the controller must be cycled up from the tenth station and all the way through the thirty-four intervening stations until it reaches the desired ninth station. This can be a time-consuming procedure which mitigates some of the advantage that could otherwise be obtained with the system.

SUMMARY OF THE INVENTION

In view of the above problems associated with the prior art, the object of the present invention is the provision of a novel and improved remote controlled multi-station irrigation system which provides for greater flexibility and responsivity to commands transmitted from a remote location, which has a reliable means of communication with the remote location, and which provides for both local and remote programming of the irrigation controller.

The principal components of the novel system include a controller capable of governing a plurality of irrigation stations, a remote transmitter, a receiver which is adapted to receive signals from the transmitter and to produce corresponding input control signals for the controller, and a connecting means which delivers input signals from the receiver to the controller. The controller includes a plurality of individual station actuator circuits, a central processor, an input terminal which is connected to provide input signals to the central processor, and interface circuitry between the processor and the station actuator circuits. The processor is responsive to input signals delivered from the receiver and input terminal to provide actuation signals to selected station actuator circuits via the interface circuitry. The remote transmitter is adapted to transmit discrete signals corresponding to respective station actuator circuits, and includes means for selecting a particular signal for transmission. In this way any station can be immediately selected to be turned on or off, without having to cycle through the entire set of stations.

In a preferred embodiment the receiver is removably mountable on the controller, and is supplied with power from the controller by a power interconnect means. The transmitter includes a keyboard and is adapted to transmit discrete radio signals in response to discrete keys being pushed. The transmitted signals are in an FM dual tone multi-frequency format, and are decoded by the receiver to a hexadecimal format for application to the controller. The controller can be operated in either a local or a remote mode, and includes a local keyboard which is connected to supply irrigation program information to the processor. In the local mode the station actuator circuits are operated in response to program information stored in the processor. Inserting a connector from the receiver into the controller input terminal interrupts the local mode and sets the controller to its remote mode, in which the processor is responsive to input signals from the receiver. The receiver connecting means comprises a removable plug which can be inserted into the controller's input terminal. The input terminal has a common connection with the controller's local keyboard to the processor, enabling the processor to be programmed with input signals from the receiver when in the remote mode.

In addition to the system's ability to immediately actuate any desired station from the remote mode, the processor includes means for remotely advancing the application of an actuating signal among the station actuator circuits. For this purpose the transmitter is adapted to transmit a discrete radio signal which causes the receiver to produce a corresponding processor input signal to activate the station actuator advancing means. Thus, the remote operator has the option of either selecting individual stations to operate, or of cycling the system through its various stations in sequence. When the transmitter and receiver are used in conjunction with a conventional controller which does not have the station actuator circuitry contemplated by the invention, this circuitry can be added to the receiver and the controller bypassed during remote operation. The transmitter is also adapted to save power by automatically disconnecting most of the circuitry from a power supply except when it is transmitting a control signal.

These and other objects of the invention will be apparent to those skilled in the art from the following detailed description of a preferred embodiment, taken together with the accompanying drawings, in which:

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of the irrigation controller with a remote signal receiver mounted on top;

FIG. **2** is a perspective view of the transmitter;

FIGS. *3a* and *3b* are schematic diagrams of the controller circuitry associated with its central processor;

FIGS. *4a* and *4b* are schematic diagrams of the controller circuitry associated with the station actuator circuits;

FIG. **5** is a block diagram of the transmitter circuitry; and

FIG. **6** is a block diagram of the receiver circuitry.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. **1** shows the exteriors of an irrigation controller **2** and of a receiver **4** which is adapted to decode remotely transmitted control signals and apply them to the controller in accordance with the invention. The controller includes a keyboard **6** with an array of keys for inputting local program information into the controller's processor, such as time, sequence of station operation, duration of irrigation for each station, irrigation cycles, station identification, etc. Controllers can be supplied with various station capacities; 12, 18, 24, 30 or 36 stations per controller are typical. A first LED display **8** provides a visual indication of the program information being applied, while a second LED display **10** has one light for each station, arrayed in a line. When any particular station is activated its corresponding light in display **10** goes on, providing a visual indication of the status of the irrigation system.

Receiver **4** has a carrying handle **12** for ease of portability, and can be mounted on top of the controller as shown. Clips, screws or the like can be provided to hold the receiver in place on the controller. An antenna **14** receives a remote control signal, typically sent by a field service person at a distant irrigation station, and decodes the received radio signal into a signal format that is recognizable by the controller's processor. This signal is delivered to the controller over a connecting cable **16**. A plug **18** is connected to the end of cable **16** and is inserted into a corresponding controller terminal receptable **20**, which in turn is connected to the processor. Cable **16** also provides a conduit for supplying electrical power from the controller **2** to the receiver **4**. An on/off switch **22** is provided on the receiver.

The remote transmitter **24** used with this system is shown in FIG. **2**. It has a carrying handle **26** which mates with the receiver handle **12**, permitting the receiver and transmitter to be carried as a unit when not in use. A keyboard **28** on the front of the transmitter has numerical keys which permit any station to be identified, ON and OFF keys for transmitting a signal to turn a designated station on or off, AUTO UP (AU) and AUTO DOWN (AD) keys which cause the controller to cycle from one station to the next, and a MASTER VALVE/PUMP (MV/P) key which permits the master valve/pump to be turned on or off. The transmitter also includes an antenna **30**, an on/off switch **32**, and a battery jack for recharging the battery.

Transmitter **24** has a range of approximately one mile. To turn any irrigation station on, the number of that station is simply keyed in, followed by pressing the ON key. The station can then be turned off by pressing the OFF key. If it is desired to turn the same station on again, this is accomplished by simply pressing the ON key, without having to press the station's number again. When a new station is desired, the new station number is punched in and the ON key depressed. In some irrigation systems a master valve is provided to control the flow of water to all stations; the master valve must be on for any station to receive water. Although it is designated by a separate key, the master valve is operated in a manner similar to all of the other stations. To actuate the master valve, the MV/P and ON keys are depressed.

Another feature of the system is the provision of AUTO UP and AUTO DOWN keys. If it is desired to exercise the stations in sequence, a first station is initially turned on. Alternately, the AUTO UP or DOWN sequence can be started with station number one by initially pressing AUTO UP or DOWN. Thereafter the processor is programmed to respond to pressing AUTO UP by turning off the current station without entering any station numbers or depressing the ON or OFF keys. Station cycling in the opposite direction is achieved by means of the AUTO DOWN key.

Referring now to FIGS. *3a* and *3b*, a schematic diagram of a microprocessor located inside the controller is shown. Depending upon the number of stations and the amount of program information to be stored, the Intel 8049 or 8050 microprocessors are suitable; the 8050 has twice the memory capacity of the 8049. The microprocessor, designated by reference numeral **36**, is shown as being split into separate parts in FIGS. *3a* and *3b*, but of course is an integral unit. Referring first to FIG. *3b*, the keyboard **28** is shown with four output lines **38** providing an input to the microprocessor or keying in local program information. The program information is also delivered to display **8** to show the information going to the microprocessor. The circuitry between keyboard **28** and display **8** includes an inverter circuit **40** and an inverter/driver circuit **42**. The output of inverter/driver **42** determines which of the eight digits of display **8** are to be actuated. The selection of numerals for the actuated digits is provided from the microprocessor over lines **44** and through an inverting buffer/driver chip **46** which boosts the signals from the microprocessor. The display system is generally conventional, and is capable of displaying the system status under both local and remote control.

The input terminal **20** for the remote control signals is connected to two different ground references. One ground connection **48** serves as a reference for control signals from the receiver. The other ground connection **50** provides a reference for the 24 volts AC controller power supply. This AC voltage is delivered over line **52** to the receiver via cable **16**.

Input signals from the receiver are transmitted to the microprocessor via lines **54**, which are connected in common with respective input lines **38** from the keyboard to the same microprocessor ports. The microprocessor has two different modes of operation: a local mode for receiving information from the keyboard, and a remote mode for receiving information from the remote terminal. It is programmed to interpret the data from the two sources in different ways so that both remote and local control functions can be accomplished from the same input ports. For this purpose the microprocessor has an interrupt port **56** which is actuated by the cable plug **18** being inserted into the controller's remote terminal **20**. In the local mode an internal microprocessor voltage V_{CCP}, which is regulated at a 5 volt DC level, is applied to interrupt port **56**. This voltage signal is dissipated through resistor R1 when the remote plug is inserted into terminal **20**, completing a circuit for V_{CCP}. This effectively removes the signal from port **56** and interrupts the local mode, setting the microprocessor into its remote mode. The microprocessor can now be supplied with program information from the remote transmitter, or it can operate the irrigation valves in response to remote inputs.

Interface circuitry is shown in FIG. 3*a* which interconnects the microprocessor with the various station actuator circuits (shown in FIGS. 4*a* and 4*b*). Microprocessor output data designating a particular station to be turned on is furnished from port **58** over line **60** to an eight bit shift register **62**. Another eight bit shift register **64** is provided for serial storage of data with register **62**, the two registers functioning in effect like a single sixteen bit register. Another signal from microprocessor port **66** clocks the data from pin **58** into the data shift registers **62** and **64**. These registers hold the data identifying the station to be turned on until the data has stabilized. Upon receiving the initial clock signal from microprocessor port **66**, the signals held in the various register ports ripple and require a finite amount of time to stabilize. Once a predetermined period of time has expired and the data in registers **62** and **64** has stabilized, the microprocessor produces a low output at port **68**. This signal is fed through an inverter **70** and then along line **71** to provide an ENABLE signal for the various station actuator circuits.

Each shift register **62** and **64** has eight outputs, each of the outputs corresponding to a particular station (fifteen irrigation stations and one master valve/pump). Each output from the shift registers **62**, **64** is delivered as one input to a respective AND gate **72**, the various AND gates being grouped in banks of four with each bank **74** acting as a buffer/driver. The output of each AND gate **72** provides an actuating signal for a respective station actuator circuit. For example, the leftmost bank **74** includes four AND gates, the outputs of which are connected to the actuator circuits for the master valve and station valves V1–V3, while the outputs of the four AND gates in the right-hand bank are connected to the actuator circuits for station valves V12–V15, respectively. Thus, the microprocessor under remote control delivers a station identifying signal to line **60** for the particular station or stations to be actuated, and a corresponding signal is produced at the output of the appropriate AND gate **72** once the data in shift registers **62**, **64** has stabilized sufficiently and an ENABLE signal is received from the microprocessor over line **71**.

A conventional microprocessor clock is provided by a 6MHz oscillator **76**. The microprocessor is held on when a POWER UP command is given by means of a capacitor C1 which is connected to an inverted RESET port **78**; capacitor C1 charges in response to a POWER UP command to turn the microprocessor on and hold it on.

Microprocessor ports **80** are connected to adjustable circuitry which sets the controller for either five, seven, eleven or fifteen stations (excluding the master valve). This feature is important in connection with the AUTO UP and AUTO DOWN control capabilities associated with the remote transmitter. Upon receiving an AUTO UP signal, the microprocessor turns off the currently active station and turns on the next station by an appropriate change in the signal at port **66**. If the microprocessor is set for seven stations, for example, it will return to station **1** when AUTO UP is received during operation of station **7**. Conversely, if AUTO DOWN is received during operation of station **1**, the microprocessor will shift to the uppermost station for which it is set.

The controller display **10** which indicates the station that is currently active is controlled by circuitry which includes a pair of eight bit shift registers **82**. The individual shift register outputs are connected through respective current limiting resistors **84** to LEDs **86** which provide pinpoint light sources for the display. A clock signal for the display shift registers is provided from microprocessor port **88**. In addition to lighting when a station is operating in the remote mode, LEDs **86** also indicate which stations are being programmed during the initial local programming sequence.

Referring now to FIG. 4*a*, the power supply for the controller and part of the station actuator circuitry is shown. The power supply, which is conventional, comprises the circuitry above dashed line **90**. A standard 115 volt AC power input is stepped down to a 24 volt AC level suitable for the controller by transformer **92**. The output of transformer **92** is connected to be shunted by a rain switch **94** operated from the front panel of the controller. The rain switch is paralleled by an RC arc suppression circuit **96**. A second transformer **98** steps the 24 volts AC down to 12 volts AC, with a transient protector **100** connected across the transformer input to guard against AC spikes. A full-wave bridge rectifier **102** is connected to the transformer output and produces a 10 volt DC signal which is applied to voltage regulators **104** and **106**, yielding regulated 5 volt DC voltages V_{CC} and V_{CCP}, respectively. Regulator **106** has a nominally 9 volt backup supply battery **108** which assures that V_{CCP} is retained when AC power is lost. V_{CCP} provides DC power to the microprocessor and to shift registers **62** and **64**, while DC power is provided to the remainder of the controller circuitry from V_{CC}.

In the illustrated controller with sixteen stations, sixteen identical actuator circuits are provided. Details of the first actuator circuit, for the master valve (MV), are shown in FIG. 4*a*. When an MV actuating signal is produced by the corresponding AND gate **72** in the controller interface circuitry, the signal is applied through a resistor R2 to the gate of a triac switch **110**. The triac switch is connected to a terminal strip **112** and thereby to a lengthy lead line **114** to the master valve actuating coil **116**. Gating the triac **110** in response to an MV actuating signal completes a circuit for MV coil **116** and causes the master valve to open. An RC snubber network **118** is provided in parallel to triac **110** to ensure that the triac turns on and off properly. Transient lightening protectors **120** and **122** are preferably provided at appropriate locations in the circuitry.

An identical actuating circuit is provided for the first irrigation valve V1. In response to a V1 actuating signal, the actuating circuit (left blank in FIG. 4a) closes a circuit for the V1 coil 124, causing V1 to open. The actuating circuits for the remaining valves are indicated in FIG. 4b.

Turning now to the transmitter/receiver system which provides remote control over the controller, transmitter 24 nd receiver 4 comprise a general purpose frequency modulated pair capable of transmitting and receiving sixteen discrete signals encoded in a dual tone multi-frequency (DTMF) format. Fifteen of the signals are active as decoded by the receiver, while the receiver's sixteenth code is considered inactive and used to indicate no transmission. In the preferred embodiment, transmitter 24 is capable of transmitting sixteen discrete signals on a fundamental frequency of 154.57 or 154.60 MHz (as set by the factory). The transmitted signals are decoded by receiver 4 into a hexadecimal data format suitable for the controller. The transmitter keys and their associated DTMF frequencies are as follows:

KEY	DTMF FREQUENCY
MV/P	852/1633
AUTO DOWN	770/1633
AUTO UP	697/1633
OFF	941/1477
ON	941/1336
0	941/1209
1	852/1209
2	852/1336
3	852/1477
4	770/1209
5	770/1336
6	770/1477
7	697/1209
8	697/1336
9	697/1477
NO KEY	941/1633

A block diagram of the transmitter is shown in FIG. 5. The DTMF tones which control the individual station operations are generated by a tone generator chip 126, which preferably is a Mostek 5087 or similar device. The transmitter keyboard 28 is indexed by rows and columns, with each row and column providing an input to tone generator 126. The tone generator continuously strobes the keyboard to detect any keys that have been depressed. In response to operation of the keyboard, an output tone signal is produced on output line 128.

Tone generator 126 receives power from a nominally 12 volt battery 130 through the hand-operated switch 32 described previously, and a zener diode 132 which reduces the battery voltage to a level suitable for the tone generator. The battery is also connected to provide power to the remainder of the transmitter circuitry via and FET switch 134. To conserve the battery, switch 134 is normally open and is closed only in response to an output tone from tone generator 126. The tone generator output line 128 is connected through a low pass filter 136 to a voltage multiplier circuit 138, which steps up the voltage to a level sufficient to gate FET 134. Thus, the production of an output tone by tone generator 126 results in FET 134 being turned on, completing a power supply circuit over line 140 between the battery and the remainder of the transmitter circuitry.

The output of low pass filter 136 is also applied to a frequency modulator circuit 142, which modulates a 154.6 MHz carrier signal produced by oscillator 144 in accordance with the generated DTMF tone. The resultant modulated signal is processed through a 154.6 MHz band pass filter 146 and then amplified by a gain of approximately 23 dB in RF broadband amplifier 148. The signal is then brought up to a transmission power level by power amplifier/filter 150 and applied to the transmitter antenna 30.

A block diagram of the circuitry employed by receiver 4 is shown in FIG. 6. A remotely transmitted signal is received by antenna 14, stepped up by RF amplifier 152 and applied to a mixer circuit 154, where it is mixed with a suitable signal from oscillator 156 to enable the 154.6 MHz carrier signal to be stripped off in a conventional manner. An IF discriminator circuit 158 strips off the carrier signal and produces an audio tone output over line 160. The latter signal is processed through a buffer amplifier circuit 162 and applied to a decoder circuit 164, which decodes the DTMF input signal to a hexadecimal output signal over four output lines 166. Decoder 164 can be implemented with a Silicon Systems, Inc. (SSI) model 202 chip. The decoder output is processed through an optical isolator circuit 168 which provides a secure ground, and then transmitted over cable 16 to the controller as discussed above. Cable 16 also includes a pair of power supply wires which bring a 24 volt AC signal to an internal receiver power supply 170, which in turn supplies power to the various receiver circuit elements (over connecting wires which are not shown in FIG. 6).

The various components of the system described thus far are designed to be compatible with each other. For example, the controller includes a microprocessor 36 which is programmed in its remote mode to respond to hexadecimal systems from the receiver. The system can also be adapted for use with conventional controllers which are not programmed in this manner. In this case actuation circuitry for the field wiring is provided in the receiver, and the controller is effectively bypassed during remote operation. This adaption is illustrated in dashed lines in FIG. 6, in which a set of switching circuitry 172 for the various field wires is provided in a manner similar to the valve actuator circuits shown in FIGS. 4a and 4b. Instead of being sent to the controller, the hexadecimal input signals from decoder 164 are delivered over lines 174 to the receiver switching circuitry 172. The switching circuitry has a separate output for each valve to be controlled, and responds to input signals from lines 174 to produce energizing signals for the identified valves. The switching circuitry is provided with power from power supply 170 over lines 176.

A remote controlled multi-station irrigation system has thus been shown and described which is much easier to operate and more convenient than previous systems, and can be adapted for use with either specially designed controllers or conventional controllers. As numerous variations and alternate embodiments will occur to those skilled in the art, it is intended that the invention be limited only in terms of the appended claims.

I claim:

1. A remote controlled multi-station irrigation system, comprising:

a controller comprising:

(a) a plurality of individual station actuator circuits,
(b) a central processor,
(c) an input terminal means connected to provide input signals to the central processor, and

(d) interface circuitry interfacing between the central processor and the station actuator circuits,

the processor being responsive to input signals from the input terminal means to provide operational control signals via the interface circuitry to selected actuator circuits,

a remote portable transmitter adapted to broadcast selectable discrete wireless station identity signals corresponding to the respective station actuator circuits, together with an operation signal to initiate the actuation or deactuation of a selected station; the transmitter including means for manually selecting a particular station identification and operational signal for transmission,

a receiver adapted to receive broadcast signals from the transmitter and to produce corresponding input signals for the central processor, the central processor responding to said input signals to provide an operational control signal corresponding to the received operational signal only to the actuator circuit for the selected station and

means connecting the receiver with the controller's input terminal means for transmitting processor input signals from the receiver to the controller.

2. The remote controlled irrigationn system of claim **1**, wherein the receiver is removably mountable on the controller.

3. The remote controlled multi-station irrigation system of claim **1**, wherein the controller includes

an electrical power supply, and a power interconnect means connected to supply electric power from the controller to the receiver.

4. The remote controlled irrigation system of claim **1**, wherein the transmitter includes a keyboard and is adapted to transmit discrete radio signals in response to discrete keys being pushed.

5. The remote controlled multi-station irrigation system of claim **1**,

wherein the remote transmitter is adapted to transmit discrete radio signals in an FM dual tone multi-frequency (DTMF) format.

6. The remote controlled irrigation system of claim **5**, wherein the receiver is adapted to decode received DTMF signals to a hexadecimal format for application to the controller.

7. The remote controlled multi-station irrigation system of claim **1**,

wherein the controller includes a local keyboard connected to supply irrigation program information to the processor, the processor being responsive to input signals from the input terminal means to provide actuation signals via the interface circuitry to the selected actuator circuit, and the controller having a local mode in which the station actuator circuits are actuated in response to program information stored in the processor, and including means for disabling the local mode and setting the controller to a remote mode, the processor being responsive in the remote mode only to input signals from the input terminal means.

8. The remote controlled irrigation system of claim **7**, wherein the local mode disabling means is responsive to the input terminal means receiving a connecting means from the receiver.

9. The remote controlled irrigation system of claim **8**, wherein the connecting means comprises a removable plug adapted to be inserted into the controller's input terminal means, the controller disabling the local mode in response to the plug being inserted.

10. The remote controlled irrigation system of claim **7**, wherein the input terminal means has a common connection with the controller's local keyboard to the processor, enabling the processor to be programmed with input signals from the receiver in the remote mode in addition to remotely controlling the operation of individual selected actuator circuits.

11. The remote controlled multi-station irrigation system of claim **1**, wherein the processor includes

means for advancing the application of an actuating signal among the station actuator circuits,

and the transmitter includes means to broadcast a discrete operational signal which causes the receiver to produce a corresponding processor input signal to activate the station actuator advancing means.

12. A controller for a remote controlled multi-station irrigation system, comprising:

a plurality of individual station actuator circuits,

a central processor,

a local keyboard connected to supply irrigation program information to the processor,

an input terminal means adapted to receive a connector from a receiver for remote signals and connected to provide remote input signals from the connector to the processor,

interface circuitry interfacing between the processor and the station actuator circuits,

the processor being responsive in a remote mode to remotely broadcast station identity and operational signals from the input terminal means to provide an operational control signal via the interface circuitry only to the actuator circuit which corresponds to a received station identity signal, and in a local mode to program information stored in the processor, and

interrupt means connected to the processor for disabling the processor's local mode and setting the processor to its remote mode.

13. The irrigation controller of claim **12**, the interrupt means being responsive to the input terminal means' receiving a connector from a receiver for remote signals.

14. The irrigation controller of claim **12**, wherein

the input terminal means has a common connection with the local keyboard to the processor, and enables the processor to be programmed with remote input signals in the remote mode, in addition to remote control over the operation of individual selected actuator circuits.

15. The irrigation controller of claim **12**, wherein the processor includes means for advancing the application of an actuation signal among the station actuator circuits in response to the receipt of a corresponding remote operational signal.

16. A communication system for use with a remote controlled multi-station irrigation system, comprising:

a portable transmitter adapted to broadcast selectable discrete station identity and operational signals on a wireless carrier signal, the transmitter including a manually operated keyboard adapted to select desired station identity and operational signals for broadcast, and

a receiver including an antenna adapted to receive signals broadcast from the transmitter, circuit means connected to the antenna for removing the carrier portion of a received signal to produce a coded input signal, a decoding means connected to the circuit means for decoding a coded input signal to a signal format which is compatible with a sprinkler controller, and output means connected to the decoding means for providing decoded station identity and operational signals to a sprinkler controller, whereby the sprinkler controller can be operated by the transmitter to perform a selected operation for any selected station from any remote location within the transmitter's broadcast range from the receiver.

17. The communications system of claim **16**, wherein the transmitter is adapted to broadcast discrete station identity and operational signals in an FM dual tone multi-frequency (DTMF) format.

18. The communications system of claim **17**, wherein the receiver is adapted to decode received DTMF signals to a hexadecimal format.

19. The communications system of claim **16**, wherein the receiver further includes a controller which comprises a plurality of individual station actuator circuits connected to receive operational signals from the output means, means connecting said actuator circuits to the field wiring for respective irrigation stations, thereby bypassing any local controller in the irrigation system, and means for directing an operational signal to the actuator circuit for the particular station which corresponds to the station identity signal received from the transmitter.

20. The communications system of claim **16**, wherein the transmitter includes a keyboard adapted to select desired command signals for broadcast, a tone generator responsive to the keyboard for generating transmission tone signals, transmission circuitry for transmitting a signal corresponding to the generated tone signal, a power supply connected to supply power to the tone generator, a switch connecting the power supply to the transmission circuitry, and circuit means responsive to the tone generator producing a transmission tone signal for closing the switch and for holding the switch open at other times, thereby conserving power by disconnecting the transmission circuitry from the power supply except when the tone generator is producing a signal for transmission.

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US005479338A

United States Patent [19]

Ericksen et al.

[11] **Patent Number: 5,479,338**

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[54] **PROGRAMMABLE CONTROLLER APPARATUS FOR IRRIGATION SYSTEMS**

[75] Inventors: **Kent C. Ericksen**, Centerville; **Kim Hayes**, Salt Lake City, both of Utah

[73] Assignee: **Pro-Mark, Inc.**, Bountiful, Utah

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[51] **Int. Cl.**[6] **G06F 19/00**

[52] **U.S. Cl.** **364/145**; 137/624.2; 239/69; 364/420

[58] **Field of Search** 364/145, 143, 364/144, 146, 188, 189, 420, 509, 510; 239/63, 67–70; 137/624.11–624.2

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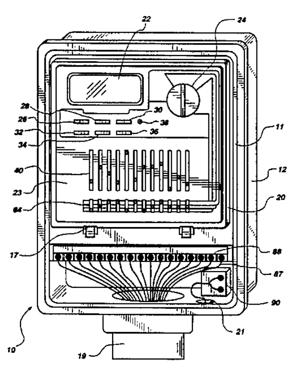
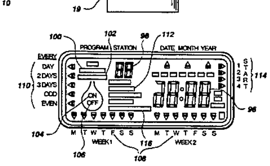
Primary Examiner—Joseph Ruggiero
Attorney, Agent, or Firm—Berne S. Broadbent; Gary D. E. Pierce

[57] **ABSTRACT**

A programmable controller apparatus and method for irrigation systems including at least one removable control module interfacing with internal circuitry of the programmable controller for activating and operating a plurality of watering valves. A housing unit is provided for the control module and the internal control circuitry of the programmable controller to prevent water contamination and unauthorized tampering. The removable control module interfaces with the internal circuitry of the controller to provide variations in programmable watering sequences for individual watering stations. The control module, in addition, comprises multiple programming keys and switches that provide interaction between the electronic programming and manual programming features which function in combination to provide easier programming options for the irrigation controller. Moreover, the stand alone capacity of the removable control module allows the control module to be programmed at a remote location from the irrigation controller. A manual mode of operation is provided for selectively overriding or deactivating previously entered programming sequences for individual watering stations without disturbing the programming sequences of other watering stations. A master valve is also included which can be selectively activated on a programmable basis for individual watering stations. Formed on the exterior of the housing unit of the programmable controller is an external default indicator that provides visual indication of faulty watering stations. Further thereto, a transmitter/receiver provides the programmable controller with radio compatible for on-site programming of faulty watering stations of the irrigation system.

16 Claims, 6 Drawing Sheets





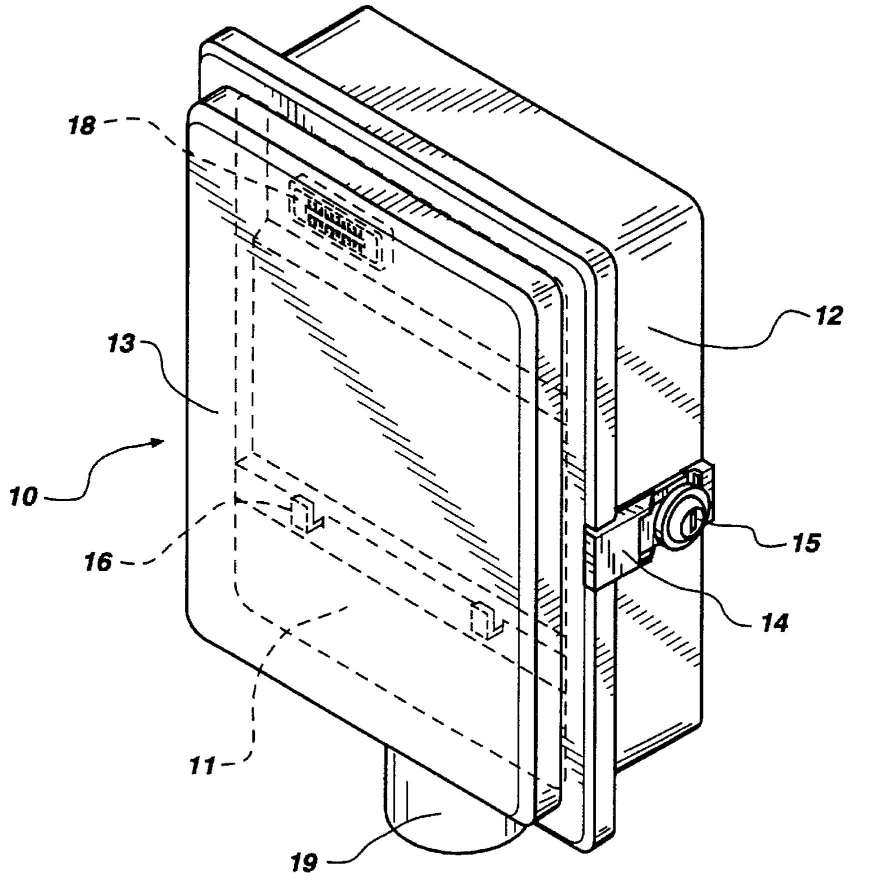
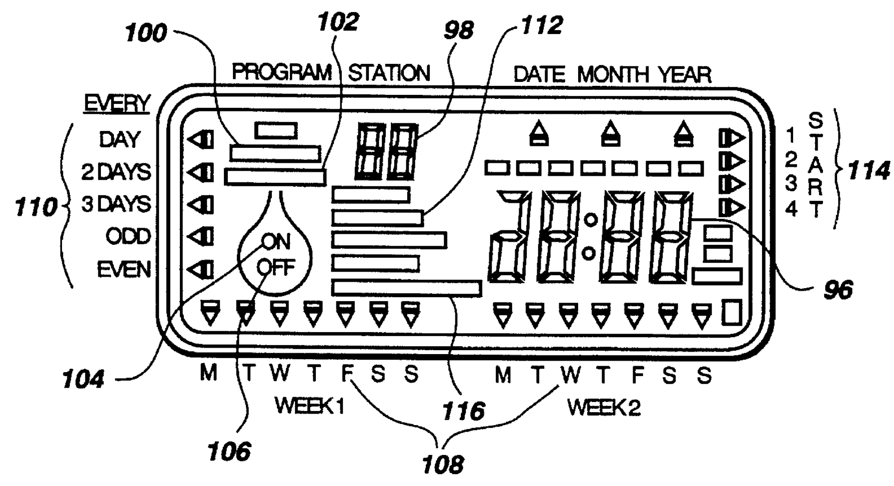

18
13
10
16
11
19
12
15
14

Fig. 1


100
102
98
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PROGRAM
STATION
DATE
MONTH
YEAR
EVERY
DAY
2 DAYS
3 DAYS
ODD
EVEN
110
ON
OFF
START
1
2
3
4
114
96
104
M T W T F S S
WEEK1
116
M T W T F S S
WEEK2
106
108

Fig. 3

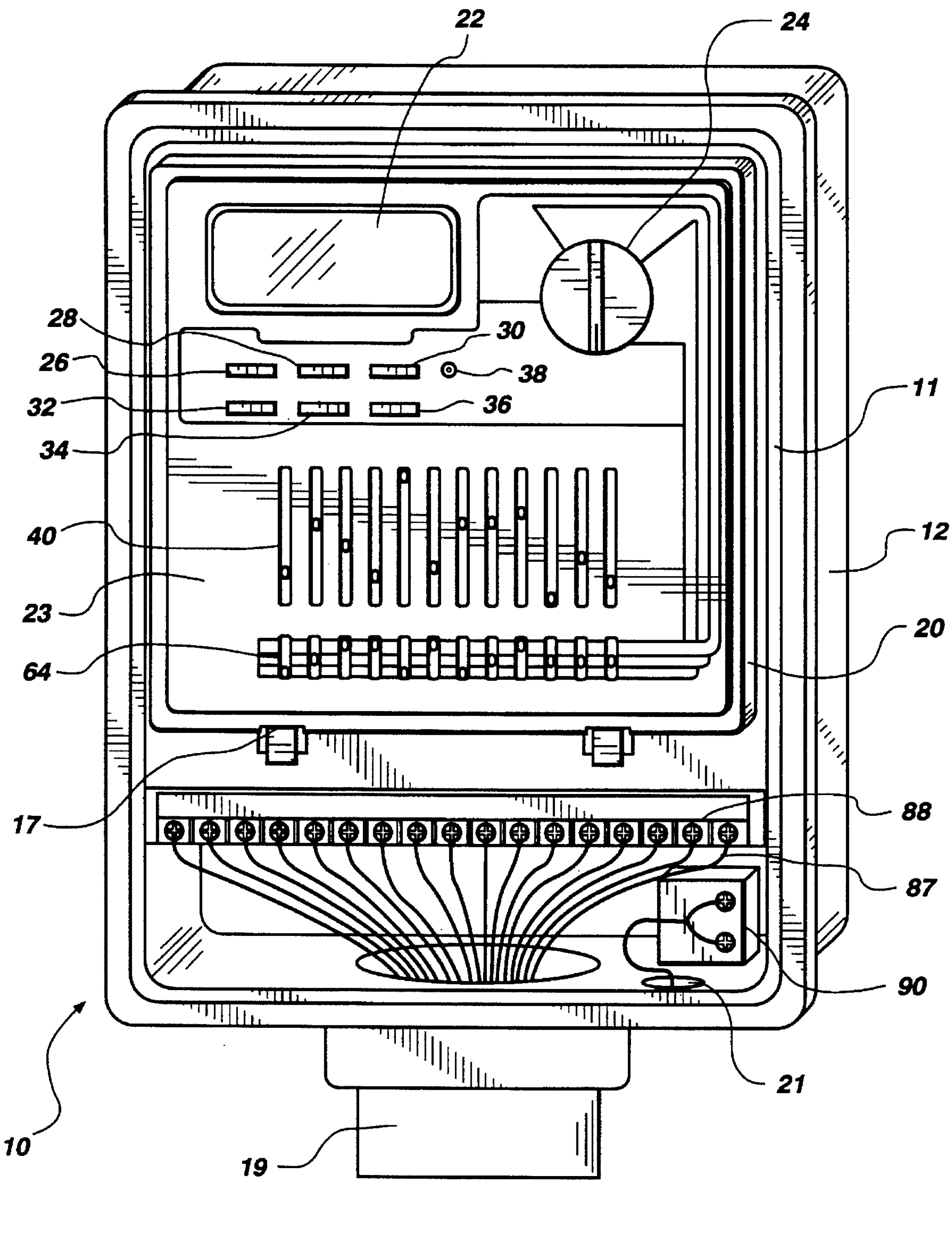


Fig. 2

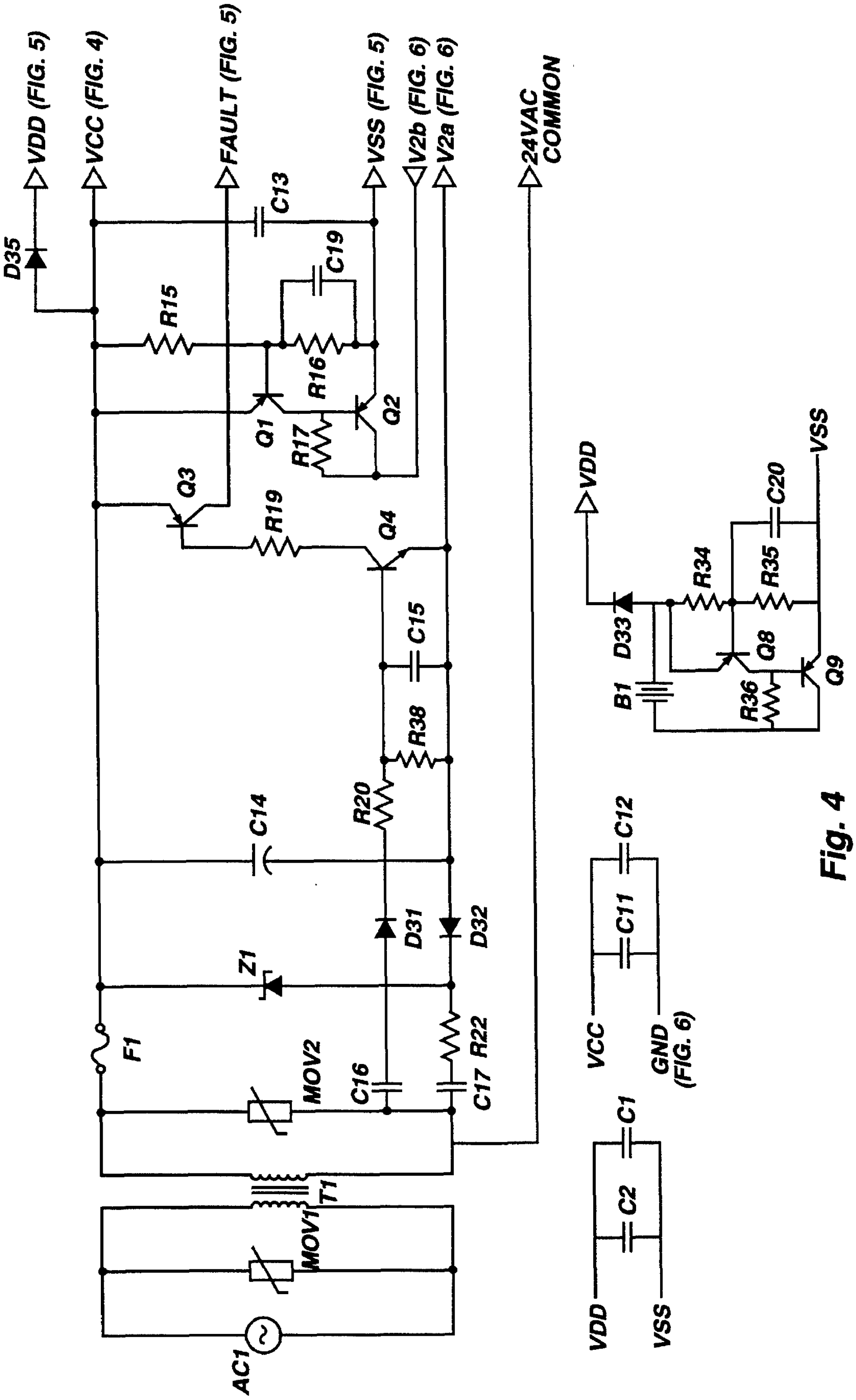
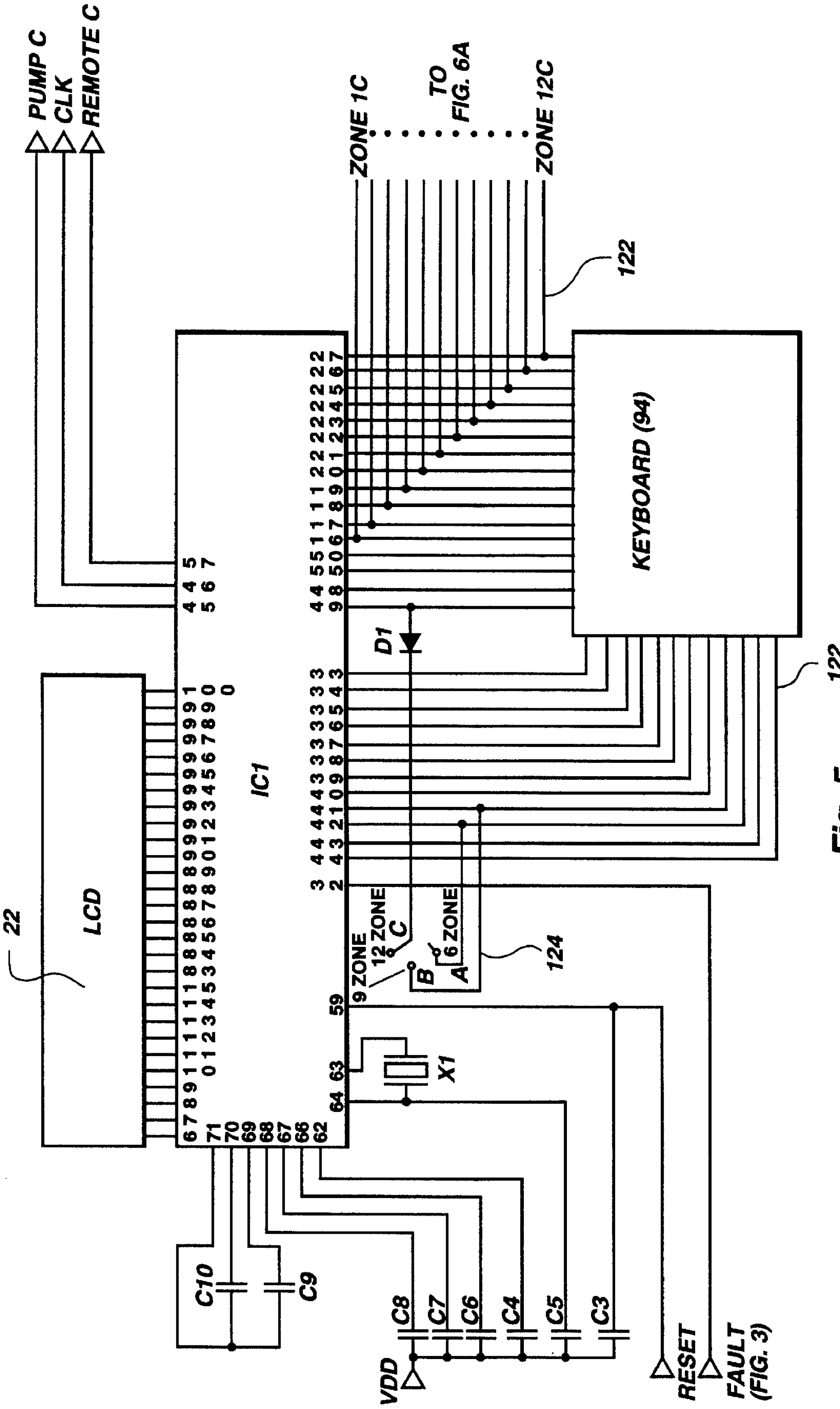

VDD (FIG. 5)
VCC (FIG. 4)
FAULT (FIG. 5)
VSS (FIG. 5)
V2b (FIG. 6)
V2a (FIG. 6)
24VAC COMMON
D35
C13
C19
R15
R16
Q1
Q2
R17
Q3
R19
Q4
C15
R38
R20
C14
D31
D32
Z1
F1
MOV2
C16
R22
C17
T1
MOV1
AC1
VDD
D33
R34
R35
C20
VSS
B1
Q8
Q9
R36
VCC
C12
C11
GND (FIG. 6)
C1
C2
VDD
VSS

Fig. 4



PUMP C
CLK
REMOTE C
ZONE 1C
TO FIG. 6A
ZONE 12C
122
KEYBOARD (94)
LCD
22
IC1
D1
122
124
9 ZONE
12 ZONE
C
B
A
6 ZONE
X1
C10
C9
C8
C7
C6
C4
C5
C3
VDD
RESET
FAULT (FIG. 3)

Fig. 5

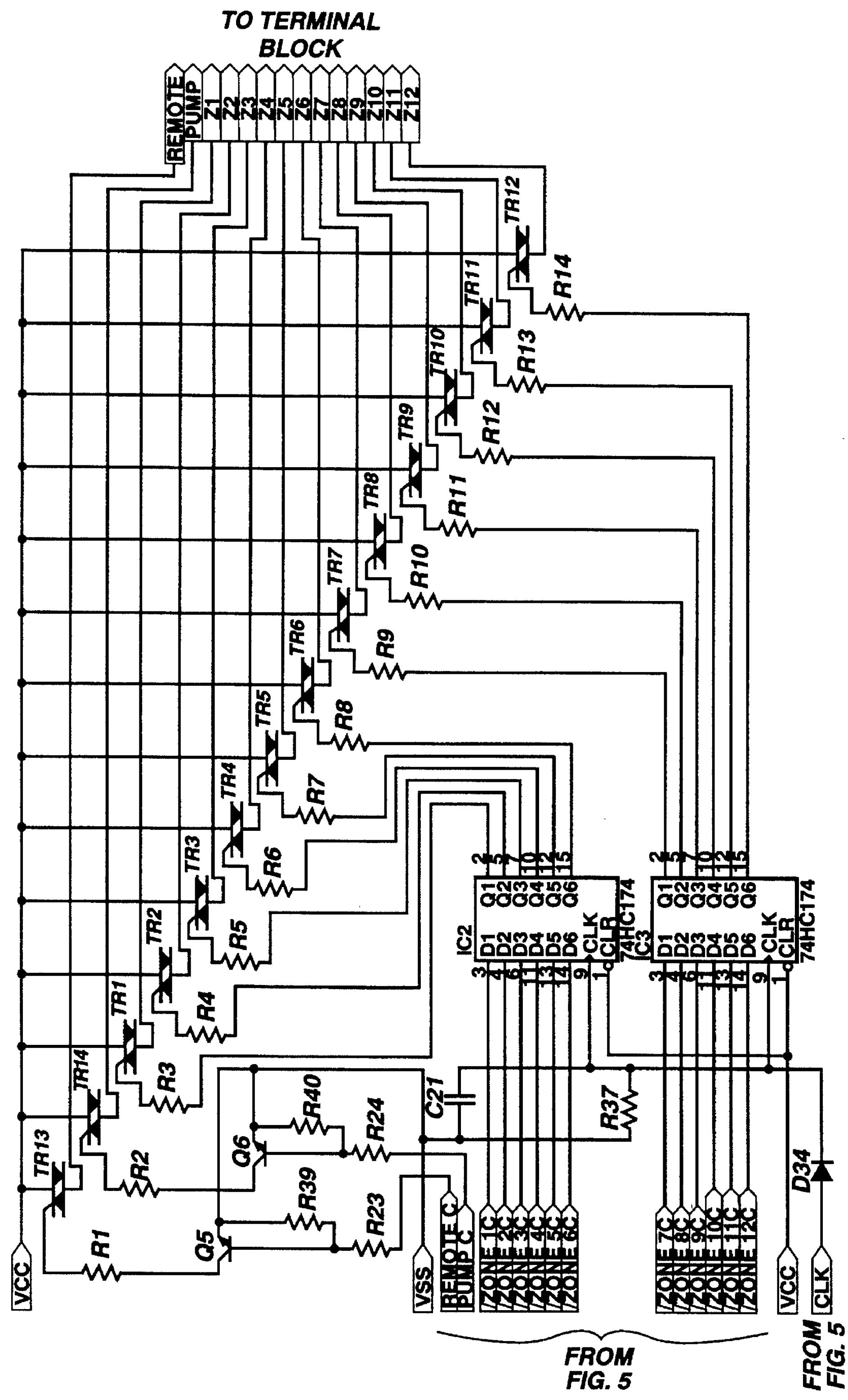

TO TERMINAL BLOCK
REMOTE
PUMP
Z1
Z2
Z3
Z4
Z5
Z6
Z7
Z8
Z9
Z10
Z11
Z12
TR1
TR2
TR3
TR4
TR5
TR6
TR7
TR8
TR9
TR10
TR11
TR12
TR13
TR14
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R23
R24
R37
R39
R40
C21
Q5
Q6
D34
IC2
IC3
74HC174
VCC
VSS
CLK
REMOTE C
PUMP C
ZONE 1C
ZONE 2C
ZONE 3C
ZONE 4C
ZONE 5C
ZONE 6C
ZONE 7C
ZONE 8C
ZONE 9C
ZONE 10C
ZONE 11C
ZONE 12C
FROM FIG. 5
FROM FIG. 5

Fig. 6A

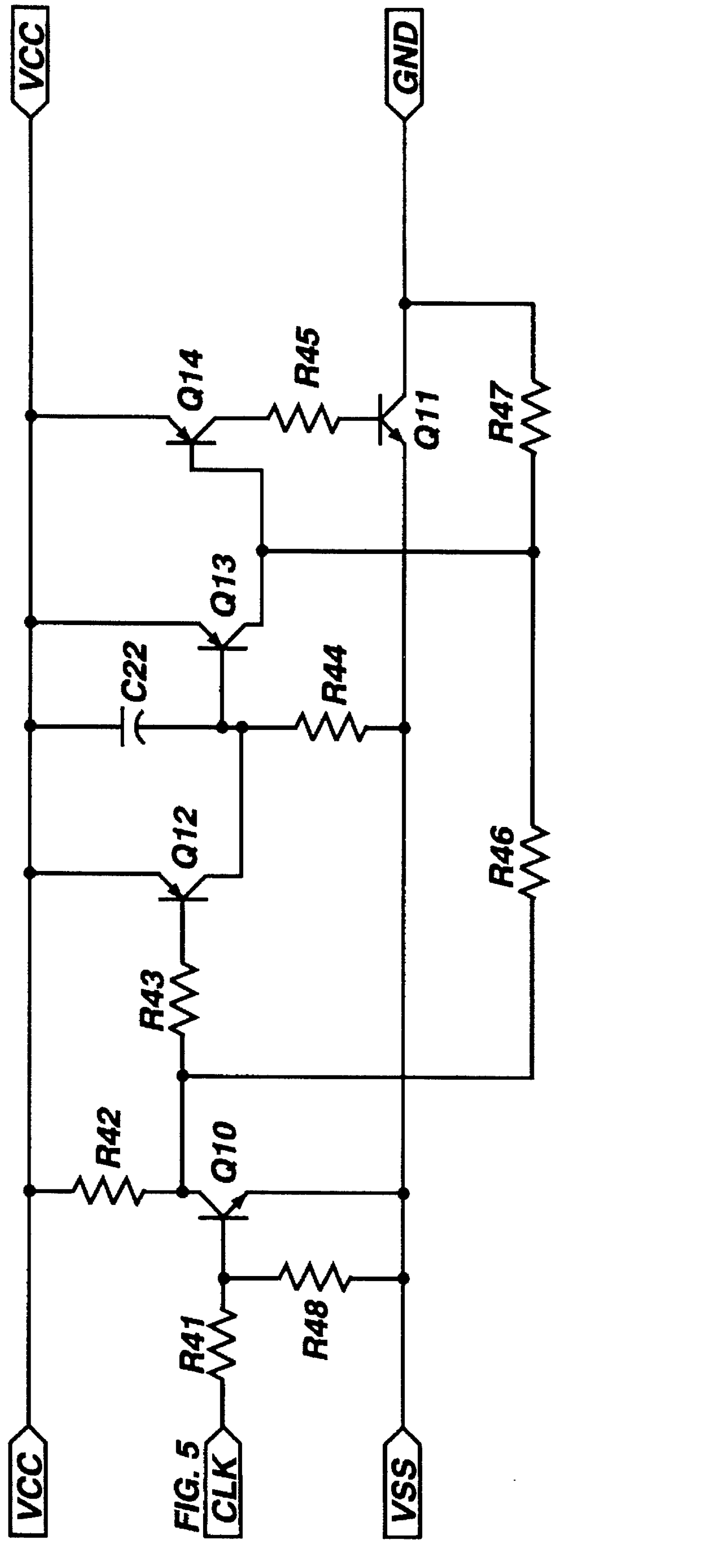

VCC
GND
Q14
R45
Q11
R47
Q13
C22
R44
Q12
R46
R43
R42
Q10
R41
R48
VCC
FIG. 5
CLK
VSS

Fig. 6B

PROGRAMMABLE CONTROLLER APPARATUS FOR IRRIGATION SYSTEMS

BACKGROUND

1. The Field of the Invention

This invention relates to solid state irrigation controllers which automatically regulate a plurality of watering stations or zones, and more particularly, to a novel programmable controller apparatus and method for irrigation systems which is capable of providing an efficient and more manageable means for programming a control module, an independent programmable pump start for each watering station, and novel means for supplementing an irrigation system with additional watering zones or stations.

2. The Background Art

Normally, vegetation and greenery grows in soil watered by rain. Where rain is so seasonal that the quantity of rainfall fails to meet the requirements of particular types of vegetation, or when the amount of rainfall is deficient or practically nonexistent, the extreme drying of the soil may retard, and eventually prevent, vegetation growth. Irrigation can compensate for the vicissitudes of nature by supplying water directly to areas of vegetation and greenery in regular intervals and in sufficient volumes.

Earlier techniques and methods of irrigation which were utilized to provide supplemental watering to vegetation and greenery located remote distances from a water source, traditionally included, for example, such methods as supplying water manually by hand and bucket directly to the vegetation, or by such means as constructing simple aqueduct systems. Aqueduct systems of the prior art were generally constructed by forming long furrows or canals immediately alongside the vegetation or greenery to provide moisture and promote vegetation growth and productivity. Over time, various other types of irrigation techniques and devices were developed by those skilled in the art to simplify and supplement traditional methods of irrigation. For example, simple mechanical lifting aids and animal-powered irrigation devices were developed to assist users in transporting water from a water source to a localized area of vegetation requiring supplemental irrigation.

As technology progressed with the advent of steam power, the internal combustion engine and electricity, irrigation systems became fully mechanized operations in many parts of the world. Many of the earlier traditional techniques and methods of providing irrigation were replaced by mechanical devices with internal programmable timer units. Moreover, mechanical irrigation devices of the prior art revolutionized the irrigation industry by providing a novel means for automating the control of water flow from a pressurized water source through such means, as for example, portable, lightweight aluminum piping, to numerous watering stations located remote distances from the water source.

Traditionally, automatic electromechanical controllers of the prior art incorporate multiple conventional motor-driven electric clocks which provide a mechanized means for programming individual start times for various irrigation cycles and watering stations. Calendar programs are generally incorporated to provide a means for selecting particular days of operational watering which normally includes a period over 14 days. Typically, calendar programs used in conjunction with prior art electromechanical controllers are functionally realized through the use of a disc being mechanically rotated to a next day position by a conventional motor-driven clock, once every 24 hours.

Employed in all but the simplest versions of electromechanical irrigation controllers of the prior art, cycle start circuits are typically provided to activate additional timer motors for advancing the irrigation controller through multiple preset watering cycles. Pins are generally placed in clock dials to close a switch at a preset time and, if the circuit is completed through a switch held closed by the calendar wheel pin on a day designated for irrigation, the watering cycle typically starts. In this regard, cycling water from station to station and programming watering intervals and timing durations for individual watering stations or zones may be accomplished by the placement and specific arrangement of various functional pins, cams, levers and other mechanical devices of prior art electromechanical controllers which interact with one another in concert to provide preprogramming automation for an irrigation system.

Increasing the number of watering zones or stations of prior art automatic electromechanical irrigation controllers to expand the watering capabilities of the irrigation system and provide water to larger areas of vegetation or greenery, such as golf courses, cemeteries, or parks, typically involves a significant number of mechanical disadvantages in the overall performance of the irrigation system. Moreover, in expansion of the watering capabilities of an irrigation system employing automatic electromechanical controllers of the prior art generally requires a dramatic increase in the number of working parts to realize and effectuate the additional programming capabilities typically required when increasing the number of watering stations or zones of an initial irrigation system.

In response to the problems associated with the dramatic increase in mechanical working parts required by prior art electromechanical irrigation controllers when expanding the watering capabilities of an irrigation system, those skilled in the art developed automatic solid state irrigation controllers which eliminated electric motors, mechanical switches, actuating pins, cams, levers, gears and other mechanical devices typically associated with electromechanical controllers and replaced them with solid state electronic circuitry. The programming potential of automatic solid state controllers of the prior art generally permits the user to program, for example, multiple start times and day programs for individual watering stations, repeat cycles, watering time selections in minutes (sometimes seconds), while maintaining the split-second accuracy of solid state timing without requiring the numerous interacting mechanical parts employed by prior art electromechanical irrigation controllers.

Automatic solid state irrigation controllers of the prior art typically provide a user with several program sequences from which to select. Generally, the user has the option to choose from multiple program sequences offered by the controller and determine the specific program options which best accommodate the particular watering needs of the user's vegetation and greenery in a most advantageous manner. In this regard, each of the various program sequences typically has its own independent start times which generally include several start times per day.

To accommodate and sustain multiple program sequences, solid state irrigation controllers of the prior art generally incorporate a programmable microprocessor-controlled user interface that provides a user with the capability of programming several sprinkling stations or zones in a variety of timing scenarios, for example, daily, weekly, odd days, even days, etc. Each watering station or zone usually includes one or more sprinklers and a solenoid valve which is generally regulated by the microprocessor unit. Solenoid valves typically control the flow of water entering a particular watering station from a pressurized water source, and provide a means for monitoring the flow of water exiting the watering station through various sprinkler lines that typically terminate into a plurality of sprinkler heads strategically located throughout an irrigation area.

Microprocessor units of prior art automatic solid state irrigation systems are generally programmable by user interface and provide the user with a means for manually entering input commands and data into designed program sequences which may then be selected to regulate any particular watering zone or station. To assist the user of the solid state irrigation controller when programming the microprocessor unit, Liquid Crystal Displays (LCD) are generally provided to visually communicate feedback to the user describing the current status of the programmable data being entered into the control module of the irrigation system by the user.

Other general features of automatic solid state irrigation controllers of the prior art may include manual modes of operation which generally function to provide the user with an option of overriding all preprogrammed automatic watering operations of an irrigation controller. For example, manual operational modes of prior art solid state irrigation controllers may be utilized when excessive amounts of rain have fallen, or when a lengthy spell of dry weather has occurred requiring greater quantities of irrigation than previously programmed by the user to sustain vegetation growth and productivity.

There are significant disadvantages, however, associated with the use of manual operational modes incorporated by solid state irrigation controllers of the prior art. For example, manual modes of operation generally fail to provide a means for overriding program sequences on a selective basis, such as between individual watering stations or zones of an irrigation system. In this regard, either all watering stations or zones of an irrigation system are operated according to established preprogrammed watering sequences, or all the watering stations or zones of the irrigation system are controlled by a manual operational mode. Since watering intervals and irrigation amounts are typically dependent upon the type of vegetation or greenery, serious disadvantages may result when operational limitations of an irrigation system are consistently manipulated by manual operational modes without regard to the specific watering needs of particular vegetation.

Automatic solid state controllers of the prior art generally include a back-up power source providing the controller with a means for storing previously entered program designations if a power outage occurs. Solid state irrigation controllers of the prior art may also incorporate fault indicators which typically provide a means for alerting the user of a faulty watering station or stations. When a fault indicator is activated, the internal programming circuitry of prior art solid state irrigation controllers generally bypass the preprogrammed operational commands of the faulty station, thereby restricting any further preprogrammed watering commands to the solenoid of the faulty station.

A meaningful disadvantage with fault indicators of prior art solid state irrigation controllers involves those problems associated with the user failing to receive some form of recognizable notice that a watering station has been designated as being faulty. In this regard, to adequately monitor the irrigation system for faulty stations, the user is generally faced with one of two alternatives. First, the user could watch the systematic watering of all the watering stations or zones to assure himself that watering was occurring at each watering station for the programmed intervals, or the user could personally inspect the LCD display of the irrigation controller on a daily basis to investigate for any visual indications that faulty stations exist. Typically, users of solid state irrigation systems do not take the time to personally inspect the control unit of the irrigation system on a daily basis, or to sit and watch a complete watering cycle to insure proper watering is taking place at each and every watering station or zone. Unfortunately, users of solid state irrigation controllers generally do not recognize that a watering station or zone has been designated as "faulty" until such time as the vegetation or greenery begins to yellow or turns brown due to the lack of sufficient irrigation.

Prior art irrigation controllers may be constructed to include a master valve which provides a means for controlling the flow of water from a designated water source. Master valves of prior art solid state irrigation controllers generally activate a water pump to provide supplemental watering to an irrigation area. Typically, water pumps of prior art irrigation systems comprise a filtration system to restrict debris from corrupting the irrigation flow systems.

A serious disadvantage with master valves of prior art solid state controllers is that when a master valve activates a water pump, the water pump typically remains activated until all programming sequences of each watering station and zone of the irrigation system has cycled at least once. In this regard, master valves of the prior art are incapable of being independently controlled or activated for individual watering stations or zones. Rather, the master valve either activates a water pump for all watering stations, or the water pump remains inactive for the duration of a complete irrigation cycle.

When a second water pump is added to an irrigation system to extract water from a secondary water source, master valves of prior art solid state irrigation controllers will typically activate both water pumps for the duration of all programming sequences of every watering station or zone, whether or not the pump is actively withdrawing water. Moreover, the constant activation of the water pump through the entire watering cycle of an irrigation system without the pump actually facilitating the extraction of water, may result in serious mechanical impediments to the water pump and filtration system, thus restricting the overall efficiency and effectiveness of the irrigation system.

Another significant disadvantage with automatic solid state irrigation controllers of the prior art is that they tend to conventionally require numerous detailed and unreasonably complicated steps to satisfactorily program the microprocessor unit of the controller. Similarly, the user is generally constrained to observe numerous lengthy and tedious programming steps when inputting individualized programming sequences for individual watering stations or zones of the irrigation system. Moreover, when a user desires to make any minor modifications to a particular programming sequence of a certain watering station or zone, the user is generally required to reprogram and reenter new program schedules for every other watering station. Further thereto, reprogramming microprocessor units of prior art solid state irrigation controllers generally involves a large investment of time, typically requiring the user to maintain a certain amount of programming literacy and expertise to avoid the numerous confusingly similar programming steps.

When programming the microprocessor unit of prior art solid state irrigation controllers or making minor modifications to program sequences of individual watering stations or zones, the user must generally be in physical contact with the control module to enter the new program commands. Automatic irrigation controllers of the prior art, however, are generally mounted outside. And, since all programming capabilities of the controller are typically entered at the physical location of the microprocessor control unit, inputting programming data outdoors may result in a significant inconvenience to the user, especially during inclement weather.

When servicing prior art automatic solid state irrigation controllers, the user typically turns on the faulty watering station at the physical location of the programmable controller and walks to the specific location of the related watering station or zone for the purpose of visually observing the operation or non-operation of the faulty station when the station is activated. After examining the activity or inactivity of the particular faulty watering station, the user generally returns to the programmable controller and deactivates the faulty watering station using the overriding manual mode of operation.

In other circumstances, maintenance and service of faulty watering stations or zones of an irrigation system may involve the employment of at least two service operators. One service operator usually remains at the physical location of the programmable controller, while the other service operator ventures to the areas where the faulty watering stations are supposed to provide supplemental irrigation. While checking the irrigation system, both service operators generally communicate with one another as to the working status of the faulty watering stations when the station is manually activated. In this regard, maintaining and servicing prior art solid state irrigation controllers can quickly amount to a lot of wasted time and effort incurred with the excessive walking of a user between the programming controller and faulty watering stations, or with the requirement that at least two service attendants are typically needed to facilitate repairs and proper maintenance to an irrigation system.

In addition to the foregoing disadvantages, expanding the watering capabilities of prior art solid state irrigation controllers to provide water to larger areas of vegetation or greenery, such as, golf courses, parks, cemeteries, etc. generally involves great expense and inconvenience with regard to programming operations. Moreover, if the user wants to provide supplemental irrigation to an area larger than the current irrigation system can facilitate, the user is typically required to establish separate programming routines for an additional and completely independent irrigation controller having its own housing unit and internal circuitry to operate the additional watering stations or zones.

BRIEF SUMMARY AND OBJECTS OF THE INVENTION

In view of the foregoing, it is a primary object of the present invention to provide a programmable controller apparatus and method for irrigation systems which provides a manual mode of operation for selectively overriding the programming sequences of designated watering stations or zones without directly influencing the preprogramming sequences of other individual watering stations of the irrigation system.

It is also an object of the present invention to provide a programmable controller apparatus and method for irrigation systems which incorporates an external warning device for alerting a user that one or more watering stations or zones have been designated as faulty.

It is a further object of the present invention to provide a programmable controller apparatus and method for irrigation systems which provides a master valve that is programmable by watering station or zone, and which allows the user the ability to program the master valve to activate a water pump and filtration system when an individual watering station is enabled.

It is a still further object of the present invention to provide a programmable controller apparatus and method for irrigation systems which provides a novel combination of electronic programming which interacts with manual programming features to provide greater ease and flexibility in programming the irrigation controller, or when making minor performance modifications to preprogrammed sequences of the watering stations or zones.

It is an additional object of the present invention to provide a programmable controller apparatus and method for irrigation systems which utilizes a removable control module that provides the user with the capability of programming the control module at some remote location from the physical location of the controller.

Likewise, it is an object of the present invention to provide a programmable controller apparatus and method for irrigation systems which is radio compatible to provide on-site programming when servicing faulty watering stations or zones.

In addition thereto, it is an object of the present invention to provide a programmable controller apparatus and method for irrigation systems which comprises a novel means for easily expanding the watering capacity of an irrigation system by inserting a control module with greater watering capability without having to incorporate more than one programmable controller or separate programming routines.

Consistent with the foregoing objects, and in accordance with the invention as embodied and broadly described herein, a programmable controller apparatus for irrigation systems is disclosed in one preferred embodiment of the present invention as including at least one removable control module which interfaces with internal circuitry of the programmable controller for activating and operating a plurality of watering valves. A housing unit is provided for the removable control module and the internal control circuitry of the programmable controller to prevent water contamination and unauthorized tampering. The removable control module interfaces with internal circuitry of the programmable controller to provide variations in programmable watering sequences for individual watering stations. The removable control module comprises multiple programming keys and switches that provide interaction between electronic programming and manual programming features which function in combination to provide easier programming options for the irrigation controller. The stand alone capacity of the removable control module allows the control module to be programmed at a remote location from the irrigation controller. An LCD display and the functional programming keys and switches of the control module provide a means for programming various watering sequences into the memory of the removable control module for activating watering stations at preprogrammed times. A manual mode of operation is provided for selectively overriding or deactivating previously entered programming sequences for individual watering stations without disturbing the programming sequences of other watering stations. A master valve is also included which can be selectively activated on a programmable basis for individual watering stations. Formed on the exterior of the housing unit of the programmable controller is an external warning indicator that provides visual indication of faulty watering stations. A transmitter/receiver provides the programmable controller with radio compatible for on-site programming of faulty watering stations of the irrigation system.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and features of the present invention will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments of the invention and are, therefore, not to be considered limiting of its scope, the invention will be described with additional specificity and detail through use of the accompanying drawings in which:

FIG. **1** is a perspective view of a programmable controller apparatus for irrigation systems illustrating one presently preferred embodiment of the housing unit of the present invention;

FIG. **2** is a perspective view of one presently preferred embodiment of the removable control module of the programmable controller apparatus of the present invention;

FIG. **3** is a perspective view of one presently preferred embodiment of the LCD display of one presently preferred embodiment of the removable control module of the programmable controller apparatus of the present invention;

FIG. **4** is an electrical schematic diagram illustrating one presently preferred configuration of the power circuitry of one presently preferred embodiment of the removable control module of the programmable controller apparatus of the present invention;

FIG. **5** is an electrical schematic diagram illustrating one presently preferred configuration of the electrical circuitry for the microcontroller, LCD display, keyboard and associated control circuitry of one presently preferred embodiment of the programmable controller of the present invention; and

FIGS. **6**A & **6**B constitute an electrical schematic diagram illustrating one presently preferred configuration of the electrical circuitry showing one presently preferred embodiment of the power terminal driving circuitry of the removable control module of the programmable controller of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of the system and method of the present invention, as represented in FIGS. **1** through **6**, is not intended to limit the scope of the invention, as claimed, but it is merely representative of the presently preferred embodiments of the invention.

The presently preferred embodiments of the invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout.

One presently preferred embodiment of the programmable controller apparatus of the present invention, designated generally at **10**, is illustrated in FIG. **1**. As shown, programmable controller **10** comprises a substantially rectangular housing unit **12** preferably formed of a rigid plastic material. It will be readily appreciated, however, that housing unit **12** can, of course, be formed from a wide variety of suitable materials and that other shapes or configurations are possible.

Housing unit **12** is sufficient in size to accommodate a removable control module **20**, generally shown in FIG. **2**, and internal circuitry of programmable controller **10**. A weather-resistant cover **13** may be hingeably attached to housing unit **12** and secured over the external front facing **11** of housing unit **12** by a conventional latch mechanism **14** and locking means **15** to prevent water contamination and unauthorized tampering of control module **20**.

Advantageously, the face of control module **20** depicted in FIG. **2** may comprise a replaceable control label template **23** having a readily peelable adhesive backing for application thereto. In this way, a control template **23** can be provided in the native language of each country in which the unit will be used, thereby allowing all of the controls to be readily and selectively identified in virtually any language without modification of the unit as a whole. Preferably, control label template **23** is designed in such a manner so as to provide graphical schematics to assist in programming control module **20**. The graphic design of control label template **23** provides multiple color-based programming depictions which provide a general basis for correlating the various operational programming features of control module **20** with each another and facilitate easier programming.

Control module **20** is removably connected to housing unit **12** by means of support tabs **16** rigidly connected to the external front facing **11** of the housing unit **12**. Support tabs **16** are inserted into complimentary openings **17** formed at the base of removable control module **20** to retain the control module **20** within housing unit **12**, as illustrated in FIG. **2**. Preferably, the external front facing **11** of housing unit **12** is formed in such a manner to assist support tabs **16** with retaining control module **20** within housing unit **12**, when inserted therein. A complimentary connector card positioned on the backside of removable control module **20** may be inserted into connector **18** which is integrally formed on the external facing **11** of housing unit **12** to provide a means for interfacing removable control module **20** with the internal circuitry of programmable controller **10**.

Referring now to FIG. **2**, a substantially circular output conduit **19** extends from the base of housing unit **12** providing a general passageway for electrical wiring **87** to be introduced therethrough and operably coupled to a terminal connector strip **88** providing a means for interfacing watering stations or zones of the irrigation system with the internal circuitry of programmable controller **10**. An opening **21** which is preferably lined with a weatherproof grommet is formed in the base of the housing unit **12** and provides means for connecting an AC power source to a connector block **90**.

As illustrated in FIG. **2**, cover **13** of housing unit **12** has been removed to expose removable control module **20** displaying various dome keys and programming switches that function to facilitate the programming of control module **20**. The combination of the solid state electronic programming features of a rotary switch **24** and dome keys **26**, **28**, **30**, **32**, **34** interacting with manual programming duration slide switches **40** provides greater ease and flexibility when programming the irrigation controller **10**. For example, rotary switch **24** provides several functional programming selections for individual watering stations or zones operated by programmable controller **10**. These functions include, for example, MASTER VALVE programming, SET TIME/DATE, Schedule "A" start times and watering days, Schedule "B" start times and watering days, and Schedule "C" start times and watering intervals. Rotary switch **24** also has a position to allow the user to set the control module **20** to AUTO mode in which the programmable controller **10** automatically waters each station or zone according to its individualized preprogrammed schedule. In addition, rotary switch **24** includes an OFF position providing an overriding means that inhibits all automatic and manual watering of the programmable controller **10**, until such time as rotary switch **24** is removed from the OFF position.

Keys **26**, **28**, **30**, **32**, **34** and **36** are preferably push-button dome keys which assist with the setup and entry of various programming functions of rotary switch **24** as described above. A MANUAL key **26** provides extra watering for all stations or for a particular individual watering station for a specific duration of time which will be described in further detail below. A CLEAR key **28** operates to clear the existing setting of the active field during programming and initialize the 24 hour inhibit mode (the mechanics of which will also be described below). A NEXT key **30** scrolls through different programming fields such as start times, watering days, interval, station number, year, month, and day etc.

A "–" key **32** and a "+" key **34** are used to alter time intervals backwards or forwards, respectively, while the user programs time settings. An ENTER key **36** confirms the existing setting of the watering station during the programming procedure. A RESET key **38**, such as, for example a pin hole type, provides a means for resetting control module **20** to a default setting. The default setting is preferably date set at "Jan 1993" clock set at 12:00 am, all outputs disabled, and all start times and programs cleared.

Twelve duration slide switches **40** are provided on the front facing of removable control module **20** of the preferred embodiment for programming watering sequences for each of the twelve watering stations or zones provided by the irrigation system. It will be readily appreciated, however, that increasing or decreasing the number of duration slide switches **40** and correlating number of watering stations or zones of the irrigation system is possible.

Duration slide switches **40** provide various selectable watering intervals, including, for example, MANUAL ON, 2 minutes, 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, 30 minutes, 45 minutes, 60 minutes, 120 minutes, and MANUAL OFF. The variations in time between watering intervals provided by duration slide switches **40** may be modified without broadening the scope of the present invention.

Watering durations are established for individual watering stations or zones by selectively placing the representative durational slide switch **40** at the desired duration interval. Apart from establishing watering intervals for watering stations of the irrigation system, duration slide switches **40** also provide an overriding manual operational mode for each of the watering stations or zones.

Twelve "3" position programming slide switches **64** are formed on the face of removable control module **20**. Programming slide switches **64** provide the user with the capability of selecting from multiple watering schedules, such as, for example, schedules A, B or C, when programming watering start times and watering days for each of the twelve watering stations or zones. By manually adjusting the positioning of programming slide switches **64**, the user can easily modify watering start times and watering days for individual watering stations. In this regard, programming slide switches **64** provide flexibility and ease of use when programming watering sequences for individual watering stations of the irrigation system of the present invention.

A Liquid Crystal Display (LCD) **22** is provided on the front facing of removable control module **20** to communicate the entry of programmed information into removable control module **20** and the current programmable status of the controller **10**. As more clearly shown in FIG. **3**, LCD display **22** preferably includes: (1) four "7" segment digit display **96** indicating year, date, time, duration of automatic watering, and fault indication, (2) one and a half "7" segment digits **98** indicating an active watering station; (3) programming indicators representing schedules A, B, C or default annunciators **100** indicating which selected watering program has been activated for a particular watering station or zone; (4) a Water Drop/WATERING signal **102** indicating the watering status of the irrigation programmable controller **10**; (5) an ON indicator signal **104** representing the activated status of the programmable controller **10** as either operating in an automatic watering mode or a manual mode; (6) an OFF indicator signal **106** manually inhibiting a watering station or zone from being electronically activated; (7) fourteen indicator flags **108** signifying a two week (Monday through Sunday period) for use when initiating Schedule A watering commands or programming options; (8) EVERY DAY, 2 DAYS, 3 DAYS, ODD DAYS and EVEN DAYS indicator flags **110** for Schedule B programmable watering sequences; (9) an INTERVAL indicator signal **112** which is activated when programming watering stations or zones according to Schedule C watering commands or programming options; (10) four start time annunciators **114**; and (11) a MASTER VALVE indicator signal **116** displaying current master valve programming for a particular watering station or zone. LCD display **22** functions to provide a readable means of communicating the programming status of the control module **20** to the user regarding watering cycles and programming modes of the controller **10**. Examples of the foregoing multiple programming capabilities are not intended to be restrictive, but merely representative of one presently preferred embodiment of the present invention. Accordingly, additional watering schedules may be used, such as, for example, a designated watering schedule that provides multiple independent, time-interval watering stations which are activated on a programmable "all days" basis by individual watering station or zone. Another alternate variation in programming capability may include, for example, a programmable watering schedule that accommodates an independent timer control option programmably designated for each individual watering station or zone.

Referring again to FIG. **2**, terminal connector strip **88** and connector block **90** are used as electrical connections for wiring extending from a plurality of water valves to the programmable controller **10** to interface therewith. Terminals **88** and **90** are preferably formed of any suitable five terminal block, such as, for example, a zinc alloy type. Terminals **88**, **90** preferably include a Remote Terminal for indicating faulty wiring, 3 Common (or Ground) terminals, twelve station or zone terminals connected to solenoids at each watering station, at least one master valve terminal, and two terminal blocks for 110 VAC (or 240 VAC) power connections.

FUNCTIONAL DESCRIPTION

The following provides a functional description of one preferred method for programming one preferred embodiment of removable control module **20** of the present invention. The user enters the current time and date into the memory or microprocessor unit of the control module **20** preferably in such manner, for example, as follows:

1. Turn Rotary Switch **24** to the SET/TIME DATE position;
2. Press '+' **34** or '–' **32** dome keys to set the current time;
3. Press 'NEXT' **30** or 'ENTER' **36** to confirm the time setting and to switch to year setting;
4. Press '+' **34** or '–' **32** dome keys to set the current year;
5. Press 'NEXT' **30** or 'ENTER' **36** to confirm the year setting and to switch to month setting;
6. Press '+' **34** or '–' **32** dome keys to set the current month;
7. Press 'NEXT' **30** or 'ENTER' **36** to confirm the month setting and to switch to date setting;
8. Press '+' **34** or '–' **32** dome keys to set the current day;
9. Press 'NEXT' **30** or 'ENTER' **36** to confirm the date setting; and
10. Alter the Rotary Switch **24** from the SET DATE/TIME position to exit from this programming mode.

Next, the user typically programs the master valve. As discussed above, each individual watering station can be independently programmed to selectively activate a pump start. All watering stations are preferably set to have a pump start by default, whereby to modify the default setting, the following steps, for example, are carried out:

1) Turn Rotary Switch **24** to SET MASTER VALVE position. Station Annunciator **98** reads '1' to indicate the programming of watering station one;
2) Press 'ENTER' **36** to set station one to activate pump start or press 'CLEAR' to disable the optional pump start for station one;
3) Press 'NEXT' **30** to move to watering station two;
4) Repeat steps 2 and 3 until all watering stations are programmed; and
5) Alter the Rotary Switch **24** from the SET MASTER VALVE position to exit from this programming mode.

When watering a station or zone of the irrigation system with the optional pump start, the pump solenoid is enabled at the programmed start time. Watering is generally enabled approximately 5 seconds after the program start time has been initiated.

The user sets the programming schedules for each watering station by selecting either watering schedule A, B or C. If watering Schedule A is selected by the user for a particular watering station, the following steps, for example, would preferably be followed to program controller **10**:

1) Turn Rotary Switch **24** to SET WATERING DAYS of Schedule A (the cursor or hyphen over each day segment **108** initially flashes on Monday);
2) Press 'NEXT' **30** to move the cursor through each day segment **108**;
3) While the cursor is on the desired day segment **108**, press 'ENTER' **36** to select that day for the Schedule A program or 'CLEAR' **28** to cancel that day from the Schedule A program; and
4) Alter the Rotary Switch **24** from the SET WATERING DAYS of Schedule A position to exit from this programming mode.

When using Schedule A for setting watering days and time intervals, the programming options provided by Schedule A include selecting watering on any particular day or days once every week or once every 2 weeks. Schedule A also crosses from Week 1 to Week 2 on Monday at 12:00 am.

If watering Schedule B is selected by the user for a particular watering station, the following steps, for example, would preferably be followed to program controller **10**:

1) Turn Rotary Switch **24** to SET WATERING DAYS of Schedule B (the cursor or hyphen at the right of each option flag **110** initially flashes at EVERY DAY);
2) Press 'NEXT' **30** to move the cursor through each option flag **110**;
3) While the cursor is on the desired option flag **110**, press 'ENTER' **36** to select that option for the Schedule B program or 'CLEAR' **28** to cancel that day from the Schedule B program; and
4) Alter the Rotary Switch **24** from the SET WATERING DAYS of Schedule B position to exit from this programming mode.

Schedule B programmable watering options preferably include: (1) watering every day; (2) watering every 2 days; (3) watering every 3 days; (4) watering on odd calendar days; and (5) watering on even calendar days. The foregoing watering options are indicated by Schedule B option flags **110**. Only one programmable watering option, however, may be selected for any particular watering station or zone.

If watering Schedule C is selected by the user for a particular watering station, the following steps, for example, would preferably be followed to program controller **10**:

1) Turn Rotary Switch **24** to SET WATERING INTERVAL of Schedule C;
2) Press '+' **34** or '–' **32** dome keys, respectfully, to set the desired watering interval within a 1–28 day range;
3) Press 'ENTER' **36** to confirm the current setting; and
4) Alter the Rotary Switch **24** from the SET WATERING INTERVAL of Schedule C position to exit from this programming mode.

Pursuant to programming Schedule C, every time the watering interval is changed the current day is set to day "0" and watering begins on day one.

Preferably, the next step of the method for programming controller **10** involves the user setting the start times for schedules A, B, and C. The general process for setting start times is identical for each watering schedule and is preferably conducted, as follows:

1) Turn Rotary Switch **24** to SET START TIME of Schedule A, B, or C;
2) The cursor or hyphen to the left of the start time annunciators **114** will flash at the first start time;
3) Press 'NEXT' **30** to cycle through four start time annunciators **114**;
4) Press '+' **34** or '–' **32** dome keys, respectfully, to set each start time;
5) Press 'ENTER' **36** to confirm each programmed start time and to advance to the next start time;
6) Repeat Steps **4** and **5** until all start times have been programmed; and
7) Alter the Rotary Switch **24** from the SET START TIME position to exit from this programming mode.

Once the controller has been programmed according to the steps described above, rotary switch **24** is preferably set to the AUTO position to enable automatic watering by programmable controller **10**. LCD display **22** displays the current time of day as long as the current time does not match any of the preprogrammed start times. At such time that the current time matches preprogrammed start times for any watering station or zone, programmable controller **10** electronically determines which schedule (Schedule A, B, or C) has been activated by its particular start time. Programmable controller **10** monitors the twelve "3" position programming slide switches **64** to determine which station or stations are to be activated during the selected programming schedule (A, B or C). During an active watering cycle, LCD display **22** oscillates between the current time and the status of the active watering program mode by means of an electronic toggle switch.

LCD display **22** indicates active watering by energizing ON indicator signal **104**. The active station number is indicated by the one and a half "7" segment digits **98** and the programming schedule is indicated by active schedule annunciator **100**. The amount of time an active station has remaining in its watering sequence is indicated by the four "7" segment digit display **96**. Watering stations are watered in sequence from station one to station twelve for the interval of time indicated by their corresponding duration slide switches **40**. Once all of the stations running on an active schedule have been watered for their preprogrammed durations, programmable controller **10** waits for the current time to meet the next preprogrammed start time, and then repeats the foregoing process.

Default Program "D" is enabled when all start times for the watering stations are clear, when the watering days for Schedules A and B have not been programmed, or when the watering intervals of Schedule C have not been set. In Default "D" mode, all watering stations are irrigated in relative sequence from station one through station twelve with the watering mode preferably beginning at approximately 5:00 am for a duration of ten minutes at each watering station. LCD display **22** indicates DEFAULT watering by actuating program annunciators **100**. Water Drop design **102** and ON indicator signal **104** indicate active watering by the programmable controller **10** of the irrigation system and the four "7" segment digits **96** indicate the duration of watering as represented by the positioning of duration slide switches **40**. Any watering station which has its corresponding duration slide switch **40** in the MANUAL ON or MANUAL OFF position will not be watered with default watering.

A manual mode of operational watering can be selected for each individual watering station by placing the respected duration slide switch **40** to the MANUAL ON position. When duration slide switch **40** is placed in the MANUAL ON position, LCD display **22** indicates the status of the watering station by activating ON indicator signal **104** which illustrates an energized watering station. Once the watering station has been activated, manual watering continues for the period of time remaining in the watering interval indicated by the LCD display on the one and a half "7" segment digits **98**. If at any time, more than one station is set to MANUAL ON, the station activated last will be served first. When the active station has completed its watering cycle, and more than one station is still set to MANUAL ON, the station with the highest station number will be served first.

An EXTRA WATERING MODE is provided by the programmable controller **10** allowing the user with the selective option of watering all stations once for a specified amount of time. When setting the EXTRAWATERING MODE, the following steps, for example, are preferably followed:

1) Press 'MANUAL' key **26** while in automatic mode;

2) Press 'NEXT' **30** to choose a particular station for extra watering;

3) Set the watering duration for the identified station by its respective duration slide switch **40**;

4) Press 'NEXT' **30** to move to the next station;

5) Repeat steps 3 and 4 until the duration of watering for at least two stations has been programmed; and

6) Press 'ENTER' **36** to start the EXTRA WATERING MODE.

LCD display **22** will indicate the status of active watering by energizing ON indicator signal **104**. After the EXTRA WATERING CYCLE is completed, programmable controller **10** returns to its normal programming sequence automatic operational mode. If a watering station is already preprogrammed for watering while manual watering is enabled (and no station is set to MANUAL ON), the preprogrammed scheduled is stored and postponed until after the extra watering is complete.

An INHIBIT MODE is provided by the programmable controller **10** which inhibits all automatic preprogrammed watering sequences for a period of 24 hours, except those stations set on MANUAL ON. When programming controller **10** for INHIBIT MODE, the user simply presses CLEAR key **28** during the normal operation of the controller **10**. To exit INHIBIT MODE and return to normal preprogramming sequences before the 24 hour inhibited period expires, the user presses ENTER key **36**.

When the effective watering of the irrigation system is driven by program start times and watering durations that exceed the next programmed start time, the exceeded start times will be pushed forward until the current watering cycle completes itself. The foregoing modification of start times will preferably be terminated by the first start time of the following day. If a particular station has both extra watering and MANUAL ON enabled, any preprogrammed start times are ignored and fail to initiate.

During normal operation of the programmable controller **10**, three triacs may be activated. The triacs/stations are activated by scheduled watering sequences, MANUAL ON, or by pump solenoid activation. The priority levels when more than one mode of operation is selected will be, for example, as follows (from highest to lowest priority): rotary switch **24** OFF position, MANUAL ON/OFF mode of duration slide switches **40**, INHIBIT MODE, EXTRA-WATERING MODE, Schedule A program, Schedule B Program, Schedule C program and Schedule D program.

Reference is next made to FIG. **4**, which illustrates in more detail one preferred embodiment of a schematic diagram showing one presently preferred configuration of the power circuitry of the programmable controller **10** of the present invention. Those of ordinary skill in the art will, of course, appreciate that various modifications to the detailed schematic diagram of FIG. **4** may easily be made without departing from the essential characteristics of the invention. Thus, the detailed schematic diagram of FIG. **4** is intended only as an example, and it simply illustrates one presently preferred embodiment of a schematic diagram that is consistent with the invention as claimed herein.

As shown, a metal oxide varistor **MOV1** is connected across the AC power supply to protect the programmable controller **10** against voltage spikes due to lightning strikes, for example. The AC voltage is connected to a transformer **T1**, such as a 120/26 V 60 Hz 750 mA UL approved transformer. This transformer steps the 110 VAC supply down to 24 V AC supply needed in the solenoid valve circuitry at each station. Another metal oxide varistor, **MOV2** is connected across the 24 VAC for added protection against voltage spikes. Fuse **F1** is connected to the 24 VAC line to protect against power surges. The 24 VAC line is then rectified by diode **D32** and regulated to 5 Volts by the resistance capacitance network composed of **C17** and **R22** and Zener diode **Z1**. The 5 Volt line is then filtered by capacitor **C14** which is connected in parallel with Zener diode **Z1**.

Capacitors C15 and C16, diode D31, resistors R20, R38 and R19, and transistors Q3 and Q4 perform the fault detecting function of the controller. If there is a fault in the valve of a watering station, when that station is activated, a large amount of current will be drawn from the 24 VAC supply. Because of the large current drain, the 24 VAC voltage will drop to a substantially smaller voltage, with the drop in voltage being proportional to the amount of current drawn. Resistors R20 and R38 detect this voltage drop which is filtered by capacitor C15 and applied to the base of transistor Q4. When the voltage drops to a low level, transistor Q4 is turned on. The collector terminal of Q4 is connected to the base of transistor Q3 through resistor R19. Thus, when Q4 is turned on, it draws current from the base of transistor Q3 causing Q3 to turn on.

The emitter terminal of Q3 is connected to the regulated 5 V voltage level, and the collector of transistor Q3 is connected to the fault line of the microcontroller, IC1 as shown in FIG. 5. When transistor Q3 is turned on, the fault line is forced to a level of 5 V, indicating that a fault has occurred. The microcontroller, IC1 thereby detects that a fault has occurred, however, the microcontroller does not have enough information to determine which watering station is faulty.

The microcontroller must turn on each individual station one at a time to gather this information. The microcontroller turns on a station, waits approximately .5 seconds, and then monitors the fault line to determine if a fault has occurred. When the microcontroller finds the faulty station, the fault is displayed by LCD display 22, and the faulty station is bypassed in all watering cycles until the faulty circuitry is repaired.

Illustrated in FIG. 5 is one preferred embodiment of a schematic diagram of the presently preferred configuration of the microcontroller, LCD display 22 and keyboard circuitry of the programmable controller 10. Those of ordinary skill in the art will, of course, appreciate that various modifications to the detailed schematic diagram of FIG. 5 may easily be made without departing from the essential characteristics of the invention. Thus, the detailed schematic diagram of FIG. 5 is intended only as an example, and it simply illustrates one presently preferred embodiment of a schematic diagram that is consistent with the invention as claimed herein.

The microcontroller IC1 is any suitable programmable device, such as an SMC6233. Preferably, the microcontroller has a clock input, LCD display controlling circuity, and various control lines. Pins 6 through 15 and 83 through 100 of the microcontroller IC1 connect to and control LCD display 22 in a manner familiar to those skilled in the art. Pins 62, 114, 67, and 110 are power connections to the device, the power line VDD being filtered through capacitors C4, C6, C7, and C8. The device X1 is an oscillator of any suitable type that produces a clock signal to the microcontroller IC1. The microcontroller also produces a series of control and status lines 122 for the keyboard 94. These lines allow the microcontroller to have access to the information programmed by the user through the keyboard 94 consisting of the rotary switch 24, twelve duration slide switches 40, twelve "3" position programming slide switches 64, and dome keys 26–36. Twelve of the control lines (ZONE1C through ZONE12C) are used by the power terminal driving circuitry of FIG. 6 as will be described later. The Reset line is connected directly to the front panel reset push button 38 and enters the microcontroller at pin 5.

Spare soldering pads 125 are placed on the printed circuit board for use by the manufacturer to specify the number of zones the present invention can control. Pin 49 of the microcontroller IC1 is soldered to pad A, B, or C to indicate a six, nine, or twelve station watering system, respectively. Pins 45, 46, and 57 of the microcontroller IC1 provide operational control to at least one pump triac, the clock, and the remote (fault indicator) circuitry shown in FIG. 6. Microcontroller IC1 is programmed in a manner familiar to those skilled in the art with the capacity for controlling every aspect of the present invention, from the control of LCD display 22 to the control of the watering output of a plurality of sprinkling valves. Capacitors C9 and C10 are part of the circuitry needed to drive the LCD display.

FIG. 6 illustrates one preferred embodiment of a schematic diagram of the configuration of the power terminal driving circuitry of removable control module 20 of the present invention. Those of ordinary skill in the art will, of course, appreciate that various modifications to the detailed schematic diagram of FIG. 6 may easily be made without departing from the essential characteristics of the invention, as described. Thus, the detailed schematic diagram of FIG. 6 is intended only as an example, and it simply illustrates one presently preferred embodiment of the power terminal driving circuitry consistent with the description and invention as claimed herein.

As shown, FIG. 6 illustrates the power terminal driving circuitry of one preferred embodiment of the programmable controller 10. ZONE1C-12C, REMOTEC, PUMPC, and CLK are provided by the microcontroller circuitry as described in FIG. 5. ZONE lines are connected to two integrated circuits IC2 and IC3 which may be 74HC174 or other suitable devices. The foregoing integrated circuits provide the function of latching the data on the ZONE lines from the microcontroller. The data indicates which watering station is to be enabled at what time. The data is also latched into the integrated circuits IC2 and IC3 only on the rising edge of the CLK signal, which is controlled by microcontroller IC1. The CLK signal is connected through a pull-down resistor and a filter capacitor to the VSS signal level. When latched, ZONE data becomes a voltage level which enables any one of the twelve station triacs, TR1 to TR12, through resistors R3 through R14. The output of the various triacs is directly fed to terminal block 88 and further introduced to a solenoid valve for each individual station.

The REMOTEC and PUMPC signals, also produced by microcontroller IC1, control the water pump and remote triacs TR14 and TR13 through a transistor switch network composed of transistors Q5 and Q6, and resistors R23, R24, R39 and R40. Under microcontroller IC1 control, the switch network can be placed in either an open or a closed condition enabling or disabling the triacs to the REMOTE terminal and to the PUMP terminal respectively. The REMOTE terminal is used to provide an external indication of a fault condition, while the PUMP terminal is used to turn the master valve on or off.

The microprocessor decides by scanning the position of the sliders and assessing other information such as the day, date, time and pre-programmed information, if and when a particular 24 VAC output should be "on" or "off." When the output should be "on," the microprocessor gives a current to the particular triac control circuitry shown in FIG. 6B through the IC and resistor circuitry, thereby turning "on" the gate of the triac. When the gate is turned "on," it allows power from the transformer to flow to the particular output terminal. In turn, each output terminal is connected to a particular solenoid-valve which when activated opens allowing water to flow to a particular watering area.

From the above description, it will be appreciated that the present invention provides a programmable controller apparatus and method for irrigation systems which provides a manual mode of operation for selectively overriding programming sequences of designated watering stations without influencing the preprogramming sequence of other watering stations. Unlike prior art irrigation controllers, the present invention incorporates an external warning device for signaling faulty watering stations and provides a master valve which is selectively programmable by watering station.

Additionally, the present invention provides a novel combination of electronic programming which interacts with manual programming features to provide greater ease and flexibility in programming the control module, or when making minor program modifications. The watering capability of the present irrigation system can also be easily expanded by removably introducing a control module providing greater watering capability, without requiring the incorporation of additional programmable controllers or separate programming routines. Moreover, the programmable controller is radio compatible for on-site activation of watering stations when servicing or maintaining the irrigation system. Based on the foregoing, the present invention thus provides significant advantages over prior art irrigation controllers now in use.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed and desired to be secured by United States Letters Patent is:

1. A programmable controller apparatus for selectively activating a plurality of irrigation valves, the apparatus comprising:

a housing unit;

at least one removable control module having memory capacity;

internal electrical circuitry confined within the housing unit for interfacing remote irrigation valves with the control module;

a power supply connected to the internal circuitry;

a rotary switch for selecting input/operational command modes for programming the control module;

a plurality of buttons for entering data into the memory of the control module;

a plurality of slide switches for selecting programming schedules and watering durations for a plurality of watering stations;

a replaceable control template removably positioned over a front facing of the control module, said control template having graphical depictions reproduced thereon for correlating programming interactions between the rotary switch, the plurality of input buttons, and the plurality of slide switches;

a display for displaying data entered into the control module, wherein said display toggles between a current time clock setting and an active watering cycle;

activating circuitry for selectively energizing the irrigation valves;

electronic circuitry for selectively activating at least one master valve and water pump to provide irrigation to one or more selected water valves;

manual programming means for selectively overriding watering sequences preprogrammed into the memory of the control module;

at least one external default-signaling means for providing visual warning of faulty irrigation valves;

means for expanding watering capacity of the programmable controller apparatus; and

a back-up battery power source for maintaining program integrity of the control module in the event of a power failure.

2. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said housing unit is formed of a weather resistant material.

3. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said housing unit is formed of a rigid plastic composite material.

4. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said housing unit comprises a hingeably attached cover.

5. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **4** wherein said housing unit further comprises a latch mechanism and locking means for securing the cover member over said housing unit to prevent water contamination and unauthorized tampering of the control module.

6. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said control module is removably connected to the housing unit.

7. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **6** wherein said removable control module comprises retaining means for supporting the control module within the housing unit.

8. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **6** wherein said removable control module comprises a connector card which interfaces with a complimentary connector means integrally formed on the housing unit for electronically interfacing said control module with the internal circuitry.

9. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said replaceable control template comprises an adhesive backing.

10. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said replaceable control template may be provided in various languages to assist in programming the control module.

11. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said data entry buttons include at least six electronic programming dome keys.

12. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **1** wherein said plurality of slide switches comprises water duration slide switches and programming slide switches.

13. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **12** wherein said duration slide switches includes multiple watering intervals representative of various increments of time.

14. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim **12** wherein said duration slide switches include twelve electromechanical switches.

15. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim 12 wherein said programming switches comprise at least two programming schedules.

16. A programmable controller apparatus for selectively activating a plurality of irrigation valves as defined in claim 1 wherein said display is a liquid crystal display.

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United States Patent [19]

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[54] **PAGER-CONTROLLED WIRELESS RADIOTELEPHONE**

[75] Inventors: **David Alan Gaulke**; **Thomas Charles Hanson**, both of Boulder; **Richard Paul Moleres**, Louisville, all of Colo.

[73] Assignee: **AT&T Corp.**, Middletown, N.J.

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[58] **Field of Search** 379/58, 59; 455/343, 455/127, 33.1, 426, 574, 573, 572, 556

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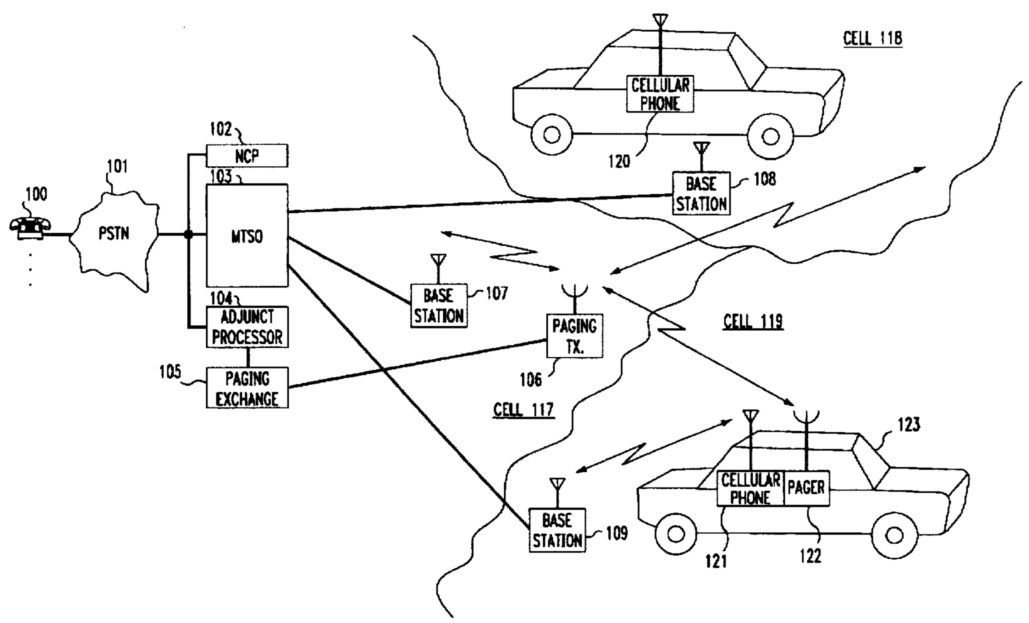
Primary Examiner—Dwayne Bost
Assistant Examiner—Myron K. Wyche

[57] **ABSTRACT**

An integrated pager and cellular phone (**123**) includes circuitry (**502**, **515**) that responds to receipt by the pager (**122**) of an incoming-call-indicative paging signal by connecting the cellular phone (**121**) to a battery power source (**513**). This activates the cellular phone, whereupon it registers with a base station (**107–109**) and thus becomes able to receive the incoming call. The circuitry further responds to receipt by the pager of a second paging signal by disconnecting the cellular phone from the battery power source. This allows the cellular phone to be kept in a deactivated condition and not draining battery power at times when the cellular phone is not in use, without missing incoming calls, and does so automatically, without intervention of the user of the cellular phone.

8 Claims, 5 Drawing Sheets



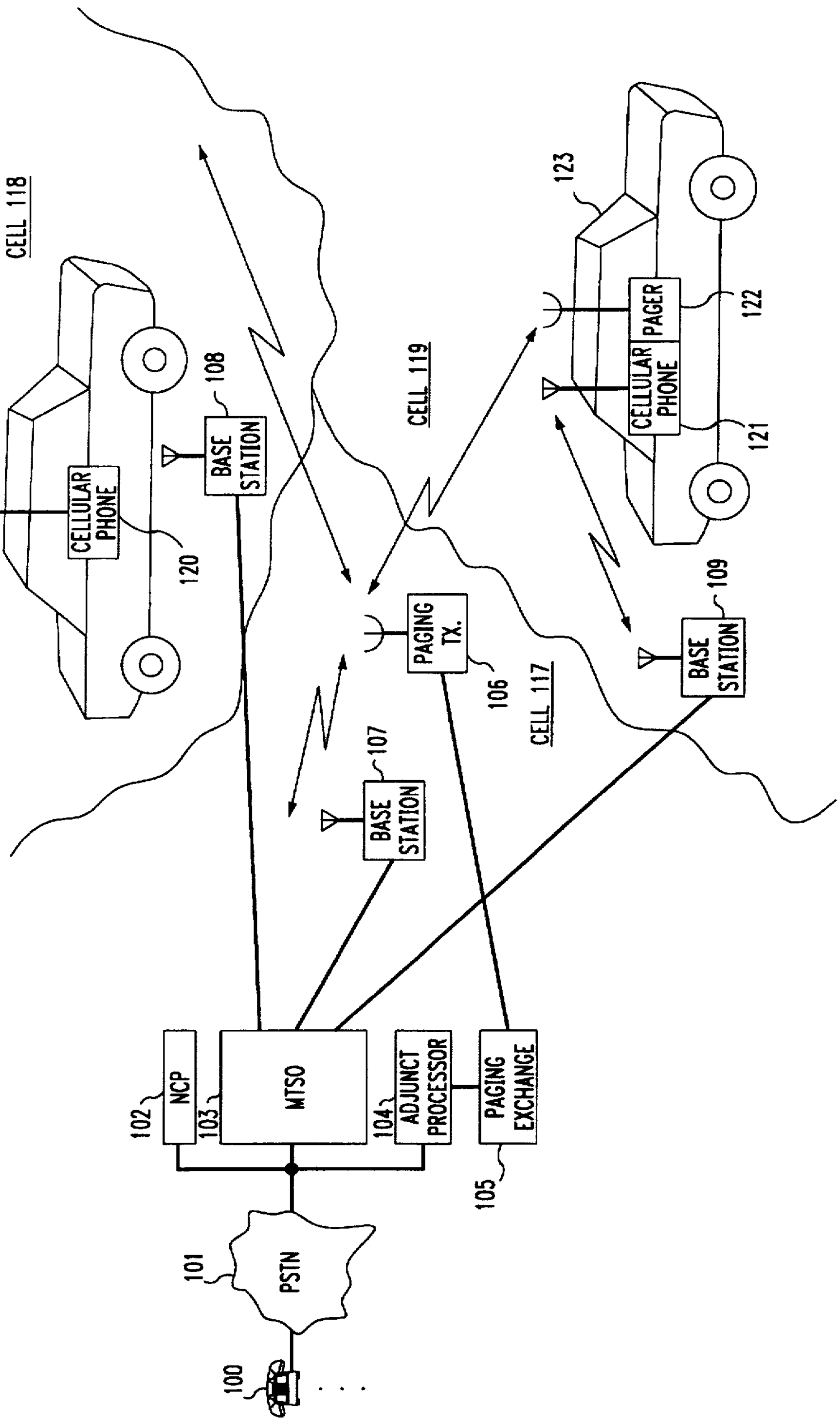

CELL 118
CELL 119
CELL 117
CELLULAR PHONE
120
BASE STATION
108
PAGING TX.
106
BASE STATION
107
CELLULAR PHONE
121
PAGER
122
123
BASE STATION
109
NCP
102
MTSO
103
ADJUNCT PROCESSOR
104
PAGING EXCHANGE
105
PSTN
101
100

FIG. 1

FIG. 2

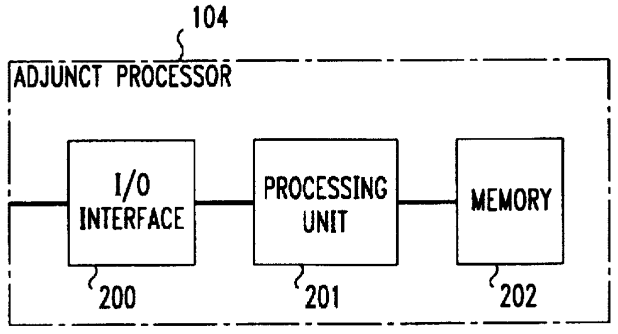

104
ADJUNCT PROCESSOR
I/O INTERFACE
PROCESSING UNIT
MEMORY
200
201
202

FIG. 3

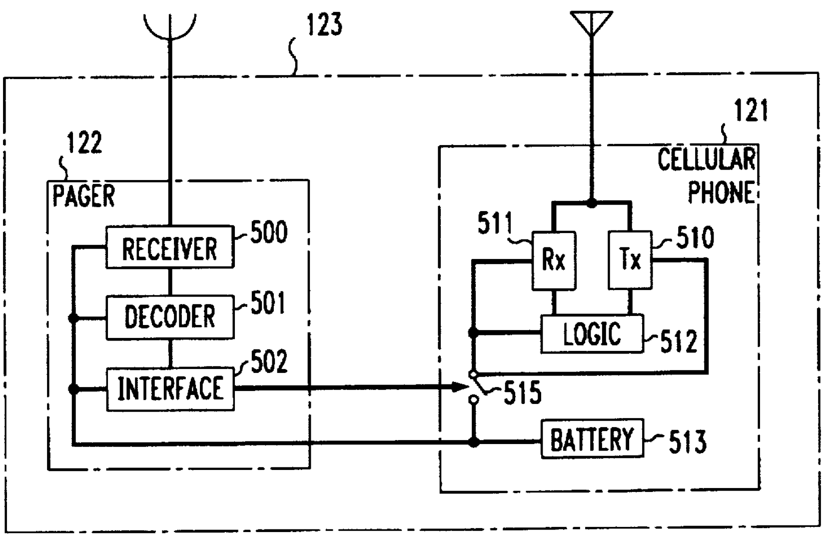

123
121
CELLULAR PHONE
122
PAGER
RECEIVER
500
DECODER
501
INTERFACE
502
511
Rx
Tx
510
LOGIC
512
515
BATTERY
513

FIG. 4

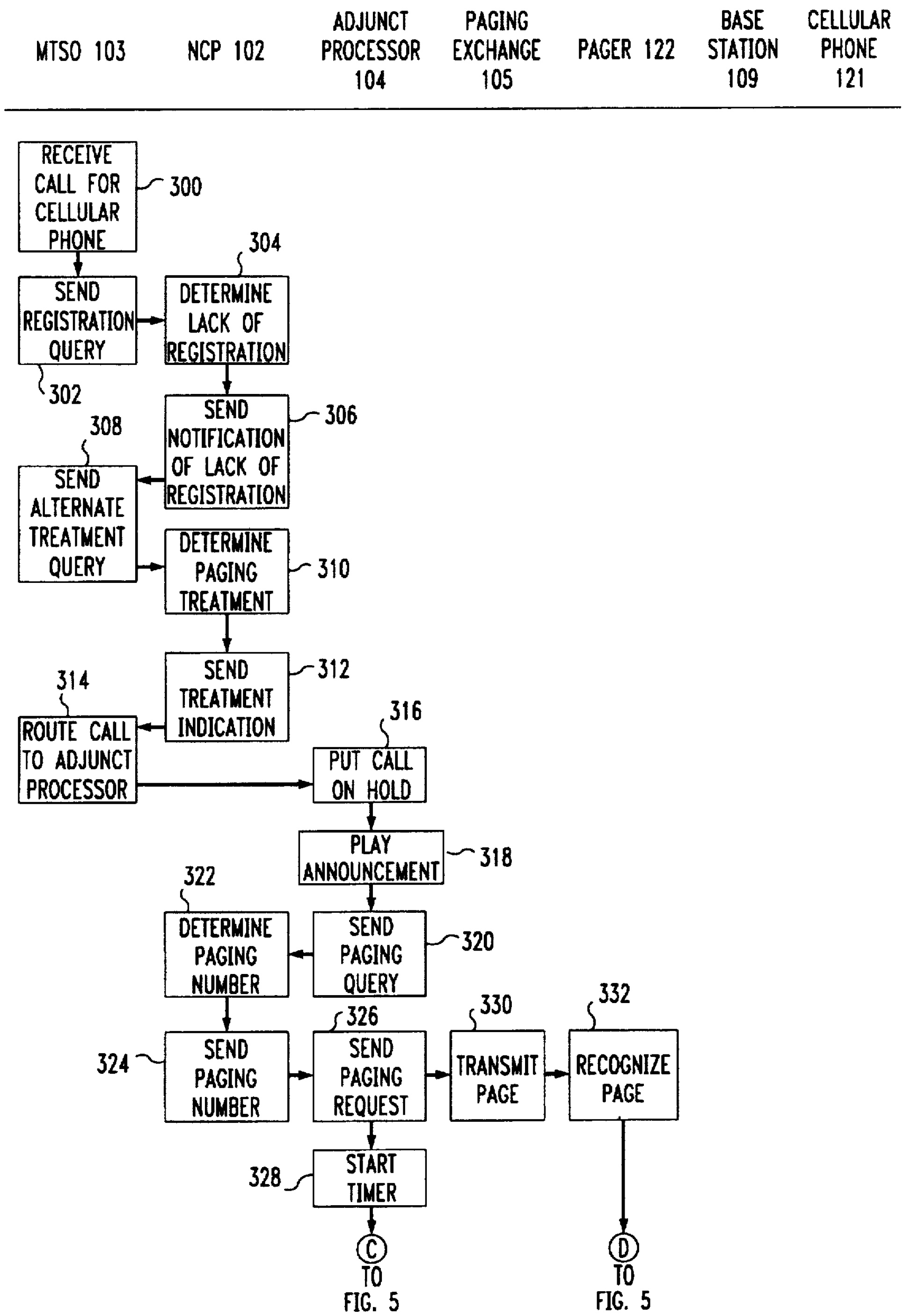

MTSO 103
NCP 102
ADJUNCT PROCESSOR 104
PAGING EXCHANGE 105
PAGER 122
BASE STATION 109
CELLULAR PHONE 121
RECEIVE CALL FOR CELLULAR PHONE
300
SEND REGISTRATION QUERY
302
DETERMINE LACK OF REGISTRATION
304
SEND NOTIFICATION OF LACK OF REGISTRATION
306
SEND ALTERNATE TREATMENT QUERY
308
DETERMINE PAGING TREATMENT
310
SEND TREATMENT INDICATION
312
ROUTE CALL TO ADJUNCT PROCESSOR
314
PUT CALL ON HOLD
316
PLAY ANNOUNCEMENT
318
SEND PAGING QUERY
320
DETERMINE PAGING NUMBER
322
SEND PAGING NUMBER
324
SEND PAGING REQUEST
326
START TIMER
328
TRANSMIT PAGE
330
RECOGNIZE PAGE
332
C
TO FIG. 5
D
TO FIG. 5

FIG. 5

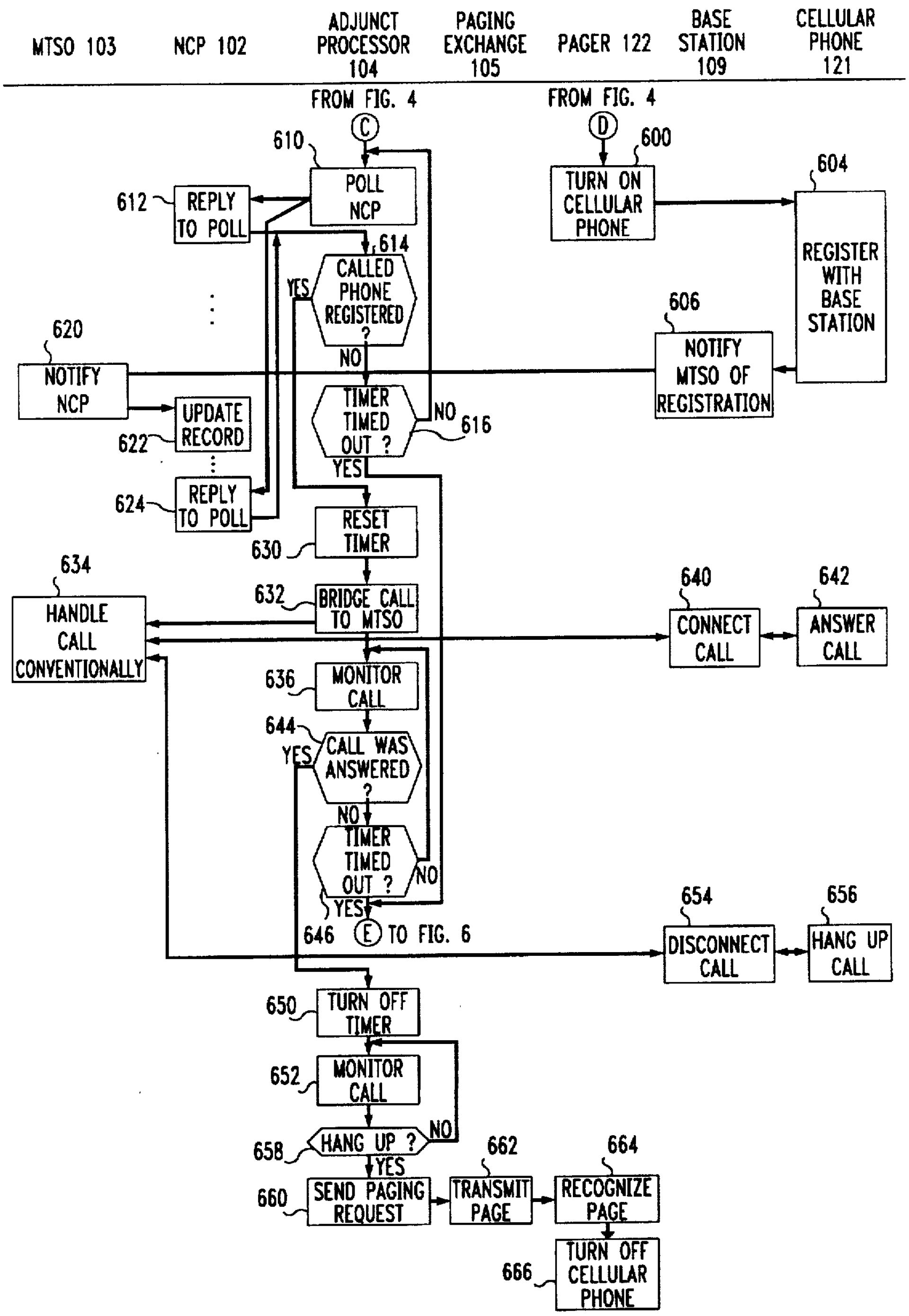
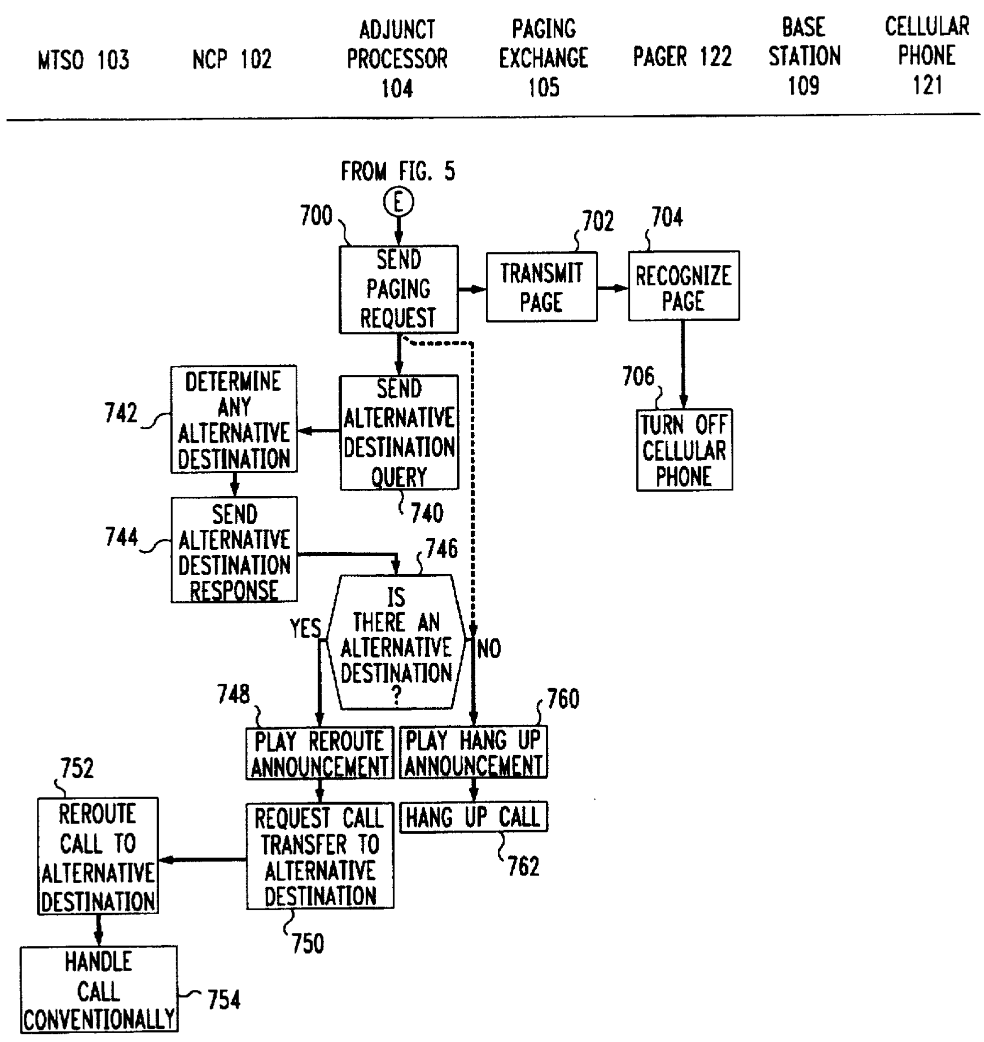

MTSO 103
NCP 102
ADJUNCT PROCESSOR 104
PAGING EXCHANGE 105
PAGER 122
BASE STATION 109
CELLULAR PHONE 121
FROM FIG. 4
C
FROM FIG. 4
D
600
TURN ON CELLULAR PHONE
604
REGISTER WITH BASE STATION
606
NOTIFY MTSO OF REGISTRATION
620
NOTIFY NCP
610
POLL NCP
612
REPLY TO POLL
614
CALLED PHONE REGISTERED ?
YES
NO
TIMER TIMED OUT ?
NO
616
YES
UPDATE RECORD
622
624
REPLY TO POLL
RESET TIMER
630
634
HANDLE CALL CONVENTIONALLY
632
BRIDGE CALL TO MTSO
640
CONNECT CALL
642
ANSWER CALL
636
MONITOR CALL
644
CALL WAS ANSWERED ?
YES
NO
TIMER TIMED OUT ?
NO
YES
646
E TO FIG. 6
654
DISCONNECT CALL
656
HANG UP CALL
650
TURN OFF TIMER
652
MONITOR CALL
658
HANG UP ?
NO
YES
660
SEND PAGING REQUEST
662
TRANSMIT PAGE
664
RECOGNIZE PAGE
666
TURN OFF CELLULAR PHONE

FIG. 6


MTSO 103
NCP 102
ADJUNCT PROCESSOR 104
PAGING EXCHANGE 105
PAGER 122
BASE STATION 109
CELLULAR PHONE 121
FROM FIG. 5
E
700
SEND PAGING REQUEST
702
TRANSMIT PAGE
704
RECOGNIZE PAGE
706
TURN OFF CELLULAR PHONE
742
DETERMINE ANY ALTERNATIVE DESTINATION
SEND ALTERNATIVE DESTINATION QUERY
740
744
SEND ALTERNATIVE DESTINATION RESPONSE
746
IS THERE AN ALTERNATIVE DESTINATION ?
YES
NO
748
PLAY REROUTE ANNOUNCEMENT
760
PLAY HANG UP ANNOUNCEMENT
752
REROUTE CALL TO ALTERNATIVE DESTINATION
REQUEST CALL TRANSFER TO ALTERNATIVE DESTINATION
750
HANG UP CALL
762
HANDLE CALL CONVENTIONALLY
754

PAGER-CONTROLLED WIRELESS RADIOTELEPHONE

CROSS-REFERENCE TO RELATED APPLICATION

This application relates in subject matter to application of Gaulke et al. entitled "Automated Wireless-Call Completion Using a Paging Network", filed on even date herewith and assigned to the same assignee.

TECHNICAL FIELD

This invention relates to paging and wireless radiotelephone services and equipment.

BACKGROUND OF THE INVENTION

Both paging systems and wireless radiotelephone systems are well known in the art. Paging systems are typically one-way radio communications systems that transmit rather powerful signals from a paging exchange to cover a large geographical area—such as an entire state or region, for example—with the broadcast in order to alert a person possessing a pager anywhere in that geographical area and to send a short message, such as a call request or a telephone number, to the pager's display. In contrast, wireless (e.g., cellular) radiotelephone systems are two-way radio communications systems that transmit rather weak signals at different frequencies from a plurality of base stations to cover a small area—a cell—around each base station with the transmissions. A mobile wireless radiotelephone communicates with the base station of whatever cell it happens presently to be located in via like rather weak signal transmissions to receive and to originate wireless telephone calls. In traditional cellular systems, each base station constantly engages all cellular telephones in its cell in specific two-way communications, called "registration", whereby the present location of any cellular phone is determined and incoming calls for that cellular phone can be directed by the cellular exchange to the base station that is presently serving that cellular phone.

Many users of cellular phones have continued to use pagers, which has led some manufacturers to combine both devices into a single unit. Illustrative examples thereof are disclosed in U.S. Pat. Nos. 5,117,449, 5,148,473, 5,153,903, and 5,247,700.

Because of the continuous two-way transmissions involved in registration, both the transmitter and the receiver of a turned-on wireless radiotelephone are active and consuming energy. Quite often, wireless radiotelephones operate on battery-supplied energy, and the transmitter drains significant amounts of energy from the battery. Many users of battery-powered wireless radiotelephones turn on their wireless radiotelephones only when making outgoing calls, in order to conserve battery life. And quite often, users simply forget to turn their wireless radiotelephones on. Consequently, it happens all too often that a user of a wireless radiotelephone misses incoming calls because the user's wireless radiotelephone is turned off and the exchange cannot complete the incoming calls to the wireless radiotelephone. In contrast, pagers have no transmitter (or at least no constantly-active transmitter) to drain their batteries of power, and their receivers consume only small amounts of power. Consequently, users typically keep their pagers turned on all of the time.

SUMMARY OF THE INVENTION

This invention is directed to solving this problem of the prior-art wireless radiotelephone systems. Generally according to the invention, there is provided an integrated pager and wireless radiotelephone which are interconnected such that the pager enables, or activates (e.g., turns on by causing power to be supplied to) the wireless radiotelephone in response to receipt of a paging signal. Preferably, the pager also disables or deactivates the wireless radiotelephone in response to receipt of another paging signal. Consequently, the wireless radiotelephone can be enabled or activated whenever there is an incoming call for the wireless radiotelephone, simply by sending to the pager a paging signal indicative of the incoming call. This allows the wireless radiotelephone to be kept in a disabled, deactivated, condition and not draining battery power at the times when the wireless radiotelephone is not in use, without missing incoming calls. Moreover, it has the advantage of activating and preferably also deactivating the wireless radiotelephone automatically, without intervention of the user of the pager and the wireless radiotelephone.

These and other advantages and features of the invention will become more apparent from the following description of an illustrative embodiment of the invention, taken together with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram of an illustrative telecommunications system that embodies an illustrative implementation of the invention;

FIG. 2 is a block diagram of an adjunct processor of the system of FIG. 1;

FIG. 3 is a block diagram of an integrated cellular radiotelephone and pager of the system of FIG. 1; and

FIGS. 4–6 are a flow diagram of the operations of the system of FIG. 1.

DETAILED DESCRIPTION

FIG. 1 shows an illustrative telecommunications system. The telecommunications system comprises a cellular system, such as the AT&T Autoplex® system, that conventionally includes a mobile telephone system office (MTSO) **103** that serves as a wireless call exchange and provides wireless call processing and call routing services, a network control point (NCP) **102** that is connected to MTSO **103** and serves as a database of information about the configuration and present status of the cellular system, a plurality of base stations **107–109** connected to MTSO **103** and each providing wireless call services to cellular telephones **120–121** that are presently located in its cell **117–119**, respectively. The telecommunications system of FIG. **1** further comprises a paging system that conventionally includes a paging exchange **105** that provides paging services to pagers, such as a pager **122**, through at least one paging transmitter **106**. The geographical area covered by a paging transmitter is typically large compared to the area of a cell, and encompasses a plurality of cells. The telecommunications system of FIG. **1** further comprises a landline telephone system that conventionally includes the public service telephone network (PSTN) **101** that interconnects a plurality of telephones, such as telephone **100**. To provide call capability between landline telephones such as telephone **100** and cellular telephones **120–121**, MTSO **103** is conventionally interconnected with PSTN **101**.

As described so far, the telecommunications system of FIG. **1** is conventional. According to the invention, however, at least some cellular system users, such as user **123**, are equipped with a cellular telephone **121** and a pager **122** that are integrated into a single unit, as shown in FIG. 3. Cellular phone **121** is substantially conventional, but for the presence of a pager-controlled switch **315**. Cellular phone **121** includes a transmitter **510** and a receiver **511** operating under control of cellular phone logic **512** and powered by a battery **513**. Circuits **510–512** are connected to battery **513** through switch **315** which is controlled by pager **122**. Pager **122** includes a conventional paging receiver **500** connected to a conventional paging decoder **501**. According to the invention, pager **122** further includes interface circuitry **502** that operates switch **315** under control of decoder **501**. Circuits **500–502** are illustratively powered by battery **513**, and are always turned on. When decoder **501** decodes a received incoming-call indication, it not only alerts user **123** thereof but also causes interface circuitry **502** to close switch **315**, thereby connecting circuits **510–512** to battery **513** and turning cellular phone **121** on. This causes cellular phone **121** to undergo registration and thus become able to receive the incoming call. And when decoder **501** decodes a received power turn-off indication, it causes interface circuitry **502** to open switch **315**, thereby disconnecting circuits **510–512** from battery **513** and turning cellular phone **121** off, whereby cellular phone **121** again becomes unable to receive incoming calls.

Further according to the invention, the telecommunications system of FIG. **1** includes an adjunct processor **104** that is connected to MTSO **103**, NCP **102**, and paging exchange **105**, and that provides for cellular-call completion with the aid of the paging system.

As shown in FIG. **2**, adjunct processor **104** is a general-purpose stored-program controlled computer that includes a memory **202** for storing control programs, a processing unit **201** connected to memory **202** for executing the control programs, and an input and output (I/O) interface **200** for enabling processing unit **201** to communicate with MTSO **103**, NCP **102**, and paging exchange **105**. Adjunct processor **104** is illustratively the AT&T Conversant® system. The control programs in memory **202** implement the adjunct-processor **104** functionality flowcharted in FIGS. **4–6**. Alternatively, the control programs in memory **202** may be stored in and executed by MTSO **103**, whereby MTSO **103** effects the functionality of adjunct processor **104** and adjunct processor **104** is not needed. FIGS. **4–6** show the operations of the entire telecommunications system of FIG. **1** that implement a first illustrative embodiment of the invention.

As shown in FIG. **4**, when MTSO **103** receives a call incoming for a cellular phone **121**, either from a landline telephone **100** via PSTN **101** or from another cellular phone **120**, at step **300**, it attempts to extend the call to cellular phone **121**. First, MTSO **103** sends a query containing the called number to NCP **102**, at step **302**, to determine if the called cellular phone **121** is registered with any base station **107–109**, and if so, which one. NCP **102** responds to the query by searching its data to determine if called cellular phone **121** is registered, at step **304**. If called cellular phone **121** is registered, it is able to receive the incoming call. So NCP **102** conventionally sends the information back to MTSO **103** in a query response, and the MTSO conventionally extends the call to called cellular phone **121** via the one of the base stations with which cellular phone **121** is registered. However, if NCP **102** finds at step **304** that called cellular phone **121** is presently not registered with any base station, it is not able to receive the incoming call and the attempt at extending the call to cellular phone **121** cannot be completed, and NCP **102** notifies MTSO **103** thereof, at step **306**. In response, MTSO **103** sends another query to NCP **102** inquiring whether alternative call treatment is being provided for this cellular phone **121**, at step **308**. Alternative treatment may include a call-coverage path, such as connecting the call to the called party's mailbox in a voice messaging system (not shown). According to the invention, the data in NCP **102** do provide for alternative call treatment for cellular phone **121**, and the first alternative call destination in the coverage path of cellular phone **121** is specified to be adjunct processor **104**. NCP **102** makes this determination, at step **310**, and sends notice thereof to MTSO **103**, at step **312**. In response, MTSO **103** routes and connects the call to adjunct processor **104**, at step **314**. Adjunct processor **104** receives the call and puts it on hold, at step **316**. While the call is on hold, adjunct processor **104** plays a pre-recorded announcement to the caller informing the caller to stay on the line while the called party is paged, at step **318**. Adjunct processor **104** also sends a paging query for called cellular phone **121** to NCP **102**, at step **320**. NCP **102** finds the pager number of pager **122** that is associated with cellular phone **121** in its records for cellular phone **121**, at step **322**, and sends this pager number to adjunct processor **104**, at step **324**. In response, adjunct processor **104** sends a paging request to paging exchange **105**, at step **326**. The paging request contains the pager number of pager **122** and a request to send it an incoming-call indication. Adjunct processor **104** also starts a timer, at step **328**, that gives cellular phone **121** a predetermined amount of time to become registered.

In response to the paging request, paging exchange **105** broadcasts an incoming-call-indicative paging signal containing the pager number provided by adjunct processor **104** and an incoming-call-indication code, at step **330**. Pager **122** receives the paging signal and recognizes its pager number, at step **332**, and in response it turns on cellular phone **121**, at step **600** of FIG. **5**. In response, cellular phone **121** automatically undergoes a conventional registration procedure with base station **109** that serves cell **119** in which cellular phone **121** is presently located, at step **604**, and so becomes able to receive the incoming call. In response to the registration, base station **109** notifies MTSO **103** of the registration, at step **606**, and MTSO **103** in turn notifies NCP **102**, at step **620**, causing NCP **102** to update its records for cellular phone **121** accordingly, at step **622**.

In the meantime, adjunct processor **104** periodically polls NCP **102** for the status of cellular phone **121**, at step **610**. Until cellular phone **121** registers with a base station, NCP **102** replies to the poll with an indication that cellular phone **121** is not registered, at step **614**. In response to the indication of non-registration, at step **614**, adjunct processor **104** repeats polling of NCP **102** at step **610** until the timer that adjunct processor **104** had started at step **328** of FIG. **4** times out, at step **616**. If cellular phone **121** registers with a base station and NCP **102** is informed thereof at step **622** before the timer times out at step **616**, NCP **102** replies to a poll at step **610** with an indication that cellular phone **121** is registered and an identification of base station **109** with which cellular phone **121** is registered, at step **624**. In response to this indication, at step **614**, adjunct processor **104** resets the timer that it had started at step **328**, at step **630**. The timer now begins to time an interval during which cellular phone **121** must answer the call. Adjunct processor **104** also bridges the call back to MTSO **103**, at step **632**. This results in the call being connected back to MTSO **103** through adjunct processor **104**, thereby allowing adjunct processor **104** to monitor the call, at step **636**. MTSO **103** responds to the bridged call as if it had just received the call, and attempts to extend (i.e., connect) the call to cellular phone **121** in the conventional manner, at step **634**, as if MTSO **103** had just received the call.

Adjunct processor **104** is monitoring the call, at step **636**. If base station **109** connects the call to cellular phone **121** at step **640**, and cellular phone **121** answers the call, at step **642**, before the timer that adjunct processor **104** had reset at step **630** times out, at step **646**, adjunct processor **104** detects the call answer, at step **644**. In response, adjunct processor **104** turns off the timer, at step **650**, and continues to monitor the call, at step **652**. When one of the parties to the call hangs up the call, e.g., at step **656**, and base station **109** proceeds to disconnect the call, at step **654**, adjunct processor **104** detects this condition, at step **658**. In response, adjunct processor **104** sends a power turn-off paging request for the pager number of pager **122** to paging exchange **105**, at step **660**. Paging exchange **105** responds by broadcasting the request via a paging signal, at step **662**. Pager **122** receives and recognizes the paging signal, at step **664**, and responds thereto by turning off cellular phone **121**, at step **666**.

If the timer that was started at step **328** of FIG. **4** times out before cellular phone **121** registers with a base station, at step **616**, or if the timer that was reset at step **630** times out before adjunct processor **104** detects that cellular phone **121** answered the call, at step **646**, adjunct processor **104** proceeds to step **700** of FIG. **6**. At step **700**, adjunct processor **104** sends a power turn-off paging request for the pager number of pager **122** to paging exchange **105**. Paging exchange **105** responds by broadcasting the request via a paging signal, at step **702**. Pager **122** receives and recognizes the paging signal, at step **704**, and responds thereto by turning off cellular phone **121**, at step **706**. Adjunct processor **104** then sends an alternative destination query to NCP **102**, at step **740**. NCP **102** responds by checking the coverage path of cellular phone **121** to determine if any alternative destinations other than adjunct processor **104**, are specified therein, at step **742**, and informs adjunct processor **104** accordingly, at step **744**. If there is an alternative destination specified for calls to cellular phone **121**, as determined at step **746**, adjunct processor **104** plays an announcement to the caller on the held call informing the caller that the called party could not be reached and that the call is being routed to an alternative destination, at step **748**. Adjunct processor **104** then sends a request to MTSO **103** to transfer the call to the alternative destination, at step **750**. MTSO **103** does so, at step **752**, and continues to process the call in the conventional manner, at step **754**.

Returning to step **746**, if it is determined there that an alternative destination is not specified for calls to cellular phone **121**, adjunct processor **104** plays an announcement to the caller on the held call informing the caller that the called party could not be reached and that the call is being terminated, at step **760**. Adjunct processor **104** then hangs up the call, at step **762**.

Alternatively, if the timer times out at step **616** or step **646**, adjunct processor **104** may dispense with trying to find an alternative destination for the call and may proceed directly to steps **760** et seq., as indicated by the dashed line in FIG. **6**.

Of course, various changes and modifications to the illustrative embodiments described above will be apparent to those skilled in the art. For example, the service may be extended to be used in conjunction with any device (e.g., fax machine, cellular modem) for the purpose of turning on and off and/or reprogramming the device via the paging network. Also, the service can be implemented in a cellular radiotelephone system without the need for a separate paging system, if the cellular system implements a paging-like capability (e.g., a "short message" capability). Such changes and modifications can be made without departing from the spirit and the scope of the invention and without diminishing its attendant advantages. It is therefore intended that such changes and modifications be covered by the following claims.

The invention claimed is:

1. An integrated wireless radiotelephone and pager comprising:

a wireless radiotelephone for receiving wireless calls that selectively receives power through a switch coupled to a battery; and

a pager, coupled to the battery independent of the switch, the pager being operable to send a control signal that closes the switch in response to receipt by the pager of a first paging signal, thereby enabling the wireless radiotelephone to receive power and an incoming wireless call.

2. The integrated wireless radiotelephone and pager of claim **1**, wherein:

the switch opens in response to receipt by the pager of a second paging signal, for disabling the wireless radiotelephone from receiving the wireless calls.

3. An integrated wireless radiotelephone and pager comprising:

a battery;

a wireless radiotelephone;

a pager; and

means connected to the pager and to the wireless radio telephone, responsive to receipt by the pager of a first paging signal, for connecting the wireless radiotelephone to the battery;

wherein the pager is coupled to the battery independent of the connecting means.

4. The integrated wireless radiotelephone and pager of claim **3** wherein:

the connecting means are further responsive to receipt by the pager of a second paging signal, for disconnecting the wireless radiotelephone from the battery.

5. The integrated wireless radiotelephone and pager of claim **4** wherein:

the wireless radiotelephone is a cellular phone, and activation of the cellular phone causes the cellular phone to register with a base station of a cellular system.

6. The integrated wireless radiotelephone and pager comprising:

wireless radiotelephone circuitry;

paging circuitry; and

a battery connected in parallel to the paging circuitry and to a pager-operated switch coupling the battery to the wireless radiotelephone circuitry;

wherein the pager-operated switch is responsive to receipt of a first paging signal by the paging circuitry for closing a connection between the battery and the wireless radiotelephone circuitry to activate the radiotelephone circuitry, and further responsive to receipt of a second paging signal by the paging circuitry for opening the connection between the battery and the wireless radiotelehone circuitry to deactivate the radiotelephone circuitry.

7. The integrated wireless radiotelephone and pager of claim **6** wherein:

the wireless radiotelephone circuitry comprises cellular phone circuitry, and activation of the cellular phone circuitry causes the cellular phone circuitry to register with a base station of a cellular system.

8. The integrated wireless radiotelephone and pager of claim **1**, wherein:

the switch opens in response to receipt by the pager of a second paging signal indicating the incoming call has been disconnected or has not been received by the wireless radio telephone within a predetermined time period.

* * * * *

US005760706A

United States Patent [19]

Kiss

[11] **Patent Number: 5,760,706**

[45] **Date of Patent: Jun. 2, 1998**

[54] **REMOTE CONTROL SYSTEM USING PARTIALLY EARTH-BURIED RF ANTENNA**

[76] Inventor: **Michael Z. Kiss**, 418 S. Meadows Ave., Manhattan Beach, Calif. 90266

[21] Appl. No.: **615,730**

[22] Filed: **Mar. 14, 1996**

Related U.S. Application Data

[63] Continuation of Ser. No. 145,875, Oct. 29, 1993, abandoned.

[51] **Int. Cl.**⁶ **G08C 17/02**

[52] **U.S. Cl.** **340/825.69**; 340/835.06; 340/835.72; 343/741; 343/848; 343/872; 343/719; 455/88; 455/352; 364/138

[58] **Field of Search** 340/825.06, 825.69, 340/825.72, 870.01; 343/702, 741, 829, 846, 848, 872, 719; 455/88, 90, 128, 347, 352, 500; 364/138

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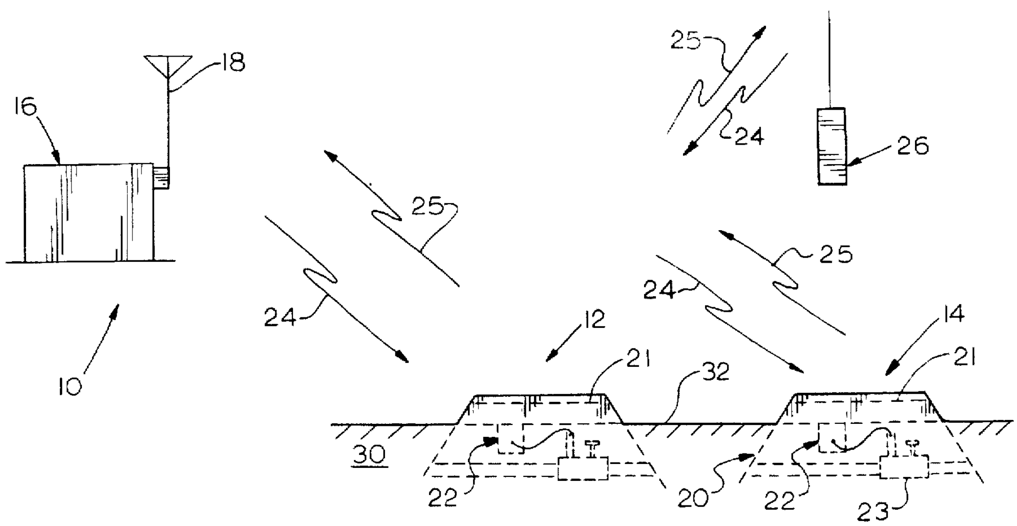
Primary Examiner—Michael Horabik
Assistant Examiner—William H. Wilson, Jr.
Attorney, Agent, or Firm—Freilich, Hornbaker & Rosen

[57] **ABSTRACT**

An RF control system characterized by the use of remotely located low profile radio frequency antennas which are concealed in conventionally appearing valve boxes or similar housings. The system includes a central control station, including a central RF transmitter, and a plurality of remote station, each including an RF receiver and antenna. A preferred remote station includes a valve box or similar housing of the type intended to be at least partially buried in the earth. The housing has a peripheral wall defining an access opening and a removable cover for bridging the opening. A directional discontinuity ring radiator (DDRR) antenna is physically mounted in the valve box housing on the interior side of the cover and is connected to a receiver, preferably also physically mounted on the cover.

16 Claims, 5 Drawing Sheets



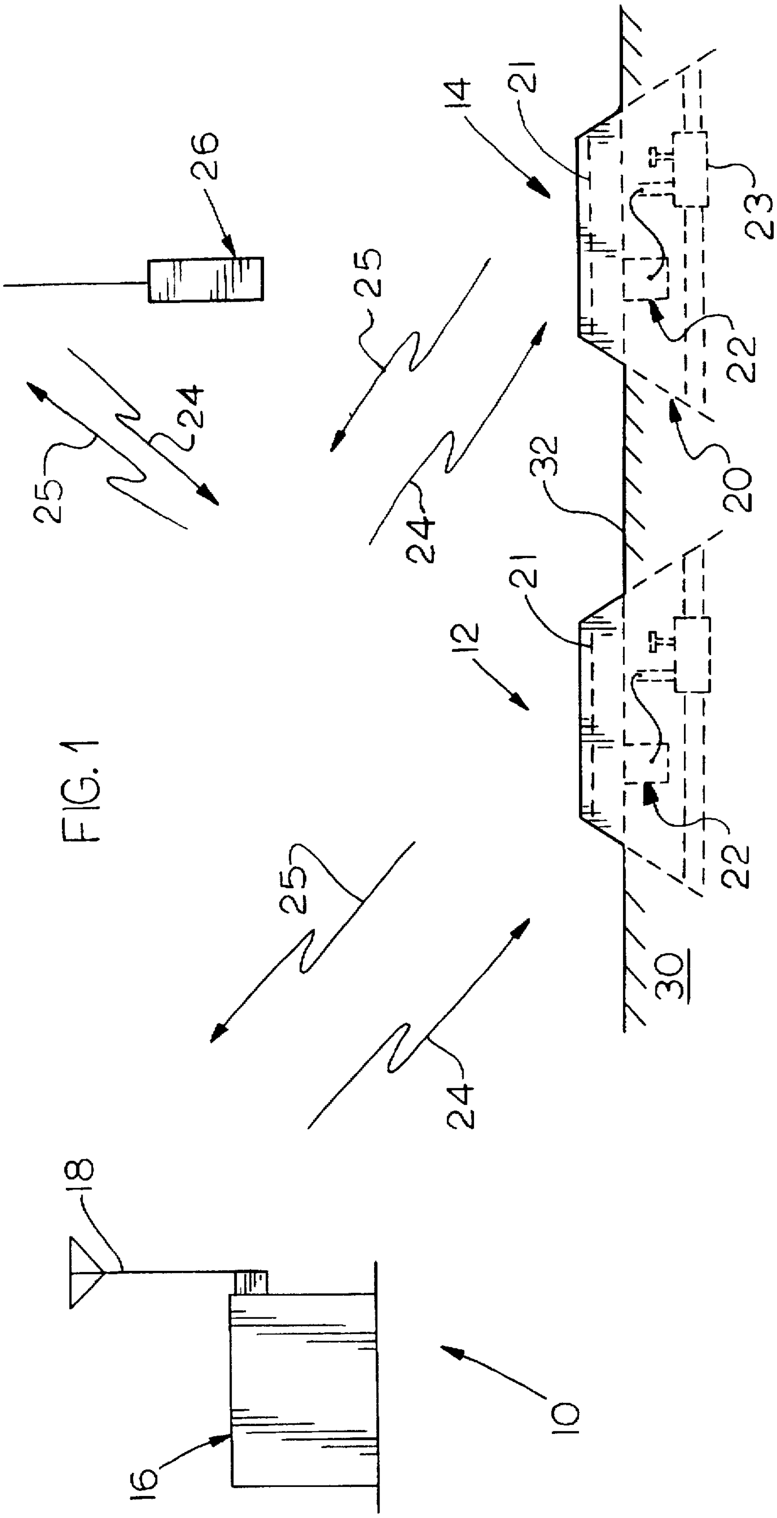


FIG. 1

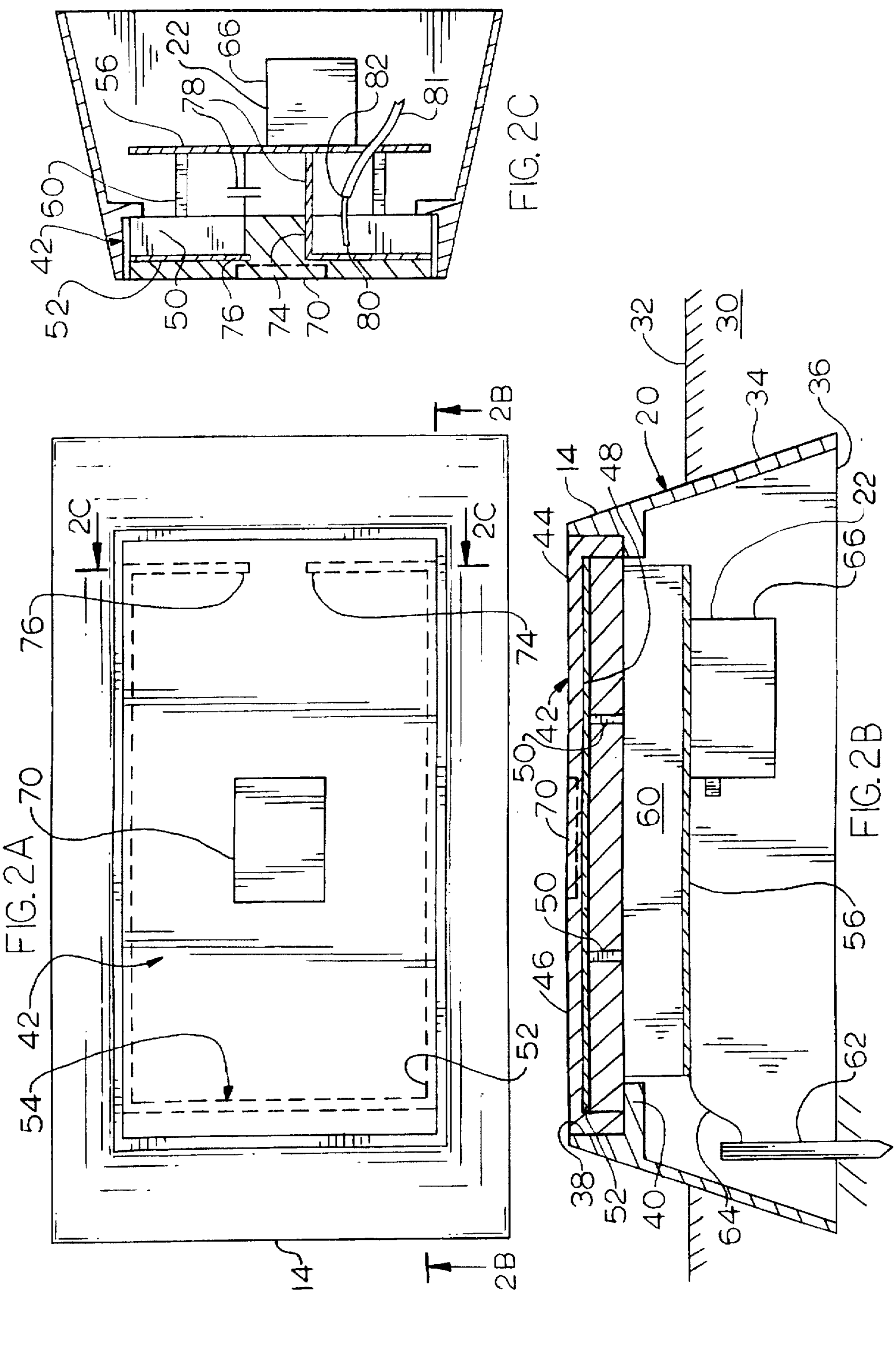


FIG. 2C

FIG. 2A

FIG. 2B

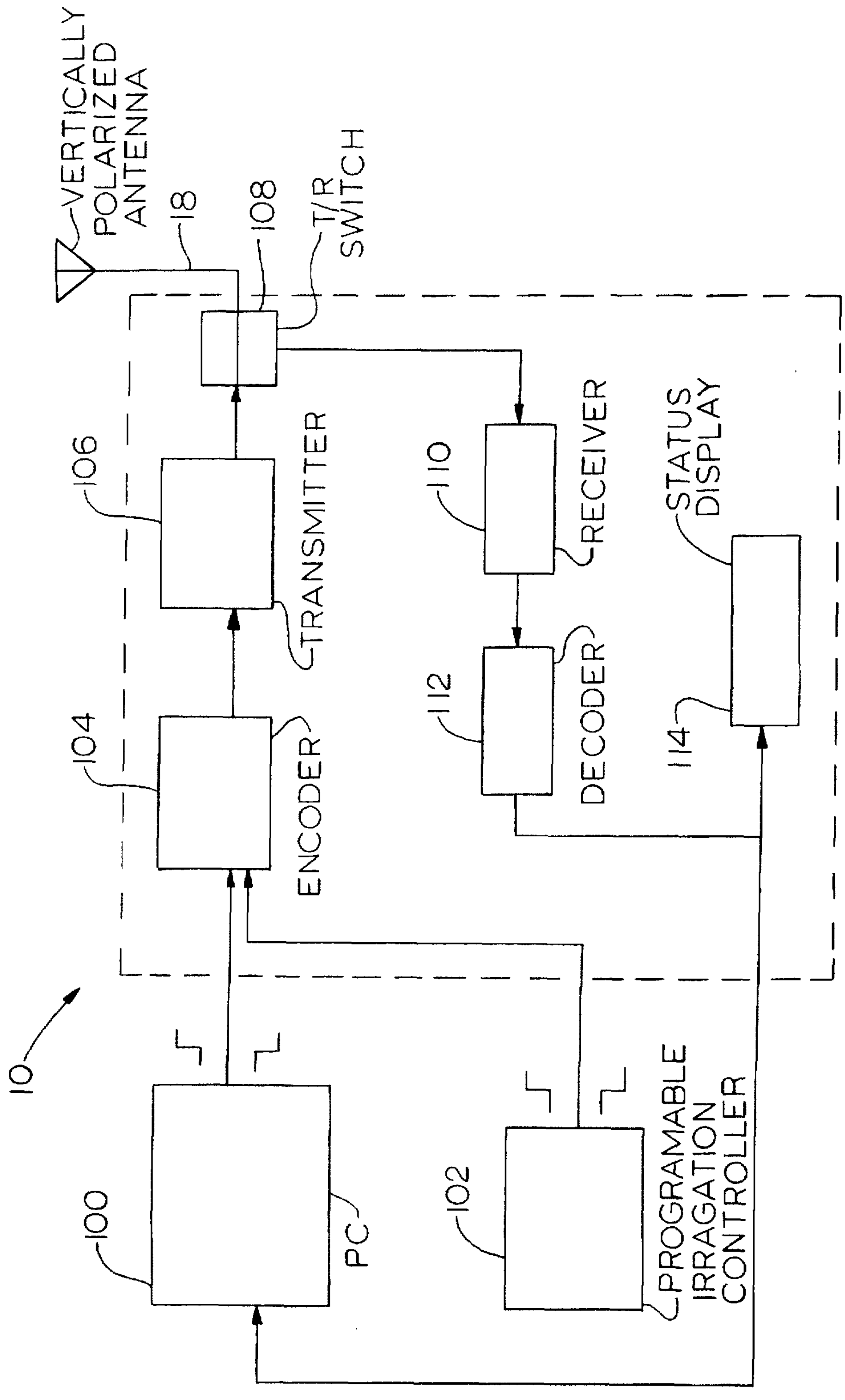

VERTICALLY POLARIZED ANTENNA
18
108
T/R SWITCH
106
TRANSMITTER
110
RECEIVER
STATUS DISPLAY
104
ENCODER
112
DECODER
114
10
100
PC
102
PROGRAMABLE IRRAGATION CONTROLLER

FIG. 3

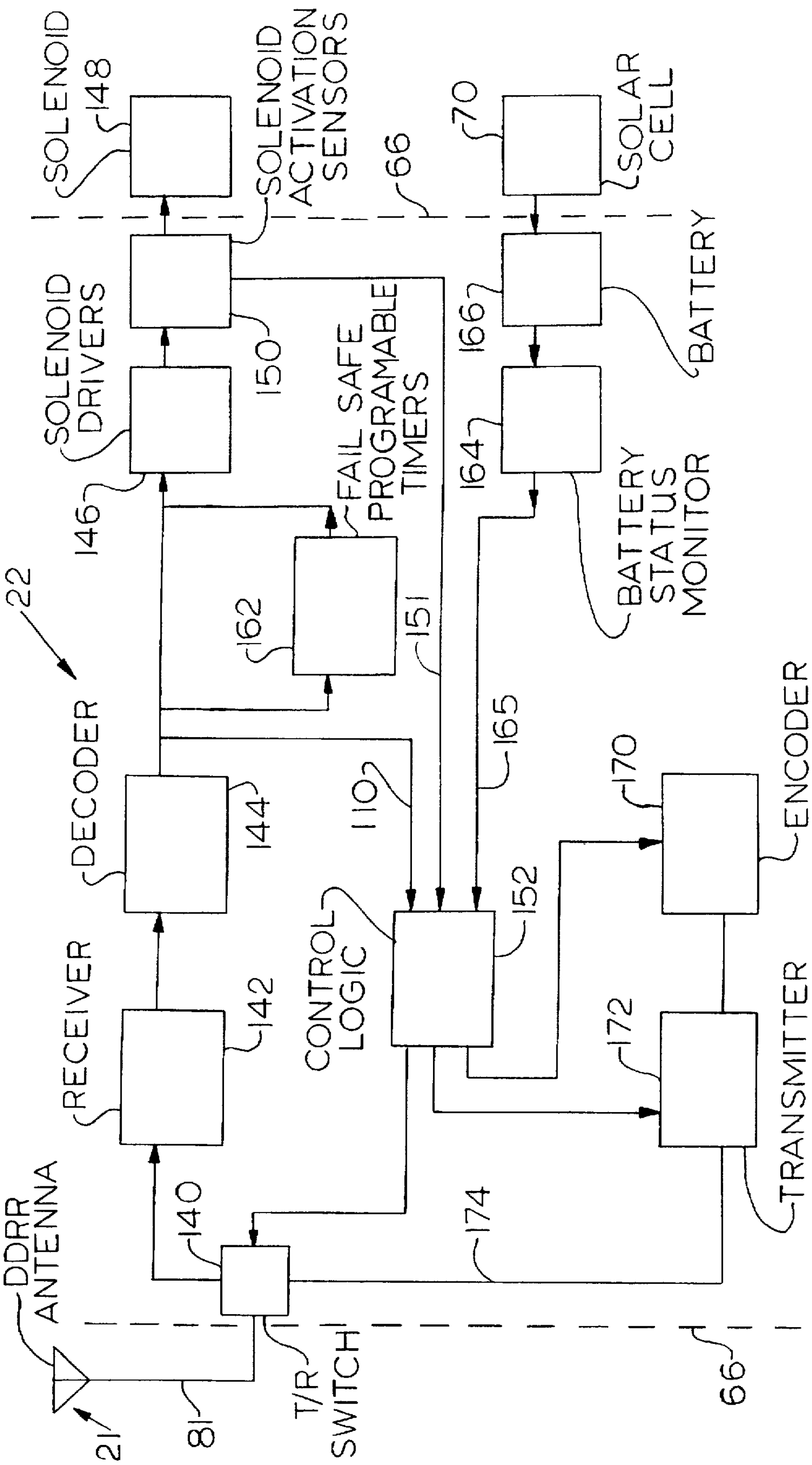

SOLENOID
148
SOLENOID ACTIVATION SENSORS
66
70
SOLAR CELL
SOLENOID DRIVERS
150
166
BATTERY
FAIL SAFE PROGRAMABLE TIMERS
146
164
BATTERY STATUS MONITOR
22
162
151
DECODER
165
144
110
170
ENCODER
152
CONTROL LOGIC
RECEIVER
142
172
TRANSMITTER
DDRR ANTENNA
140
174
T/R SWITCH
21
81
66

FIG. 4

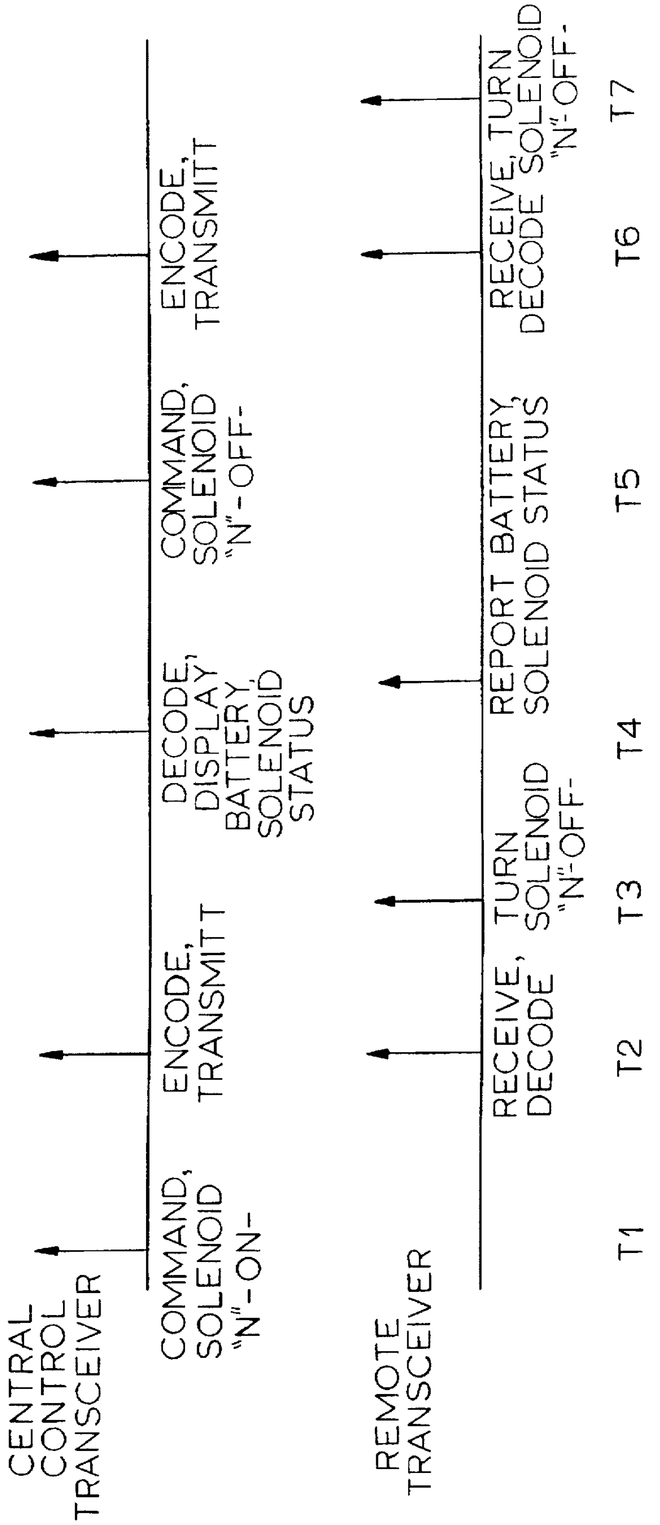

CENTRAL CONTROL TRANSCEIVER
COMMAND, SOLENOID "N"-ON-
ENCODE, TRANSMITT
DECODE, DISPLAY BATTERY, SOLENOID STATUS
COMMAND, SOLENOID "N"-OFF-
ENCODE, TRANSMITT
REMOTE TRANSCEIVER
RECEIVE, DECODE
TURN SOLENOID "N"-OFF-
REPORT BATTERY, SOLENOID STATUS
RECEIVE, DECODE
TURN SOLENOID "N"-OFF-
T1
T2
T3
T4
T5
T6
T7

FIG. 5

REMOTE CONTROL SYSTEM USING PARTIALLY EARTH-BURIED RF ANTENNA

This is a continuation of application Ser. No. 08/145,875, filed Oct. 29, 1993, now abandoned.

FIELD OF THE INVENTION

This invention relates generally to radio frequency control systems suitable for use in large irrigation projects and the like for controlling remote devices such as solenoid valves.

BACKGROUND OF THE INVENTION

Various wireless systems exist which use radio frequency (RF) signals for controlling remote solenoid valves. For example, such systems are frequently used for irrigating golf courses, cemeteries, traffic medians, agricultural tracts, and for controlling waste treatment plants. Typical wireless RF systems employ visually conspicuous vertically polarized antennas which are prone to vandalism and, in many situations, are aesthetically displeasing.

Short height low radio frequency antennas have been described in U.S. Pat. Nos. 3,151,328; 3,247,515; and RE.26,196, all issued to J. M. Boyer, and in an article authored by J. M. Boyer entitled "Hula Hoop Antennas, A Coming Trend?", *Electronics*, Jan. 11, 1963. Such antennas, which are sometimes referred to as directional discontinuity ring radiators (DDRR), are characterized by at least one elongate conductive member forming a planar ring oriented in a substantially horizontal plane. In a typical configuration, as described in U.S. Pat. No. 3,151,328, the elongate conductive member comprises a nearly closed ring having a first end electrically connected directly to a common conductive plane and a second end connected to the common plane through a capacitive tuning means.

SUMMARY OF THE INVENTION

The present invention is directed to an improved RF control system characterized by the use of remotely located low profile radio frequency antennas which are preferably concealed in conventionally appearing valve boxes or similar housings.

A system in accordance with the present invention includes a central control station, including a central RF transmitter, and a plurality of remote stations, each including an RF receiver and antenna. A preferred remote station in accordance with the invention includes a valve box or similar housing of the type intended to be at least partially buried in the earth. The housing has a peripheral wall defining an access opening and a removable cover for bridging the opening. In accordance with a preferred embodiment of the invention, a DDRR antenna is physically mounted in the valve box housing on the interior side of the cover and is connected to a receiver, preferably also physically mounted on the cover.

In accordance with an important feature of the preferred embodiment, a solar cell is externally mounted on a panel which functions as the housing cover for charging a remote station battery.

A preferred irrigation system in accordance with the invention includes a central station transceiver and a plurality of remote station transceivers. In operation, the central station transceiver transmits an encoded RF command identifying one or more of the remote stations. An identified station responds to the command, e.g. activates it local solenoid valves, and additionally transmits information back to the central station bearing remote station status information, e.g., battery condition.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram generally depicting a system in accordance with the present invention;

FIG. **2A** is a plan view of a preferred valve box in accordance with the present invention;

FIG. **2B** is a sectional view taken substantially along the plane 2B—2B of FIG. 2A;

FIG. **2C** is sectional view taken substantially along the plane 2C—2C of FIG. 2A;

FIG. **3** is functional block diagram of the RF transceiver electronics in a preferred central station in accordance with the present invention;

FIG. **4** is a functional block diagram of a preferred remote station in accordance with the present invention; and

FIG. **5** is a timing chart depicting a typical operational sequence for a preferred system embodiment.

DETAILED DESCRIPTION

Attention is now directed to FIG. **1** which generally depicts a radio frequency control system in accordance with the invention comprised of a central station **10** and one more remote stations **12** , **14**. The central station **10**, described in greater detail in connection with FIG. **3**, is generally comprised of control and RF transceiver (i.e. transmitter and receiver) electronics **16** and a vertically polarized RF antenna **18**. A typical remote station **14** in accordance with the invention is comprised of a partially buried valve box or similar housing **20** containing a low profile RF antenna **21**, RF transceiver electronics **22**, and a remote controllable device **23**, e.g., solenoid valve, all to be discussed in greater detail in connection with FIG. **4**.

In the operation of the system of FIG. **1**, the central station **10** transmits RF signals from antenna **18** which are typically encoded with commands identifying particular remote stations and particular actions to be taken. The identified remote stations receive and decode the RF signals **24**, take the commanded action (typically, a solenoid valve closure), and transmit a return RF signal **25** to the central station **10**. The RF signals **25** transmitted by the remote stations are preferably encoded with acknowledgement information and/or status information, e.g. battery status. In an exemplary embodiment, the RF links, **24**, **25** operate at approximately 27 megahertz.

In an exemplary application of the system of FIG. **1**, as for example in a golf course irrigation system, the remote stations **12**, **14** can be located up to several thousand feet away from the central station **10**. To facilitate local control and trouble shooting of the system, it is preferable to also provide a portable control transceiver **26** which can be readily carried by an operator for locally replicating encoded RF signal transmissions from the central station **10**.

Attention is now directed to FIGS. **2A**, **2B**, and **2C** which illustrate a preferred remote station **14**, in accordance with the present invention. The remote station **14** is comprised of a substantially conventional valve box or similar housing **20** of the type intended to be at least partially buried in the earth **30** below ground surface **32**. Such valve boxes are readily commercially available in various geometric shapes (e.g., circular, rectangular, etc) and sizes and materials (e.g., concrete, plastic, etc). Typically, such valve boxes are comprised of a peripheral wall **34** which is generally open at the bottom **36** to provide access for underground conduits. The peripheral wall **34** additionally defines a top access opening at **38** above an inwardly extending flange **40**. A top cover **42** is provided which is shaped and dimensioned (e.g., approximately 13 by 20 inches) to fill the access opening **38** and rest on the flange **40**. The cover **42** can either be removable or hinged relative to the peripheral wall **34** to provide access to the interior of the box **20** via the top access opening **38**.

As illustrated, the cover **42** comprises an essentially flat panel **44** having an exterior surface **46** and an interior surface **48**. Strengthening partitions **50** depend from the interior surface **48**. In accordance with a preferred embodiment of the invention, a directional discontinuity ring radiator (DDRR) antenna is physically mounted on the panel **44** depending from the interior surface **48**. The DDRR antenna **21** is comprised of an elongate conductive member **52** configured to define a planar ring **54**. The elongate member **52** is physically mounted to the interior surface **48** of panel **44** so as to be oriented horizontally, as depicted in FIG. **2B**, when the cover is positioned on an installed box **20**.

A conductive planar member **56**, forming a ground plane is physically suspended from the interior surface of panel **44** by a dielectric member **60**. The ground plane member **56** is spaced from (e.g., about 3 inches) and oriented parallel to the elongate conductive member **52** defining the planar ring **54**. As depicted in FIG. **2B**, the housing **20** is preferably buried to a level whereat the ground plane member **56** is essentially aligned with the ground surface **32**. A conductive ground stake **62** is preferably provided to electrically connect ground plane member **56** to an earth ground via flexible wire **64**.

FIG. **2B** also depicts an electronics box **66**, containing transceiver and related electronics **22**, which is physically suspended from the panel **44** beneath the ground plane member **56**. The cover **42** is additionally provided with a solar cell **70** mounted on the exterior surface **46** of panel **44** for charging a battery (FIG. **4**) for powering the transceiver electronics **22** and/or solenoid **23**.

As is characteristic of DDRR antennas, the planar ring **54** formed by elongate conductive member **52** is nearly, but not completely, closed. Rather, conductive member **52** defines a first end **74** which is electrically connected directly to ground plane member **56**. Further, the elongate conductive member defines a second end **76** which is connected to the ground plane member **56** via a tuning capacitor **78**. RF energy is fed into or out of the antenna through a first connection **80** near the first end **74** of the conductive member **52**. This RF energy is preferably carried by the center conductor of a coaxial cable **81** whose ground shield is connected at **82** to the ground plane member **56**. A loading inductive coil (not shown) may be incorporated in the conductive member **52** proximate to the connection **80** to enhance performance at certain frequencies and dimensions.

Attention is now directed to FIG. **3** which depicts a functional block diagram of a preferred central station **10** in accordance with the present invention. Two operator controllable input sources are shown; namely, a personal computer **100** and a programmable controller **102**, e.g. a commercially available irrigation controller. Computer **100** and controller **102** supply command to encoder **104** to encode RF signals produced by transmitter **106**. The encoded RF signals are then applied to vertically polarized RF antenna **18** via a transmit/receive (T/R) switch **108**. Signals received via the RF antenna **18** are applied to receiver **110** via T/R switch **108** and, after decoding by decoder **112**, are supplied to computer **100** and a status display **114**.

Attention is now directed to FIG. **4** which depicts a functional block diagram of the RF transceiver electronics **22** in a preferred remote station **14** in accordance with the present invention. The remote station DDRR antenna **21** is connected via aforementioned coaxial feed cable **81** to a T/R switch **140**. The receive output of switch **140** is connected to receiver **142** whose output is provided to decoder **144**. If the decoder **144** recognizes that a received command identifies its remote station, it sends an appropriate control signal to solenoid driver **146** to cause a solenoid **148** (which can be physically located in box **20** or remote therefrom) to take the commanded action, e.g., ON or OFF. A sensor **150** detects the activation status of the solenoid **148** and feeds back a signal via line **151** to control logic **152**.

The output of decoder **144**, in addition to operating solenoid driver **146**, is also sent to control logic **152** via line **160**. In addition, the output of decoder **144**, when activating solenoid driver **146**, initializes a fail safe programmable timer **162**. The fail safe timer **162** can be set to a selected duration (e.g., 15 minutes to 17 hours) to assure that the solenoid **148** will be deactivated at a certain point in time, even if the receiver **142** and decoder **144** fail to receive an "OFF" signal via the RF link from the central station **10**.

A third input to the control logic **152** is derived from a battery status monitor **164** via line **165** which monitors the status of battery **166** which is charged by aforementioned solar cell **70**. The control logic **152** responds to the acknowledgement information (provided by line **160**), the solenoid status information (provided by line **151**), and the battery status information (provided by line **165**) to encode, via encoder **170**, the RF energy supplied by transmitter **172**, via line **174** and T/R switch **140**, to the DDRR antenna **21**.

FIG. **5** is a timing chart which depicts a typical operational sequence of a system in accordance with the present invention. Note at time T1 the central control transceiver **16** generates a command "Solenoid N-ON-". At time T2, the command is transmitted from antenna **18** via RF signal **24** (FIG. **1**) and received by a remote station DDRR antenna **21**. The remote station decoder **144** decodes the signal and as a consequence solenoid N (**148**) is turned on at time T3. At time T4, the remote station transceiver reports its battery and solenoid status via transmitter **172** and DDRR antenna **21**. This information is decoded by the central station decoder **112** and displayed by the computer **100** and status display **114**. At time T5, the computer **100** or controller **102** issues a command to turn solenoid N off. This command is then transmitted by the central station transmitter **106** at time T6 and received and decoded by the remote station receiver **142** and decoder **144**. At time T7, the solenoid is turned off.

From the foregoing, it should be apparent that an improved radio frequency control system has been disclosed herein which is characterized by remote stations using low profile DDRR antennas concealed in substantially conventional valve boxes. As a consequence, systems in accordance with the invention are considerably less prone to vandalism or aesthetic objections.

I claim:

1. In a system for controlling from a central station a device located at a remote station, the improvement comprising:

a valve box having a peripheral wall defining an access opening;

a panel configured for mounting on said wall to substantially bridge said opening, said panel having an interior surface facing into said valve box;

said valve box comprising a structure suitable for direct burial in the ground to position said panel substantially horizontally and slightly vertically above the surface of said ground proximate thereto; and a radio frequency antenna physically mounted on said panel adjacent said panel interior surface, said antenna including:

an elongate electrically conductive member forming a planar ring supported from said panel proximate to said interior surface; and

an electrically conductive ground plane member suspended from said panel spaced from said interior surface and essentially vertically aligned with said ground surface proximate thereto.

2. The system of claim 1 further including an enclosure containing an electronic circuit; and

means supporting said enclosure beneath said panel interior surface.

3. The system of claim 1 further including a solar cell mounted proximate to said panel exterior surface and electrically connected to said electronic circuit.

4. A method for forming and positioning an antenna in a remote station for receiving vertically polarized RF signals, comprising the steps of:

forming a remote station comprising a housing including a peripheral wall defining an upper access opening and a removable panel bridging said opening, said panel having interior and exterior surfaces;

placing receive electronics for receiving said RF signals in said housing;

positioning a vertically polarized RF antenna coupled to said receive electronics in said housing; said RF antenna comprising (1) a conductive ground plane member horizontally oriented in said housing and (2) an elongate conductive member mounted in said housing proximate to said panel interior surface defining a planar ring oriented parallel to and spaced above said ground plane member; and

partially burying said housing in the earth such that said ground plane member is substantially aligned with the earth surface surrounding said housing and said elongate conductive member is positioned above the earth surface.

5. The method of claim 4 wherein said positioning step additionally includes physically mounting said elongate conductive member to said panel interior surface.

6. The method of claim 4 wherein said positioning step additionally includes suspending said ground plane member from said panel interior surface by a dielectric member at a spacing further from said panel interior surface than said elongate conductive member.

7. The method of claim 4 wherein said forming step additionally includes physically supporting said receive electronics from said panel interior surface.

8. A wireless control system comprising:

a central station including a central RF transmitter, a vertically polarized central RF antenna functionally connected thereto, and a central encoding means for applying command information to RF signals produced by said central transmitter;

at least one remote station including a vertically polarized remote RF antenna, a remote RF receiver functionally connected thereto, and a remote decoding means for decoding RF signals received by said remote receiver to produce decoded command information; and

a controllable device located at said remote station responsive to said decoded command information;

said remote station including a housing comprising a peripheral wall defining an upper access opening and a removable panel bridging said opening, said panel

having interior and exterior surfaces, said housing being at least partially buried in the earth and positioned to orient said panel substantially horizontally with said interior surface spaced vertically above the proximate surface of the earth;

said remote RF antenna comprising (1) a conductive ground plane member horizontally oriented in said housing and substantially vertically aligned with the proximate surface of the earth and (2) an elongate conductive member mounted in said housing proximate to said panel interior surface defining a planar ring oriented parallel to and spaced vertically above said ground plane member.

9. The system of claim 8 additionally comprising a central RF receiver functionally connected to said vertically polarized central RF antenna; and wherein

said remote station further includes a remote RF transmitter functionally connected to said remote RF antenna and remote encoding means for applying command information to RF signals produced by said remote transmitter.

10. The system of claim 9 wherein said controllable device is responsive to said decoded command information for selectively switching from a first to a second state; and wherein

said remote encoding means is responsive to information indicative of the state of said controllable device.

11. The system of claim 9 additionally comprising:

a battery located at said remote station;

a solar cell mounted on said panel exterior surface for charging said battery; and wherein

said remote encoding means is responsive to information indicative of the charge status of said battery.

12. A centrally controlled wireless system for remotely operating a controllable device, said system comprising:

a central station including:

transmitter means for producing an RF signal;

source means for producing command information;

encoder means responsive to said command information for encoding said RF signal;

a vertically polarized central antenna for broadcasting said encoded RF signal; and,

at least one remote station including:

a housing comprising a structure suitable for being at least partially buried in the earth and including a peripheral wall defining an upper access opening and a removable panel bridging said opening, said panel having interior and exterior surfaces;

a vertically polarized remote antenna mounted in said housing for receiving said broadcast RF signal;

decoder means mounted in said housing responsive to said received broadcast RF signal for producing decoded command information;

a controllable device responsive to said decoded command information;

said remote antenna including (1) a conductive ground plane member horizontally oriented in said housing and (2) an elongate conductive member mounted in said housing proximate to said panel interior surface defining a planar ring oriented parallel to and spaced vertically above said ground plane member; and wherein said housing is at least partially buried in the earth with said conductive ground plane member oriented substantially horizontally and positioned substantially in alignment with the surface of the earth proximate thereto.

13. The system of claim 12 wherein said remote station further includes transmitter means for producing a remote RF signal and means responsive to the state of said controllable device for encoding said remote RF signal and coupling said signal to said remote station antenna means for transmission to said central station; and wherein

said central station further includes receiver means for receiving said remote RF signal transmitted from said remote station.

14. The system of claim 13 additionally comprising a solar cell mounted on said panel exterior surface for providing power to said decoder means.

15. The system of claim 14 additionally comprising battery means in said housing; and wherein

said solar cell is coupled to said battery for charging said battery.

16. The system of claim 13 wherein said remote station additionally comprises transmitter means for producing a remote RF signal and means responsive to the charge state of said battery for encoding said remote RF signal for transmission to said central station; and wherein

said central station additionally comprises receiver means for receiving said remote RF signal transmitted from said remote station.

* * * * *

US006108590A

United States Patent [19]

Hergert

[11] **Patent Number: 6,108,590**

[45] **Date of Patent: *Aug. 22, 2000**

[54] **INTEGRATED IRRIGATION OPTIMIZATION POWER CONTROL SYSTEM**

[76] Inventor: **C. David Hergert**, 1104065 County Rd 17, Mitchell, Nebr. 69357

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/016,844**

[22] Filed: **Jan. 30, 1998**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/721,226, Sep. 26, 1996.

[51] **Int. Cl.**[7] **G05D 11/00**

[52] **U.S. Cl.** **700/284**; 700/14; 700/16; 700/231; 137/624.11; 239/63; 239/69

[58] **Field of Search** 700/16, 231, 14, 700/284; 137/624.11; 239/63, 69

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Product Literature, Valley Irrigation Products, Control Technology.

Product Literature, Valley Irrigation Products, Remote Link.

Product Literature, Valley Irrigation Products, C:A:M:S Control Panel.

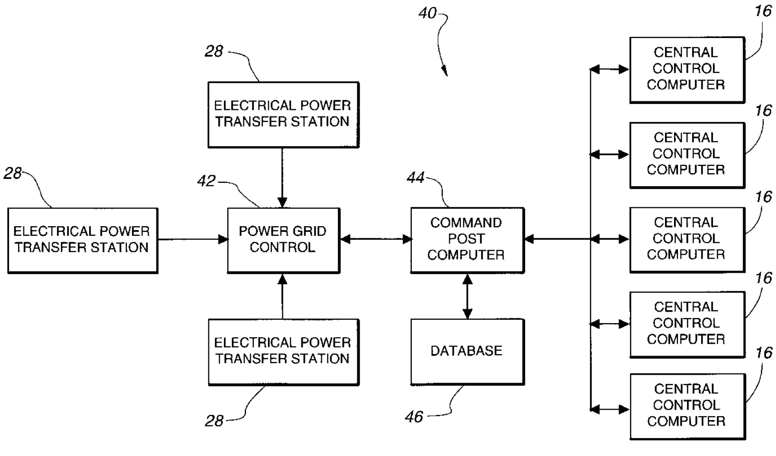
Product Literature, Valley Irrigation Products, C:A:M:S Base Station.

Primary Examiner—Paul P. Gordon
Assistant Examiner—Ramesh Patel
Attorney, Agent, or Firm—Merchant & Gould P.C.

[57] **ABSTRACT**

A system for optimizing the operation of a plurality of irrigation systems includes at least one control computer, a storage device coupled to the control computer for storing data, a plurality of irrigation device controllers remotely coupled to each of the control computers, and a grid power monitor coupled to the computers for providing power grid demand and usage data. The system may also include GPS and GIS receivers to determine remotely position and soil condition and/or a plurality of sensors located in each of the irrigated fields which transmit soil information directly to the control computers. The control computers each in turn generate priorities of operation for the irrigation systems based on the soil condition information and most economical load operating periods from the electrical power utility. The system is optimized by generating position data for each of the irrigation systems, generating soil condition data at the position of the irrigation system, including current and/or historical weather data and crop information either manually inputted or determined from remote sensors or satellites, and calculating a required period and priority of each irrigation system operation based on the soil conditions at the location of each of the irrigation systems, the historical and/or predicted weather data, the crop data, and finally, automatically scheduling the irrigation system operations based on input from the electrical utility command computer as to the most economical time period for operation.

17 Claims, 3 Drawing Sheets



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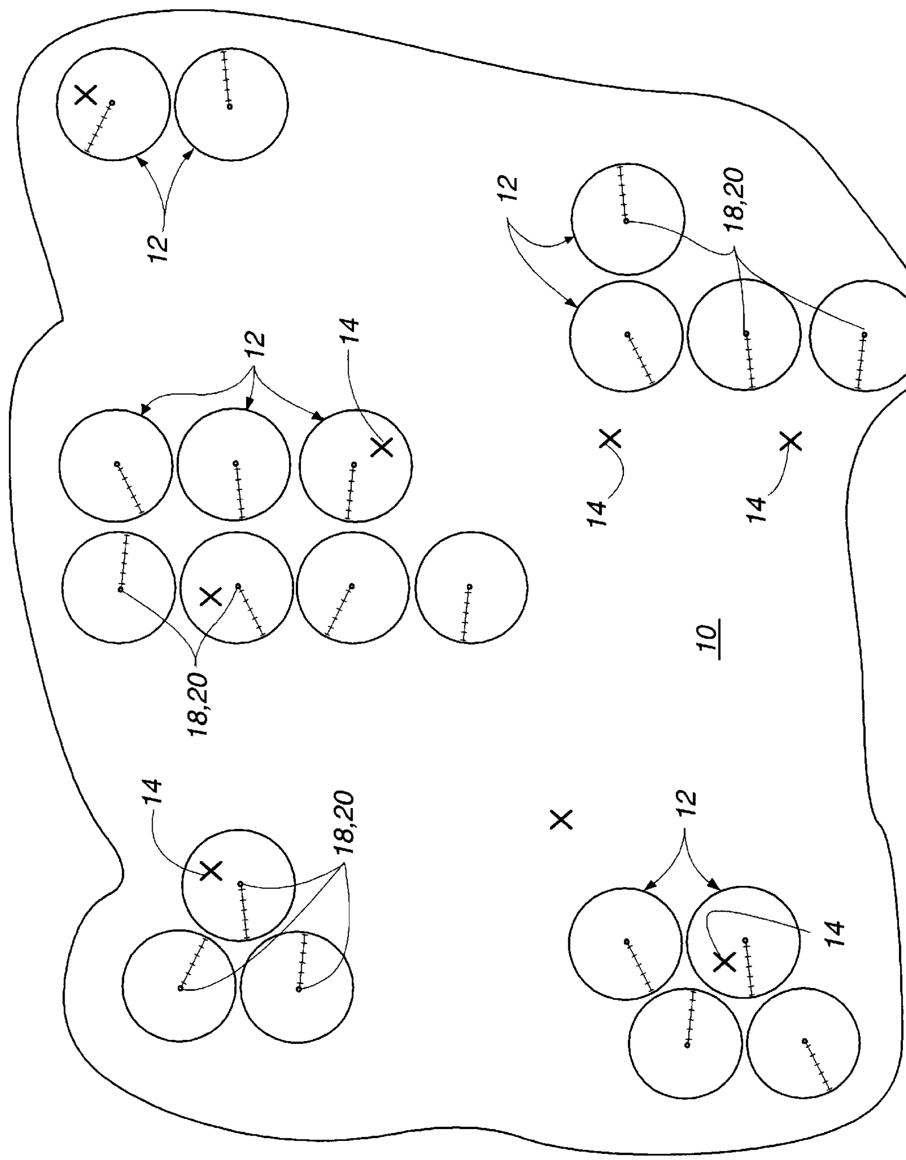


Fig. 1

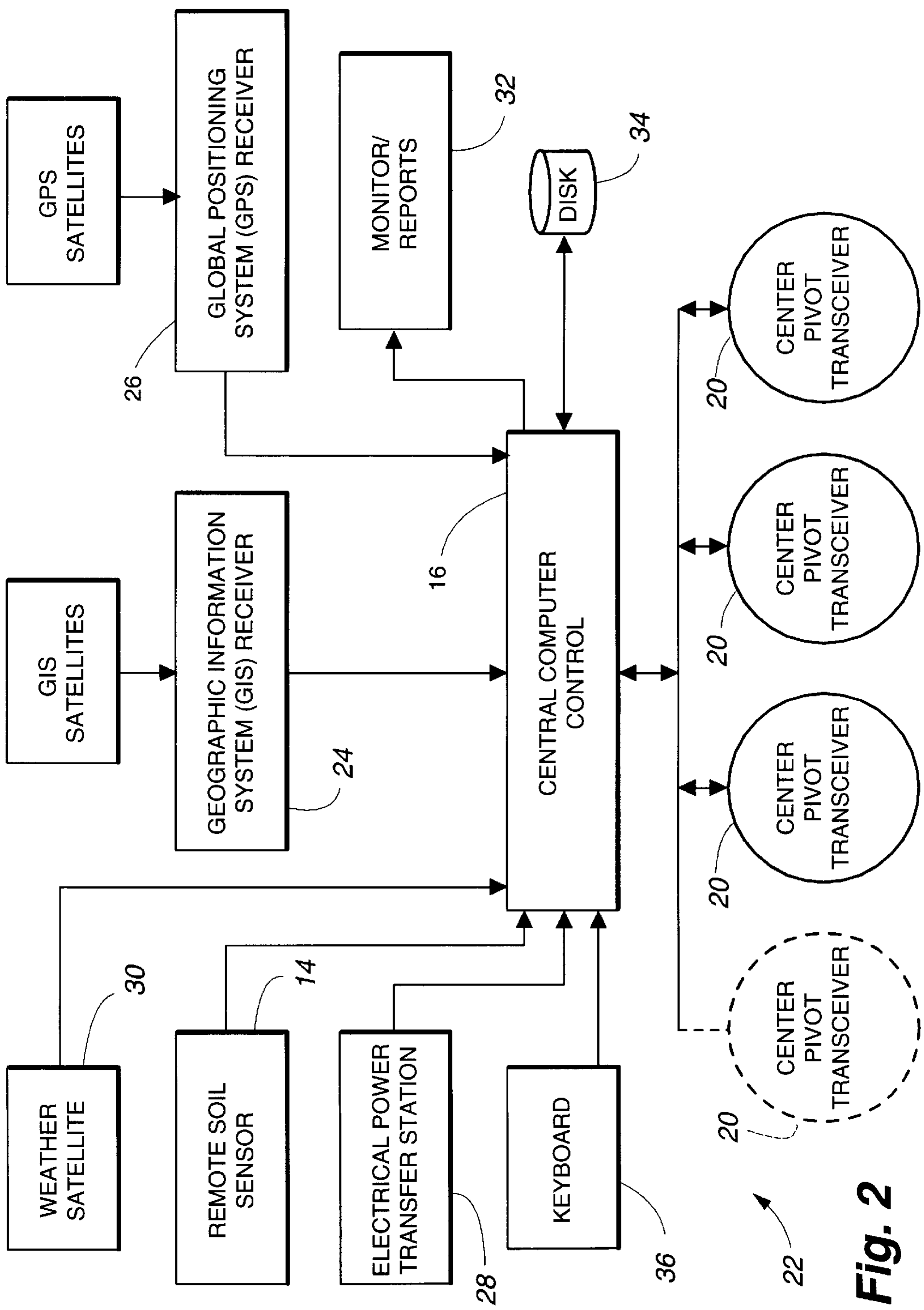
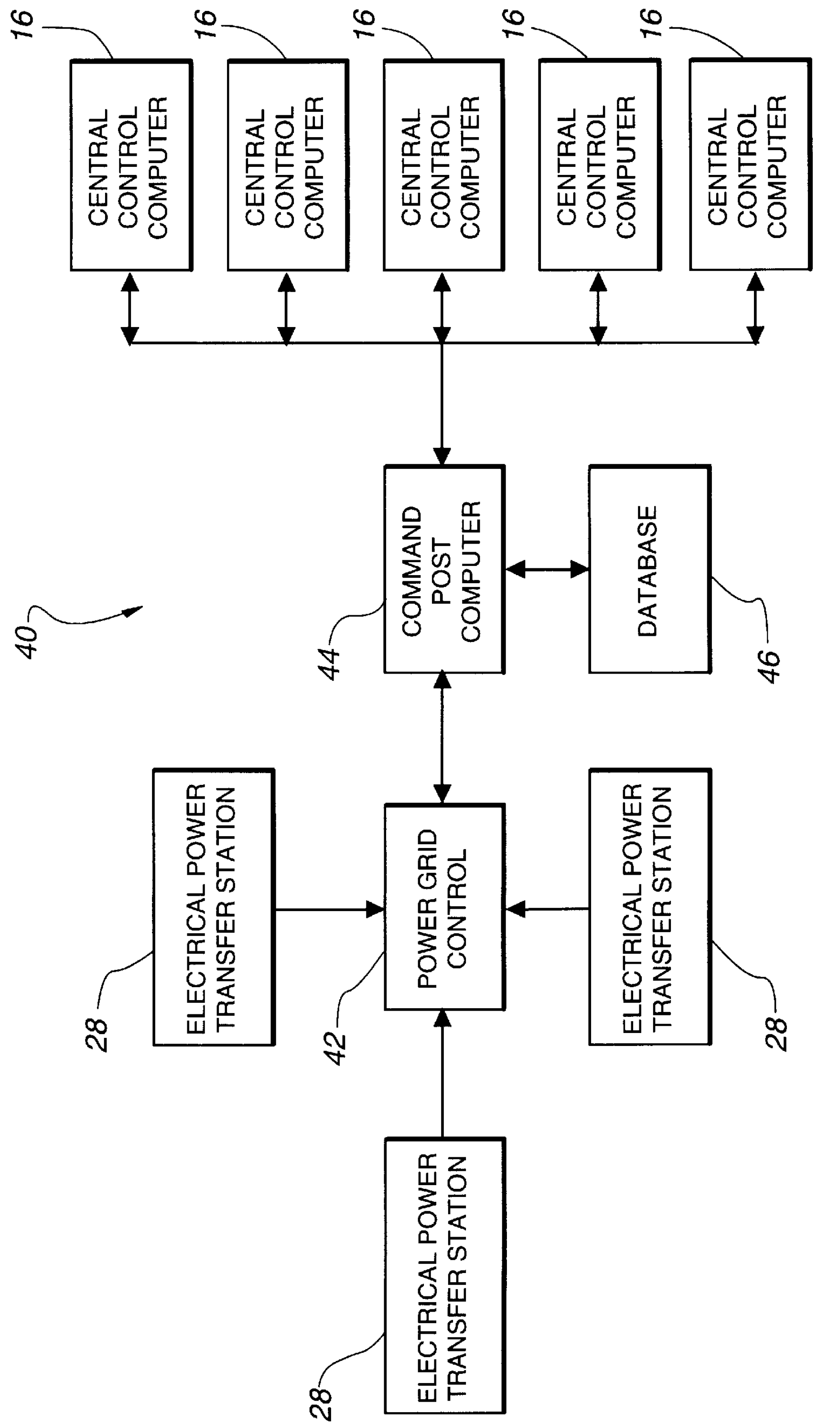

GPS SATELLITES
GLOBAL POSITIONING SYSTEM (GPS) RECEIVER
26
MONITOR/ REPORTS
32
DISK
34
GIS SATELLITES
GEOGRAPHIC INFORMATION SYSTEM (GIS) RECEIVER
24
16
CENTRAL COMPUTER CONTROL
CENTER PIVOT TRANSCEIVER
20
CENTER PIVOT TRANSCEIVER
20
CENTER PIVOT TRANSCEIVER
20
CENTER PIVOT TRANSCEIVER
20
WEATHER SATELLITE
30
REMOTE SOIL SENSOR
14
ELECTRICAL POWER TRANSFER STATION
28
KEYBOARD
36
22

Fig. 2


16
CENTRAL CONTROL COMPUTER
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CENTRAL CONTROL COMPUTER
16
CENTRAL CONTROL COMPUTER
16
CENTRAL CONTROL COMPUTER
40
44
COMMAND POST COMPUTER
DATABASE
46
28
ELECTRICAL POWER TRANSFER STATION
42
POWER GRID CONTROL
ELECTRICAL POWER TRANSFER STATION
28
28
ELECTRICAL POWER TRANSFER STATION

Fig. 3

INTEGRATED IRRIGATION OPTIMIZATION POWER CONTROL SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation in part application of U.S. patent application Ser. No. 08/721,226, filed Sep. 26, 1996, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates, in general, to the field of electrical power distribution and control systems. More particularly, the present invention relates to a computer controlled irrigation power control system.

2. Description of the Related Art

Today, a farming operation typically covers a very large land area. Many of today's farming operations are becoming increasingly automated and operated remotely wherever possible. Computers are cropping up more and more in the farmhouse in order to maximize yields and practice precision farming techniques. Similarly, the irrigation requirements for such large areas become more complex. To meet this demand, pivot irrigation systems which may cover a circle on the order of a mile across have become very popular and wide spread throughout the mid-west and western states. Since it may take a farmer or his/her employee in these areas an hour or more to reach a distant field, the ability to remotely monitor and operate irrigation systems operation, including fertilizer applications, in that remote field quickly becomes economically advantageous.

For example, the T**16** Ranch in southeast Washington state manages 64 central pivot irrigation systems covering 6700 acres of cultivated land with the help of an automated telemetry networked system coupled to a personal computer at the ranch headquarters. The telemetry system monitors start and stop of each pivot, monitors water pressure, monitors end gun hours, and auxiliary pump operation for addition of chemicals through the system. The computer includes a display of the status of each pivot system. The computer software allows the farmer to remotely start and stop and reverse pivot systems from a central location. Remote data collection stations are also located at the pivot locations which provide data to the computer database on wind speed, rainfall, temperature and water flow. This data may then be easily stored, tabulated and compiled into reports on the operations of the individual pivots or the entire farming operation.

Global positioning system receivers mounted on tractor cabs in conjunction with soil parameter sensors on the cultivators are also used to gather field specific soil condition information and provide input to a central computer database. This information is then used by the farm management software to generate grid maps of the fields and their conditions which can then be stored in a computer database. The farmer can then view these maps and make decisions as to appropriate fertilization and conditioning actions necessary to achieve optimum yields. These same receivers may also be used with appropriate moisture and grain flow sensors mounted on the harvesting equipment to obtain and monitor location specific yield information. This information is then integrated into the mapping database to provide the farmer with field specific information to aid in future decision making. These systems go a long way toward

assisting the farmer in achieving efficient farm operations. However, there are a number of limitations on these systems and there are several things that these conventional systems do not do. They do not provide data on actual soil conditions in real time over the growing period.

There is currently no remote mechanism for monitoring the actual conditions in the field during the growing season short of actually installing remote sensors in the field which sense, only at the sensor location, such characteristics as soil moisture, phosphorous, nitrogen and potassium content, etc. Soil conditions are dynamic. They change over the growing season depending on local rainfall, irrigation amounts, number of sun days, fertilizer and chemical applications etc. Therefore there is a continuing need for more accurate and dynamic monitoring systems and remote control systems applied to everyday farming operations and such precision farming operations as are described above.

A number of universities and the US Department of Agriculture currently provide, on commercial radio, general irrigation guidelines to farmers. For example, the information may include year to date rainfall averages in a listening area and current moisture requirements, particular crop aspiration rates and recommendations for various crops as an aid to the farmer in determining how much water is needed this week and next, etc. However, this information is general in nature and does not typically reflect the specific soil conditions in the particular farmers field, only general conditions. This published information is useful and constitutes a database of historical information that can be utilized to predict future needs.

Unfortunately, many farm operators are not sophisticated in interpreting this information for the farmer's and the field's specific requirements. Therefore there is a need for a system that can perform this interpretation automatically and either provide to the farmer site specific requirements based on either actual field measurements or historical data coupled with, if available, current weather data and the farmer specific crop and soil conditions or automatically determine and schedule appropriate irrigation operations automatically in the most cost efficient manner to the farmer or property irrigation manager.

Further, irrigation pumping systems for pivots require a great deal of electrical power. The typical rural electrical coops and power company generating stations are historically geared for supplying electrical power only for local farm yard type equipment and residential requirements. They are not generally equipped to handle the major power surges associated with operation of hundreds of pivot system pumps simultaneously. One solution which is utilized by power companies is to price the power to the farmer according to system supply availability and predicted usage at various rates. The power companies are also interested in levelizing the power demand to minimize the amount of power which must be obtained from outside in order to meet peak demands. Consequently, there is a need for an irrigation control system which integrates the irrigation requirements and needs of the farmer with the economically advantageous power rate periods. In addition, there is a need in the power distribution community to levelize the overall electrical load requirements in order to provide their customers with power in the most economical, yet adequate manner

Therefore there is a need for a complete optimization system and method for irrigation control which takes into account actual weather conditions, actual soil conditions, ongoing actual power system demands, special requirements of the farmer/operator, and prioritizes irrigation system operation in accordance with these needs and predetermined constraints.

SUMMARY OF THE INVENTION

The irrigation optimization system and method in accordance with the present invention particularly addresses and meets the above identified needs in the farming community and is equally applicable as well to the suburban and urban municipal and commercial settings.

It is therefore an object of the present invention to provide an irrigation control and optimization system which utilizes historical crop requirements, historical weather information, nominal crop aspiration rates and/or actual soil condition information and actual weather condition information to determine the need for irrigation system operations and coordinate user designated priorities to optimize operation of an irrigation system.

It is another object of the invention to provide an optimized control system and method for controlling the operation and timing of operation of a plurality of irrigation systems.

It is another object of the invention to provide a control system and method which prioritizes irrigation needs of particular pivot or sprinkler systems in accordance with actual soil and weather conditions and electrical power availability.

It is another object of the invention to provide a control system for irrigation systems which has the capability to automatically equalize the power load on the power grid;.

It is a still further object of the present invention to provide a control system and method which includes maintaining a database of reported soil conditions, irrigation water application rates, power usage, weather conditions, rainfall, etc.

The system in accordance with the present invention comprises a plurality of control computers, a storage device coupled to each of the control computers for storing data, one or more irrigation device controllers remotely coupled to each one of the control computers, a command computer operably connectable to each of the control computers for managing input from the control computers, receiving and maintaining historical soil condition and moisture records, and tracking power usage via the control computers, a grid power monitor communicating with the command computer for providing plant availability, power grid demand and usage data to the command computer, and a database storage device coupled to the command computer for storing and retrieving power usage data and

The software control for each of the control computers monitors the various inputs and optimizes the irrigation device, such as a pivot, operation frequency, duration and timing in order to provide optimized irrigation at the most economical power price. The software also provides periodic reports of power usage, pivot operations, soil conditions, etc., as may be desired by the municipal facility operator and/or farmer. The software control for the Command post computer monitors actual power consumption by irrigation system users, tracks power production and availability of power and distribution on the area's power grid, and stores and maintains time and usage data for each control computer for tracking and subsequent billing purposes.

The method in accordance with the invention of optimizing operation of a plurality of remotely controlled irrigation systems basically comprises the steps of:

1) generating soil condition information and crop information at the position of the irrigation device or devices being operated. This typically will involve manual data entry or may incorporate of one or more of the following:
   a) receiving a global positioning system (GPS) signal representative of a position of the irrigation system;
   b) receiving a geographic information system (GIS) satellite signal and optionally receiving signals from remote sensors located in the agricultural area of soil conditions in the agricultural area in which the irrigation system is located;
   c) correlating the GIS signal and/or remote sensor signals with the GPS signals to generate soil condition information at the position of the irrigation system; and
2) calculating a required period of irrigation system operation based on the soil conditions at the location of the irrigation system and supplemental watering requirements of the crop being grown.

This method preferably further comprises the step of prioritizing operation of the irrigation system based on the type of crop, soil condition information and receiving power demand and generating capacity information from a power generating facility supplying power to the irrigation system. The actual period of system operation is then scheduled to occur when the power is cheapest in order to levelize the power demand on the grid.

The method also preferably includes receiving a weather satellite signal of predicted weather conditions in the agricultural area, receiving a weather condition signal from the irrigation system location and then correlating the weather satellite signal with the GPS signal to generate predicted weather conditions at the irrigation system. The method also preferably includes collection of rainfall data at each pivot location and on site at golf course implementations of the irrigation system and incorporation of this information in determination of the required amounts of supplemental irrigation necessary for optimum maintenance of plant growth conditions. The required period of irrigation, and thus its priority, may then be modified so that the required period of operation may be based on the predicted weather conditions and rainfall accumulations at the irrigation system in addition to the other considerations.

The method according to the invention preferably further comprises the steps of receiving power demand and generating capacity information from a power generating facility supplying power to the irrigation system through a command computer and scheduling operation of the irrigation system in accordance with the priority based on the soil conditions, the generating capacity information and a predetermined power capacity criteria or priority provided by the user such as a farmer, municipal grounds supervisor, or commercial facilities manager.

These and other objects, features, and advantages of the invention will become more apparent from a reading of the following detailed description when taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic plan view of a large agricultural area having a number of operational pivot irrigation systems.

FIG. **2** is a block diagram of the irrigation control system in accordance with the present invention.

FIG. **3** is a block diagram of the irrigation power optimization system in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. **1**, a partial plan view of a geographical agricultural area **10** is shown. The area is representative of a much larger agricultural area typically covering a number of counties. The area **10** includes a large number of irrigation units **12** which operate to supply water, chemicals, and other application substances to the fields over which they operate. As is shown, these units are central pivot irrigation systems. However, the system and method in accordance with the present invention may also be utilized with other irrigation systems such as part circle systems and traveling systems. Many traveling systems are diesel powered, however, and therefore do not represent a drain on the area electrical power system. The center pivot systems predominate in the agricultural arena and therefore are illustrated and are exemplary here. The present invention also applies to other relatively large scale irrigation system such as golf courses, greenbelts, commercial and municipal grounds and parks and other managed irrigation areas. Accordingly, throughout this specification, when an agricultural system of pivots is described, it is to be understood that the pivot devices are exemplary only and any irrigation control device may be substituted and is within the scope of the invention.

Also located at various positions in the agricultural area **10** may optionally be a plurality of removable stationary soil monitoring sensors **14**. These stationary monitors **14** transmit to a central control computer **16** data representative of the actual soil condition parameters at the sensor location such as moisture, nitrogen, phosphorus, and potassium content. Optionally, the measurements by the sensors **14** may be separately taken by the farmer and then the data manually entered into the control computer, since many farm operators would prefer not to have to cultivate around such stationary sensors.

Each of the pivot units **12** also includes environmental sensors **18** and transceiver **20** which gathers and transmits rainfall data, temperature, wind direction and pivot operational data such as water flow rate, electrical power status, etc. to the central control computer **16** and receives commands to from the central control computer **16** to control the start, stop and direction of the pivot pumping equipment and drive motors.

Referring now to FIG. **2**, a block diagram of the system **22** in accordance with the invention is shown. The system **22** basically comprises a plurality of irrigation systems **12**, optionally and preferably includes a global positioning system receiver **24** to receive and provide position data for each of the irrigation systems **12**, optionally and preferably includes a geographic information system (GIS) receiver **26** which receives soil condition data from a geographic information satellite, and a central control programmable computer **16** which receives GIS and GPS data from the receivers **24** and **26** and correlates this data to generate grid maps of each of the irrigation systems **12**, generates and transmits operational commands to each of the systems **12**.

The system **22** preferably also may include input to the computer **16** from a plurality of remote sensors **14** which provide further soil condition information, input from a power transfer station **28** and input from a weather satellite **30**. The remote sensors **14** provide preferably continuous signals to the computer **16** of parameters such as soil moisture, nitrogen, phosphorus, and potassium concentrations at the sensor locations. This information may be used by the computer **16** to supplement and/or confirm the remote signals received from the GIS satellites, or may be used in place of such signals, particularly when frequent cloud cover prevents accurate transmission of such data from the GIS satellites.

The input from the power transfer station **28** is used to monitor the demand on the power grid and transmit signals from the power company as to the most economical time to operate the pivot pumps and drive motors based on electrical system demand. This input may be the most important consideration in sequencing the pivot operations since the pivot pumps and drive motors consume a large amount of power. Therefore, ensuring that they are operated so as to levelize power demands on the power grid represents a savings to the power company and to the commercial customers such as the farm operators in the form of lower rates charged by the power company for such power.

Each of the center pivots **12** preferably carries a transceiver and remote controller **20** for the pivot pumps and motors. This controller starts and stops the pivot pump, monitors operational hours, controls optional additive pumps, and provides status signals to the central control computer **16** for monitoring purposes. The pivot **12** also preferably includes sensors **18** which provide environmental parameter signals to the transceiver **20** which are in turn sent to the central computer **16** for processing.

The central computer **16** receives the GPS signals from the receiver **26** and GIS signals from the GIS receiver **24** and generates maps of the agricultural area **10** with the pivot systems **12** and remote sensors **14** accurately positioned or located on the maps. The computer **16** then continually updates the maps based on the GIS input, the remote sensor input data, and the input from pivot sensors **18** to generate the soil condition data.

Alternatively, the historical weather and soil condition data may be manually inputted or received from a remote database along with crop data. The computer **16** then compares this historical data and/or real time inputted soil condition data to predetermine irrigation requirements provided for the system operator to determine whether and which irrigation systems should be operated. The computer **16** then assigns a priority to each pivot system based on the difference between actual and desired moisture conditions or other differences as preprogrammed by the operator. Next the computer **16** queries the power transfer station **28** to determine the best time for pivot operation and automatically schedules pivot system operation accordingly. The historical data and rainfall and crop moisture needs may also be used to determine the best duration for pivot operation. The computer **16** then can automatically schedule the time for system operation accordingly to minimize total cost.

The central computer **16** also preferably may receive input data from a weather satellite **30** either automatically or by manual input of weather data. The software program in the computer **16** preferably maps the weather data received or manually inputted onto the GIS map and therefore modifies the priority established for operation of each pivot **12** based on forecasted near term weather conditions. For example, if heavy rain is forecasted for the next twenty four hour period in the vicinity of one of the pivots, the computer **16** could automatically delay operation of the irrigation system pivot **12** to permit the remote sensors at the pivot location to confirm that, indeed, heavy rain did fall within the period. If remote sensors were not provided in the particular system configuration, this information could be manually inputted for generation of subsequent irrigation requirements.

Finally, the computer may generate reports and maps **32** of irrigation usage and soil conditions as well as historical data reports from data continuously stored and updated in the database storage device **34** such as a hard disk drive. The computer also issues and automatically transmits appropriate operational signals to each of the pivot system controllers **20**.

Each of the pivot controllers **20** may also be locally operated or remotely operated by radio signals which override the signals provided from the computer. These local operations result in changes to the automatic scheduling of operations. The transceivers **20** on the center pivots **12** automatically transmit such local operations data to the computer **16** so that the computer can account for these changes. These changes may be necessary due to corrective or preventive maintenance being performed on the system components. In addition, the computer **16** may be controlled manually to operate the pivot systems as may be from time to time desired.

The method in accordance with the invention of optimizing operation of a remotely controlled irrigation system in an agricultural area basically comprises the steps of:

1) manually entering historical soil condition information and crop data or;
   a) receiving a global positioning system (GPS) signal representative of a position of the irrigation system;
   b) receiving a geographic information system (GIS) satellite signal or historical data and optionally receiving signals from remote sensors located in the agricultural area of soil conditions in the agricultural area in which the irrigation system is located;
   c) correlating the historical data, GIS signal and/or remote sensor signals with crop requirements or the GPS signals to generate soil condition information at the position of the irrigation system; and
2) calculating a required period of irrigation system operation based on the actual or historical soil conditions at the location of the irrigation system.

More preferably, the method in accordance with the invention of optimizing operation of a plurality of separately remotely controllable irrigation systems in an agricultural area comprises the steps of:

1) entering or recalling historical soil condition data for an area to be irrigated along with supplemental crop watering requirements, or alternatively;
   a) receiving soil condition signals from a plurality of remote sensors located in the area to be irrigated;
   b) receiving a global positioning system (GPS) signal representative of a position of each of the irrigation systems and each of said remote sensors;
   c) receiving a geographic information system (GIS) satellite signal representative of soil conditions in the agricultural area in which the irrigation systems are located;
   d) correlating the GIS signal with the GPS signals to generate soil condition information at the position of each of the irrigation systems;
   e) comparing the GIS signal with said remote sensor signals to verify soil conditions at said remote sensor locations; and
2) calculating a required period of irrigation system operation for each system based on the soil conditions and crop supplemental watering requirements at the location of each of the irrigation systems.

More preferably, the optimization system of the invention further comprises the steps of:

3) prioritizing operation of the irrigation system based on the soil condition information and supplemental water requirements for the particular crop; and
4) receiving power demand and generating capacity information from a power generating facility supplying power to the irrigation system; and

scheduling operation of each irrigation system according to the priorities established and when the power is cheapest in order to levelize the power demand on the local electrical grid.

The method also preferably may include the steps of receiving a weather satellite signal of predicted weather conditions in the agricultural area, receiving an actual weather condition signal from each of the irrigation system locations and then correlating the weather satellite signal and the actual weather condition signals with the GPS signal to generate predicted weather conditions at each of the irrigation systems. The required operating period and/or its priority may then be modified to account for anticipated weather conditions. For example, the computer would prevent irrigation system operation in the event of imminent or actual rain falling at the irrigation system location. Thus the optimization system in accordance with the invention adjusts the required period of operation based on the predicted weather conditions in addition to the other considerations.

The priority assigned to each pivot system may be determined by the sensed soil conditions and the unit electrical power grid costs. For example, the farmer may assign priority categories as to electrical costs as follows: $0.08 per kilowatt hour=Category "A"; $0.06 per kilowatt hour=Category "B"; and $0.04 per kilowatt hour+Category "C". He or she may then simply designate in which category a particular pivot irrigation system is to operate, and let the computer make the final run time assignments based on the soil conditions in combination with the rate category. The farmer may change the category assignments at any time and may override the computer generated priorities in order to meet unanticipated or changing conditions from the transceiver **20** at the pivot location, remotely via phone or radio communication to the computer **16** directly (via coded transmission) or indirectly through an operator at the computer keyboard **36**.

The control computer **16** in the system **22** is preferably located in the business center such as a farmhouse. When the system **22** is utilized for irrigation of golf courses, greenbelts, city or community parks, etc., the central control computer **16** will most likely be located in an appropriate central office or business location.

An integrated irrigation power management and optimization system **40** is shown in block diagram form in FIG. **3**. This integrated system **40** provides automated management, coordination and control for a plurality of systems **22** each having a central control computer **16** located at a business or farmhouse and which in turn control operation of irrigation pumps, central pivots **12** and/or sprinkler head devices to provide irrigation to a particular soil section such as the agricultural area **10** shown in FIG. **1**. It is to be understood that the area **10** may alternatively be a golf course, a park, or other network of irrigation devices.

The integrated irrigation optimization system **40** essentially interfaces between a number of Electrical power transfer stations **28** through a power grid control computer **42**, a command post computer **44**, and a plurality of central control computers **16** as described above with reference to FIG. **2**. Each of these central control computers **16** may control operation of a system of agricultural pivots, or commercial or municipal sprinkler systems. In addition, the optimization system may be adapted to control operation of any other high power consumption electrical load in order to most cost effectively manage utilization of available power resources.

Basically, the optimization system **40** requires that the end user, such as the farmer, establish a letter priority for each of the devices under his system. For example, the priority "A" device would come on any time the soil conditions programmed into the central computer determined irrigation was needed. The priority "B" device would come on any time the soil conditions programmed into the central computer determined irrigation was needed and the command computer determined that the B rate of power was available. For example, this might occur when the electrical grid load drops at about 6:00 pm and the charge is 8 cents per kilowatt-hour. After 9:00 pm the grid load drops again to 6 cents per kilowatt-hour. This level might be priority "C".

The command post computer **44** monitors the availability of electrical power from the various power transfer stations or power plants **28** and monitors the demands received from the various central control computers **16** in each of the systems **22** tied into the overall irrigation optimization system **40**. In addition, the command post computer **44** tracks and stores in a database **46** the duration of usage for each system **22** tied into it and the priorities under which the systems **22** were used. This information may then be used for billing purposes. Thus the main function of the command computer **44** is to monitor power availability and monitor user set priorities and provide the database for billing.

While there have been described above the principles of the present invention in conjunction with specific apparatus, it is to be clearly understood that the foregoing description is made only by way of example and not as a limitation to the scope of the invention. Particularly, it is recognized that the teachings of the foregoing disclosure will suggest other modifications to those persons skilled in the relevant art. Such modifications may involve other features which are already known per se and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure herein also includes any novel feature or any novel combination of features disclosed either explicitly or implicitly or any generalization or modification thereof which would be apparent to persons skilled in the relevant art, whether or not such relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as confronted by the present invention. The applicants hereby reserve the right to formulate new claims to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

What is claimed is:

1. A system for optimizing operation of a plurality of independent soil irrigation systems comprising in combination:

a global positioning system (GPS) receiver receiving GPS satellite transmission position information for one or more of said irrigation systems to generate a map;

a geographical information systems (GIS) receiver receiving GIS satellite transmitted soil condition information for said irrigation systems on said map;

a programmable computer having a data storage device for storing data coupled to said GPS and GIS receivers for mapping said soil condition information onto said map;

a software program means in said computer for integrating said position information and said soil condition information to produce a priority schedule for operation of each of said irrigation systems in accordance with predetermined irrigation criteria; and

a transmission means coupled to said computer and to each of said irrigation systems for sending a control signal to each of said irrigation systems in accordance with said priority schedule.

2. The system according to claim **1** wherein said GIS receiver receives nitrogen, phosphorus and moisture content information for each of said irrigation systems.

3. The system according to claim **1** wherein each of said irrigation systems is a circle pivot irrigation system.

4. The system according to claim **3** further comprising said computer having report generating means for producing soil and irrigation usage reports for each of said plurality of pivot systems.

5. A system for optimizing operation of a plurality of independent soil irrigation systems comprising in combination:

a means for determining soil irrigation system position and soil condition information for each position;

a programmable control computer having a data storage device for storing said soil condition information onto an irrigation system map;

a power grid monitor coupled to said computer for tracking electrical power demand and capacity available to said irrigation systems on said map;

a software program means in said computer for integrating said position information, said power demand and available capacity and said soil condition information, together to produce a priority schedule for operation of each of said irrigation systems in accordance with predetermined irrigation criteria and available power criteria; and

transmission means coupled to said computer and to each of said irrigation systems for sending a control signal to each of said irrigation systems in accordance with said priority schedule.

6. The system according to claim **5** further comprising a plurality of central control computers connected to a command computer communicating with said power grid, said command computer determining availability priority levels for power from said power grid, and monitoring usage of power by said irrigation systems at said assigned priority levels.

7. The system according to claim **6** further comprising said control computer having report generating means for producing soil and irrigation usage reports for each of said plurality of irrigation systems.

8. A system for optimizing operation of a plurality of independent soil irrigation systems comprising in combination:

a programmable control computer having a data storage device for storing data for mapping soil condition and position information onto a map;

a weather satellite receiver coupled to said computer receiving weather forecasting information for said irrigation systems;

a power grid monitor coupled to said computer through a command computer for tracking electrical power demand and capacity available to said irrigation systems on said map;

a software program means in said control computer for integrating said position information, said soil condition information, and said weather forecast information together to produce a priority schedule for operation of each of said irrigation systems in accordance with predetermined irrigation criteria and available power criteria; and

transmission means coupled to said control computer and to each of said irrigation systems for sending a control signal to each of said irrigation systems in accordance with said priority schedule.

9. The system according to claim **8** wherein each of said irrigation systems is a circle pivot irrigation system.

10. A method optimizing operation of a remotely controlled irrigation system in an area of soil comprising the steps of:

receiving a global positioning system (GPS) signal representative of a position of said irrigation system;

receiving a geographic information system (GIS) satellite signal of soil condition information in said area;

correlating said GIS signal with said GPS signal to generate a map of said soil condition information; and

calculating in a control computer a required period of irrigation system operation based on said soil condition information at the location of said irrigation system.

11. The method according to claim **10** further comprising the step of prioritizing operation of said irrigation system based on said soil condition information.

12. The method according to claim **10** further comprising the steps of receiving power demand and generating capacity information from a power generating facility supplying power to said irrigation system in said control computer and scheduling operation of said irrigation system in accordance with said priority, said generating capacity information and a predetermined power capacity criteria.

13. The method according to claim **10** further comprising receiving a weather satellite signal of predicted weather conditions in said area;

receiving a weather condition signal from said irrigation system location

correlating said weather satellite signal with said irrigation system location to generate predicted weather conditions at said irrigation system; and

modifying said required period of operation based on said predicted weather conditions at said irrigation system.

14. The method according to claim **13** further comprising the step of prioritizing operation of said irrigation system based on said soil condition information.

15. The method according to claim **13** further comprising the steps of receiving power demand and generating capacity information from a power generating facility supplying power to said irrigation system and scheduling operation of said irrigation system in accordance with said priority, said generating capacity information and a predetermined power capacity criteria.

16. A method of optimizing operation of a remotely controlled irrigation system in an area comprising the steps of:

generating soil condition information at each position of said irrigation system;

calculating in a control computer a required period of irrigation system operation based on said soil conditions at the location of said irrigation system;

receiving power demand and generating capacity information from a power generating facility supplying power to said irrigation system in said control computer; and

scheduling operation of said irrigation system in accordance with said priority, said generating capacity information and a predetermined power capacity criteria.

17. A method of optimizing operation of a remotely controlled irrigation system in an area comprising the steps of:

generating soil condition information at each position of said irrigation system;

calculating in a control computer a required period of irrigation system operation based on said soil conditions at the location of said irrigation system;

receiving weather satellite signal of predicted weather conditions in said area;

receiving a weather condition signal with said irrigation system location to generate predicted weather conditions at said irrigation system;

modifying said required period of operation based on said predicted weather conditions at said irrigation system;

receiving power demand and generating capacity information from a power generating facility supplying power to said irrigation system in said control computer; and

scheduling operation of said irrigation system in accordance with said priority, said generating capacity information and a predetermined power capacity criteria.

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United States Patent [19]

Janzen et al.

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[45] **Date of Patent: Oct. 31, 2000**

[54] **COMPUTER-AIDED FARMING SYSTEM AND METHOD**

[75] Inventors: **David C. Janzen**, Metamora; **Louis G. Alster**, Morton, both of Ill.

[73] Assignee: **Caterpillar Inc.**, Peoria, Ill.

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Navigation: Journal of the Institute of Navigation vol. 43, No. 2 Carrier–Phase DGPS for Closed–Loop Control of Farm & Construction Vehic.

Primary Examiner—Jacques H. Louis-Jacques
Attorney, Agent, or Firm—Steve D. Lundquist

[57] **ABSTRACT**

A computer-aided farming system having a first control system which receives data defining a plurality of parameters. The first control system responsively determines a plurality of nodes located at an agricultural field, and determines a condition status associated with each node. The system also has a second control system located on an agricultural machine which receives data defining the nodes and the condition status at each node. The second control system then plans a path as a function of the nodes, and determines a desired work operation relative to each node. A machine controller controls the agricultural machine to perform the desired work operation at each node.

50 Claims, 6 Drawing Sheets

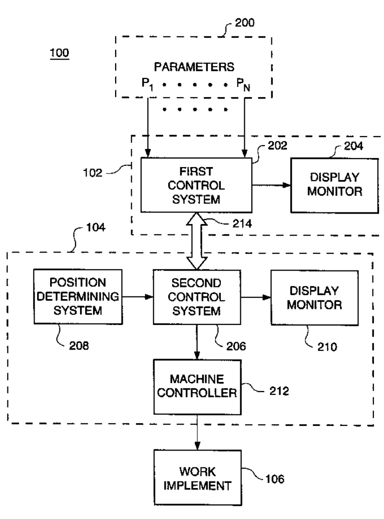


Fig. 1

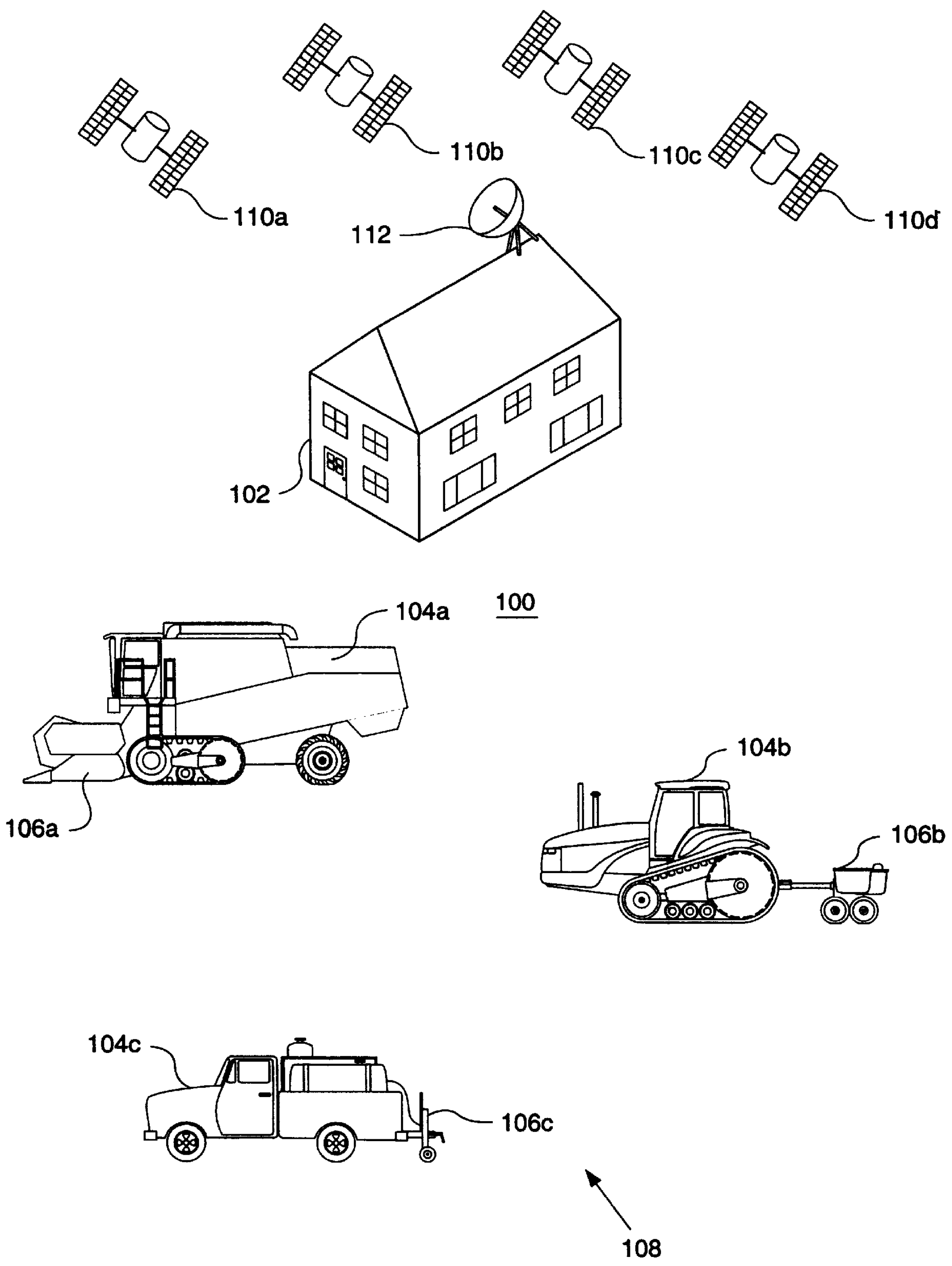

110a
110b
110c
110d
112
102
100
104a
106a
104b
106b
104c
106c
108

FIG. 2

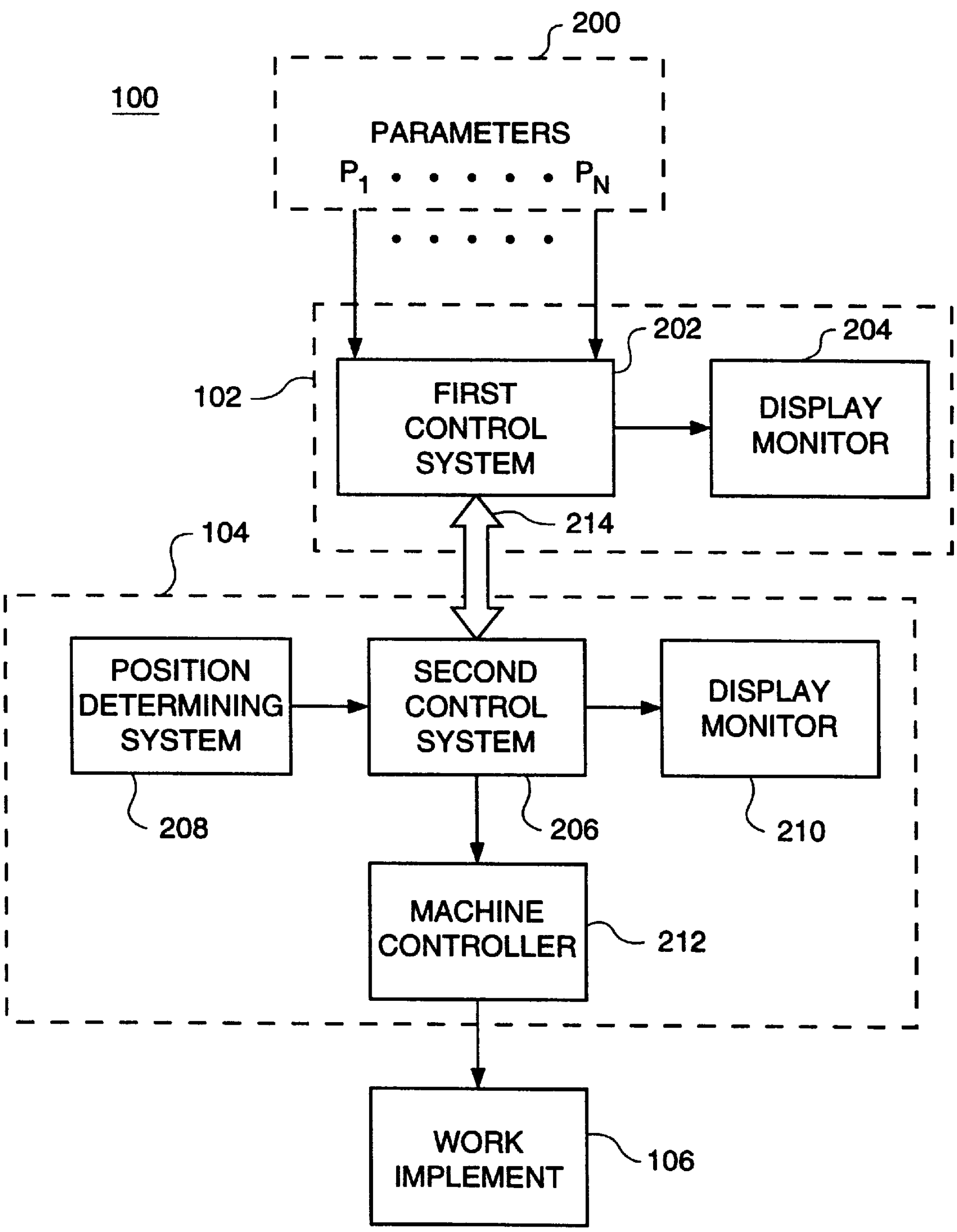

200
100
PARAMETERS
P1 • • • • • PN
• • • • •
202
204
102
FIRST CONTROL SYSTEM
DISPLAY MONITOR
214
104
POSITION DETERMINING SYSTEM
SECOND CONTROL SYSTEM
DISPLAY MONITOR
208
206
210
MACHINE CONTROLLER
212
WORK IMPLEMENT
106

Fig. 3

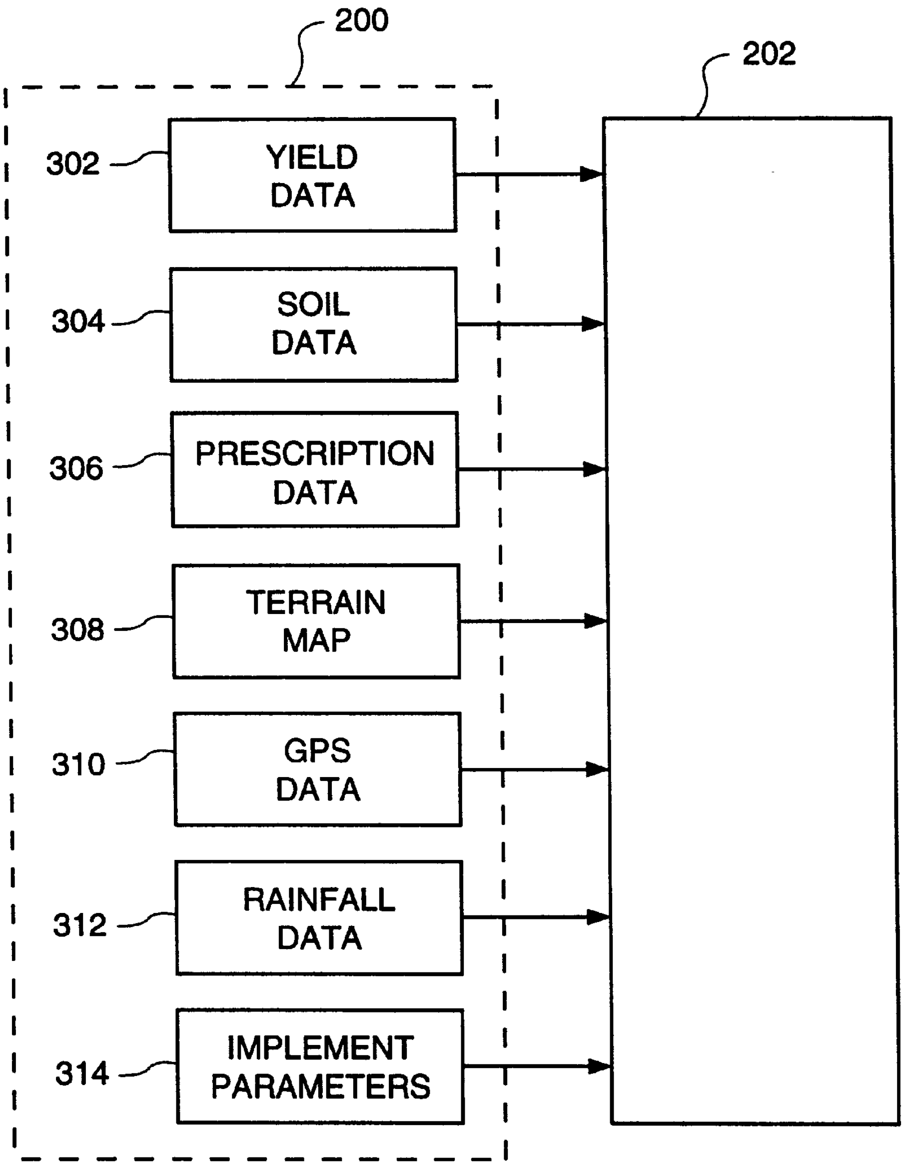

200
202
302
YIELD DATA
304
SOIL DATA
306
PRESCRIPTION DATA
308
TERRAIN MAP
310
GPS DATA
312
RAINFALL DATA
314
IMPLEMENT PARAMETERS

FIG. 4

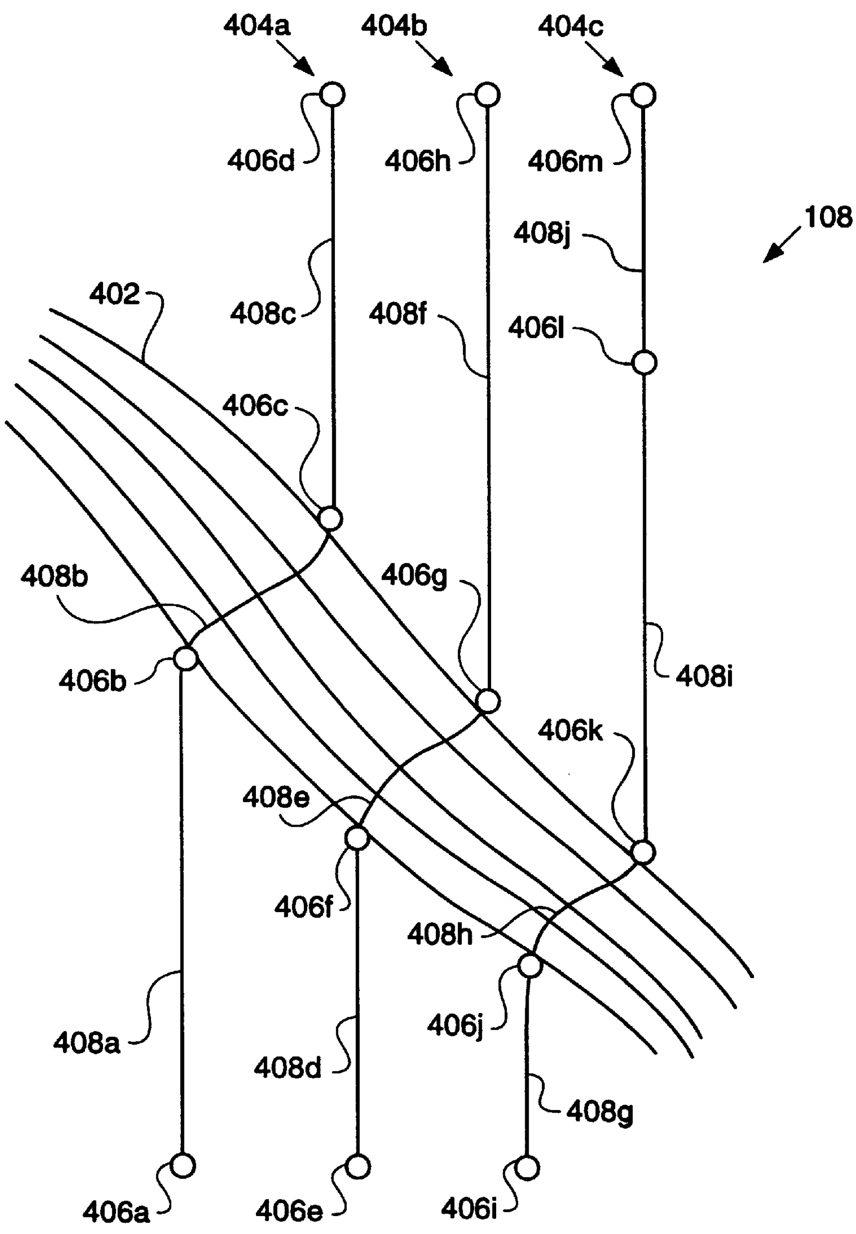

404a
404b
404c
406d
406h
406m
108
408j
408c
408f
406l
402
406c
408b
406g
406b
408i
406k
408e
406f
408h
406j
408a
408d
408g
406a
406e
406i

Fig. 5

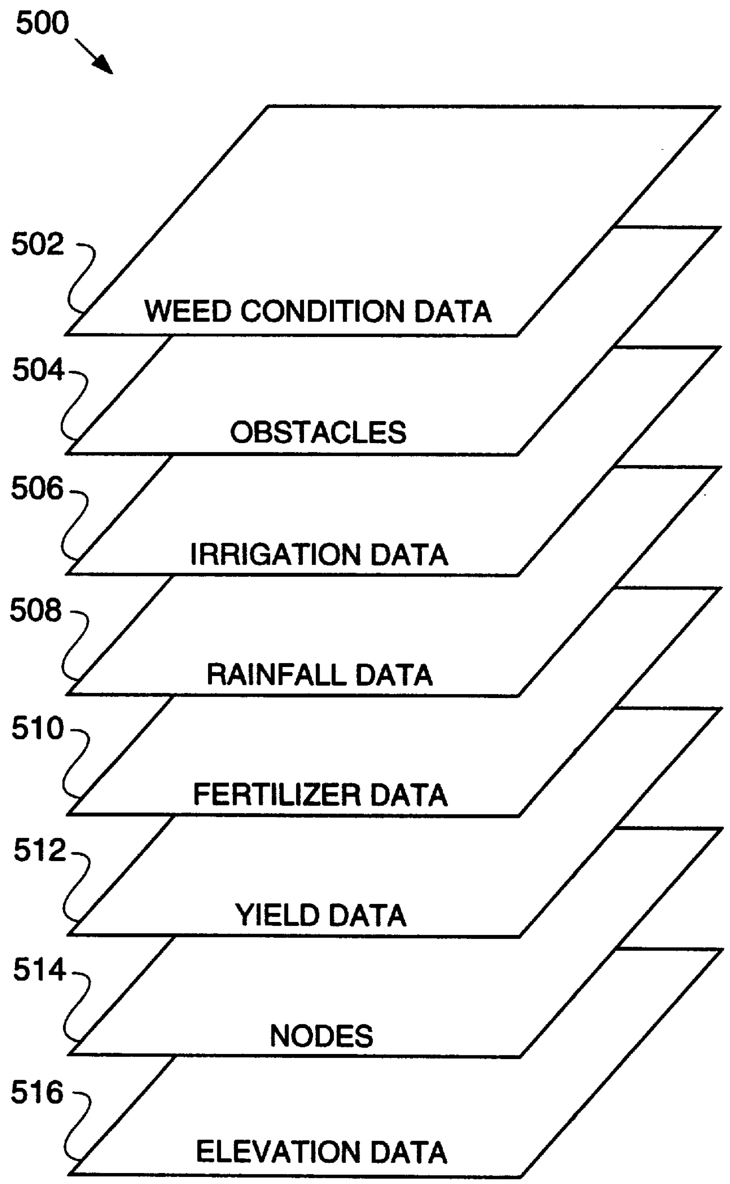
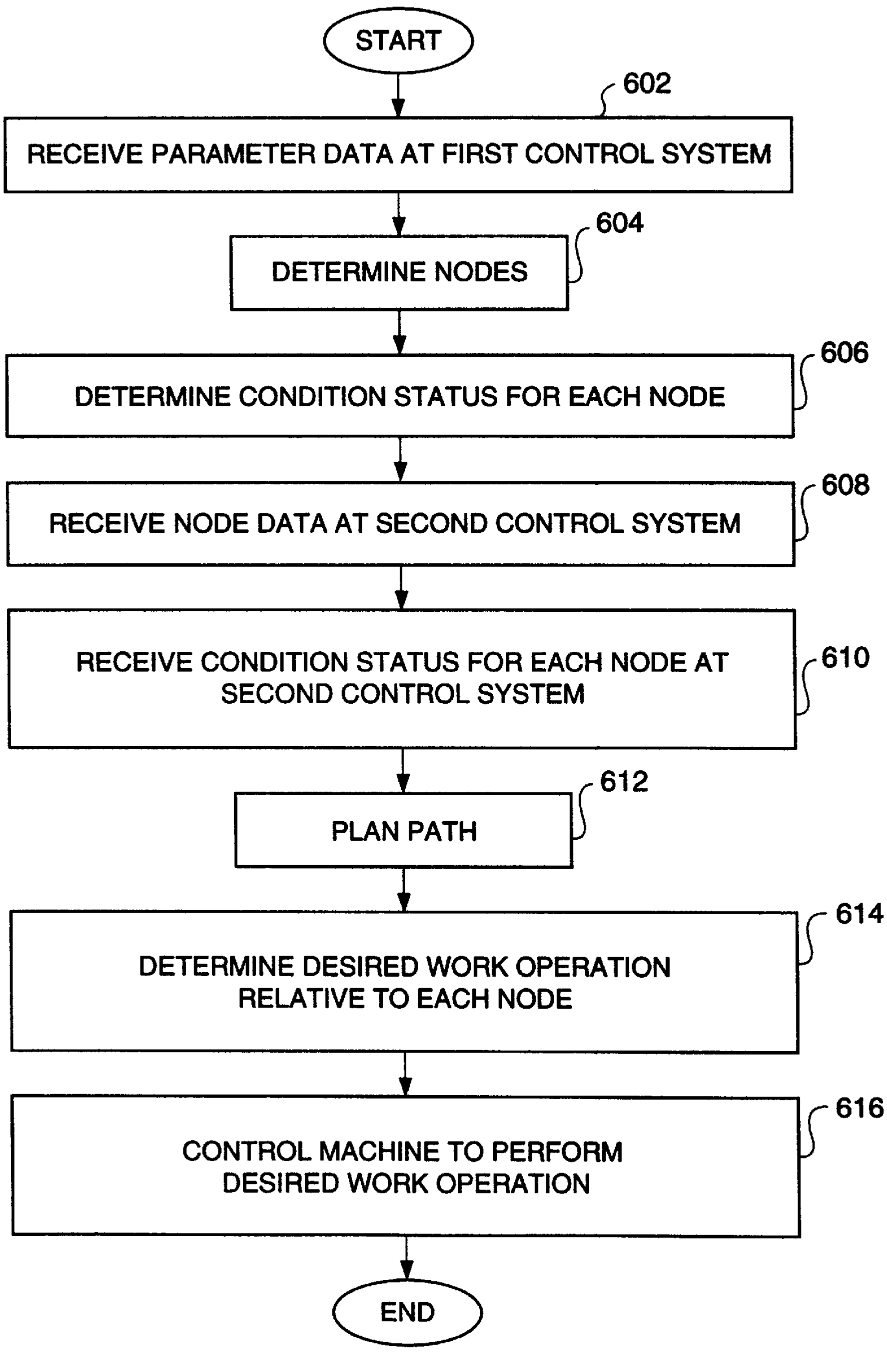

500
502
WEED CONDITION DATA
504
OBSTACLES
506
IRRIGATION DATA
508
RAINFALL DATA
510
FERTILIZER DATA
512
YIELD DATA
514
NODES
516
ELEVATION DATA

Fig. 6


START
602
RECEIVE PARAMETER DATA AT FIRST CONTROL SYSTEM
604
DETERMINE NODES
606
DETERMINE CONDITION STATUS FOR EACH NODE
608
RECEIVE NODE DATA AT SECOND CONTROL SYSTEM
610
RECEIVE CONDITION STATUS FOR EACH NODE AT SECOND CONTROL SYSTEM
612
PLAN PATH
614
DETERMINE DESIRED WORK OPERATION RELATIVE TO EACH NODE
616
CONTROL MACHINE TO PERFORM DESIRED WORK OPERATION
END

COMPUTER-AIDED FARMING SYSTEM AND METHOD

TECHNICAL FIELD

This invention relates generally to a system for controlling an agricultural machine and, more particularly, to a system for selectively controlling an agricultural machine as a function of a plurality of predetermined nodes located at an agricultural work site.

BACKGROUND ART

It has long been a desire in agricultural operations to reduce costs and increase efficiency and productivity by performing only those tasks that are needed at specific locations. For example, an agricultural field may require an application of fertilizer or chemicals, but only on certain areas of the field. The conventional method of applying the chemicals over the entire field results in unnecessary costs. In addition, current environmental concerns make excess chemical applications undesirable.

In U.S. Pat. No. 5,050,771, Hanson et al. discloses a control system in which a field may be sprayed selectively, based on a map showing areas where application is desired. An agricultural machine uses sensors to track the distance the machine travels. Checkpoints and flags provide a machine operator with means to determine position relative to the areas for application. Hanson et al. offers a method to selectively control the locations to apply chemicals in a field. However, the method requires the placement of flags and markers to give an operator a set of references. Placing these flags requires considerable effort, and results in a system that is low in accuracy and reliability. In addition, the locations for spraying must be stored in a memory. Any desired changes would require reprogramming the existing memory locations.

Recent advances in technologies, such as Global Positioning Satellite (GPS) systems and computer technologies, have paved the way for developments commonly known as precision farming. By knowing the location of an agricultural machine relative to a known terrain map, navigation of the machine can be controlled. Also, the tasks performed by the machine can be controlled in selective areas.

As an example of precision farming, Anderson, in U.S. Pat. No. 5,684,476, discloses a navigation system for an agricultural machine which uses GPS and dead reckoning technology to determine the location of the machine and correct for determined navigation errors. Anderson also discloses the use of a terrain map and checkpoints to aid in navigating the machine. However, the checkpoints are determined based on sensed operations of the machine. For example, when the GPS system determines that the machine has changed direction, a checkpoint indicating a boundary of the field is determined. Other checkpoints are determined based on sensed elevation changes, sudden turns, and the like. The system which Anderson discloses does not provide checkpoints in advance for path planning and implement control. In addition, Anderson does not provide for a central control system which provides data and checkpoints to allow multiple agricultural machines to cooperatively work in a field, providing the same or different operations.

In U.S. Pat. No. 5,712,782, Weigelt et al. discloses a method for multiple agricultural machines to communicate with a central controller. Each machine is equipped with an on-board processor to control the machine to some extent. However, Weigelt et al. does not disclose path planning or implement control by the machine processors.

The present invention is directed to overcoming one or more of the problems as set forth above.

DISCLOSURE OF THE INVENTION

In one aspect of the present invention a computer-aided farming system is disclosed. The system includes a first control system to receive data defining a plurality of parameters, determine a plurality of nodes located at an agricultural field, and determine a condition status associated with each node. The system also includes a second control system located on an agricultural machine to receive data defining the nodes and the condition status at each node, plan a path as a function of the nodes, and determine a desired work operation relative to each node. The system further includes a machine controller to control the agricultural machine to perform the desired work operation at each node.

In another aspect of the present invention a computer-aided farming method is disclosed. The method includes the steps of receiving parameter data at a first control system, determining a plurality of nodes at an agricultural field, and determining a condition status associated with each node. The method also includes the steps of receiving data defining the nodes and the condition status at each node at a second control system, planning a path as a function of the nodes, and determining a desired work operation relative to each node. The method further includes the step of controlling the agricultural machine to perform the desired work operation at each node.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic illustration of an embodiment of the present invention;

FIG. **2** is a block diagram illustrating an embodiment of the present invention;

FIG. **3** is a block diagram further illustrating a portion of the embodiment of FIG. **2**;

FIG. **4** is a diagrammatic illustration of one aspect of the present invention;

FIG. **5** is a diagrammatic illustration of a layered database map; and

FIG. **6** is a flow diagram illustrating a method of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to the drawings, and with particular reference to FIG. **1**, a diagrammatic illustration of a computer-aided farming system **100** is shown.

A base station **102** provides a central location for the computer-aided farming system **100**. The base station **102** may be located near an agricultural field **108**, or may be at a remote location, such as, for example, in a large farming operation consisting of multiple fields over a large geographic area. The base station **102** is shown with a base station GPS antenna **112**, adapted to receive signals from a plurality of GPS satellites **110**, four of which are shown in FIG. **1** and depicted as **110***a,b,c,d*. However, it is understood by common knowledge in the art that more than four GPS satellites **110** exist and any number greater than or less than four GPS satellites **110** may be in range of the base station GPS antenna **112** at any given time.

The base station GPS antenna **112** functions as a differential GPS antenna (DGPS) in the computer-aided farming system **100**. The base station GPS antenna **112** is shown located at the base station **102**. However, the base station GPS antenna **112** may be positioned at any known, stationary location that provides signal coverage over the agricultural field **108**. Differential GPS technology is well known in the art and will not be discussed further.

Located in the agricultural field **108** is at least one agricultural machine **104**. As shown in FIG. **1**, an agricultural machine **104** may be a harvester machine **104***a*, a tractor **104***b*, a truck **104***c*, or one of any number of other types of mobile machines used for agricultural applications. Preferably, the agricultural machine **104** includes a work implement **106**. For example, a harvester **104***a* may have a thrasher or crop gathering header **106***a*, a tractor **104***b* may have a seed planter, disks, or furrower **106***b*, and a truck **104***c* may have a liquid sprayer or granular applicator **106***c*. Other types of work implements **106** may be attached to the agricultural machine **104** to perform a wide variety of agricultural tasks.

Referring now to FIG. **2**, a block diagram of an embodiment of the present invention is shown.

A first control system **202** is shown located at the base station **102**. However, the first control system **202** may be located at a site other than the base station **102**, such as a remote site or on an agricultural machine **104**, without deviating from the spirit of the invention. Preferably, the first control system **202** provides an output to a display monitor **204**.

The first control system **202** is adapted to receive a plurality of parameters **200** from a variety of sources. For example, parameters **200** may be received from sensors (not shown) located at the agricultural field **108**, from agricultural machines **104**, and from agricultural services created to analyze and supply data. Examples of parameters **200** are described below with reference to FIG. **3**.

The first control system **202** is further adapted to determine a plurality of nodes located at the agricultural field **108**, and to determine a condition status associated with each of the nodes. The condition status at each node is a function of the parameters **200**. The nodes and the condition status of each node are discussed in more detail below.

A second control system **206**, preferably located on the agricultural machine **104**, is adapted to receive data defining the nodes and the condition status at each node from the first control system **202**. A communications system **214** provides communications between the first control system **202** and the second control system **206**. In the preferred embodiment, the communications system **214** is a wireless communications system. However, in an alternative embodiment, the communications system may be a wired communications system, enabled by electrically connecting the first control system **202** to the second control system **206**. As a further alternative embodiment, the communications system may be enabled by use of data receptors at the first and second control systems **202**,**206**, the data receptors being adapted to receive data mediums such as removable storage mediums. Examples of removable storage mediums include, but are not limited to, disks, CD ROMS, tapes, and flash cards.

Other types of communications systems may be used without deviating from the invention.

The second control system **206** is adapted to plan a path as a function of the nodes. Additionally, the second control system **206** is adapted to determine a desired work operation relative to each node as a function of the condition status at each node. Planning a path and determining a desired work operation are discussed in more detail below.

A position determining system **208**, located on the agricultural machine **104**, is adapted to determine the position of the agricultural machine **104** relative to the agricultural field **108**. The position determining system **208** is electrically connected to the second control system **206**, and delivers a position signal to the second control system **206**. Preferably, the position determining system **208** includes a GPS receiver. However, the position determining system **208** could alternatively use other means for determining position, such as dead reckoning, laser positioning, and the like, or the position determining system **208** could incorporate a combination of position determining methods.

In the preferred embodiment, a display monitor **210**, located on the agricultural machine **104**, is connected to the second control system **206**.

A machine controller **212**, located on the agricultural machine **104**, is adapted to control the agricultural machine **104** and the work implement **106** to perform the desired work operation at each node. In one embodiment, the machine controller **212** is adapted to control navigation of the agricultural machine **104** to traverse the path. In another embodiment, the machine controller **212** is adapted to control a function of the work implement **106**. For example, the machine controller **212** may control a rate of application of a material, such as fertilizers, chemicals, and seeds. As another example, the machine controller **212** may control the position of the work implement **106** relative to the agricultural machine **104**, such as an elevation of the work implement **106**.

Referring now to FIG. **3**, a block diagram illustrating exemplary parameters **200** are shown.

A yield data parameter **302** provides historical data on crop yields on an annual basis. Preferably, yield data is obtained from sensors on the agricultural machine **104** during harvest to associate yield data with locations on the agricultural field **108**. By compiling historical yield data, trends in yield production can be determined.

A soil data parameter **304** provides data on soil condition at desired locations throughout the agricultural field **108**. Soil data may be obtained from a variety of methods that are known in the art. For example, a GPS equipped agricultural machine **104** may traverse the agricultural field **108** for the express purpose of obtaining soil samples for analysis by a lab. After analysis, the lab would provide the resultant data. As another example, the agricultural machine **104** may be equipped to sample the soil as the machine **104** traverses the field **108** for other purposes. Soil data would then be communicated back to the first control system **202** by the communications system **214**.

A prescription data parameter **306** provides data, preferably historical, describing chemical prescriptions that have been added to the agricultural field **108**. The data would also include the locations and amounts of the prescriptions added. With the advent of precision farming, the use of prescription chemicals can be monitored with great accuracy, thus providing an historical data base to help determine exactly what chemicals are needed, where they are needed, and how much of each chemical is needed. The prescription data parameter **306** can also be used to monitor the effectiveness of the prescription chemicals.

A terrain map parameter **308** provides terrain map data having characteristics of the agricultural field **108** to the first control system **202**. Examples of terrain map data include, but are not limited to, contours of the field **108**, obstacles located in the field **108**, areas of discontinuous contour in the field **108**, e.g., holes, cliff sides, and drop-offs, and areas of non-tillable terrain in the field **108**. Terrain map data may be provided by several means including, preferably, terrain-related data being communicated by agricultural machines **104** as they traverse the field **108**.

A GPS data parameter **310** includes GPS-related data from the agricultural machines **104** in the field **108**. In one embodiment, the first control system **202** monitors the locations of the agricultural machines **104**. In another embodiment, the first control system **202** receives data from the machines **104** and associates the data with the locations of the machines **104**. For example, an agricultural machine **104** may apply fertilizer at specific locations on the field **108**, and the location of the machine **104** during application is determined from the GPS data from the machine **104** at the time of application.

A rainfall data parameter **312** provides historical data pertaining to the amount of rainfall at the agricultural field **108**. Rainfall data may be obtained from available weather information sources or may be obtained directly by rainfall sensors installed at strategic locations. In larger agricultural operations, multiple rainfall sensors may provide more accurate information during periods of scattered and intermittent rains.

Implement parameters **314** include information about the work implements **106**, such as the type of work an implement **106** performs, the physical dimensions and characteristics of the work implement **106**, and historical data which tracks the operation of the work implement **106**.

It is to be noted that the above discussed parameters **200** are exemplary of the types of parameters that may be used, and is not an all-inclusive listing. Other parameters may be received by the first control system **202** for use in the present invention.

Referring now to FIG. **4**, a diagrammatic illustration of one aspect of the present invention is shown. A portion of an agricultural field **108** is illustrated with a series of paths **404***a,b,c*. The paths **404** are determined by connecting a plurality of nodes **406***a–m* by a plurality of segments **408***a–j*. For example, a first path **404***a* includes nodes **406***a,b,c,d*, which are connected by segments **408***a,b,c*. In like manner, a second path **404***b* includes nodes **406***e,f,g,h*, which are connected by segments **408***d,e,f*; and a third path **404***c* includes nodes **406***i,j,k,l,m*, which are connected by segments **408***g,h,i,j*. The paths **404***a,b,c* are shown approximately parallel with each other. However, adjacent paths may be created non-parallel with each other if desired.

A contour **402** is shown in FIG. **4** to illustrate a situation where it may be desired to alter the direction of movement of the agricultural machine **104**. In the example of FIG. **4**, it is desired to change the heading of the machine **104** to traverse the contour **402** at essentially right angles to the slope of the contour **402**. This change in heading would allow the machine **104** to travel up and down the contour **402** in a manner that would give the machine **104** more control on the sloped surface.

The nodes **406**, as discussed above, are determined by the first control system **202**. Additionally, the condition status at each node **406** is determined by the first control system **202** as a function of the parameters **200**. For example, in FIG. **4**, nodes **406***b,f,j* signify one side of the contour, and nodes **406***c,g,k* signify the other side of the contour. The condition status for the nodes **406***b,c,f,g,j,k* indicate a desired change in heading of the agricultural machine **104**. In addition, the condition status for nodes **406***b,c,f,g,j,k* may contain other conditions, e.g., do not plant or plow, vary the rate of a prescription application to a desired rate, alter the depth of till, and the like.

Nodes **406***a,e,i* and nodes **406***d,h,m* may indicate, as an example, the start or end of a row in the field **108**. Alternatively, nodes **406***a,e,i* and nodes **406***d,h,m* may be located within a portion of rows, and may be associated with conditions such as; vary the rate or type of application, do not plow or plant, or change the depth of till to a desired level.

In path **404***c*, node **406***l* is located between straight line segments **408***i* and **408***j*. Node **406***l* is not required for path planning, but may have been created to associate with a change in condition status such as; a change in the moisture content in the soil, a change in the prescription chemicals in the soil, the presence of an obstacle, and the like.

Segments **408** are, preferably, created by the second control system **206** during path planning by connecting adjacent nodes. The segments may be created using straight line path planning techniques, as illustrated by segments **408***a,c,d,f,g,i,j*. Alternatively, the segments may be created using curve fitting techniques, as illustrated by segments **408***b,e,h*. Path planning using curve fitting techniques are well known in the art. For example, in U.S. Pat. No. 5,648,901, Gudat et al. discloses path planning methods using curve fitting techniques such as b-splines and clothoids.

Referring now to FIG. **5**, a diagrammatic illustration of a preferred embodiment for storing and processing data in the present invention is shown. Data is separated into categories and is shown embodied in a set of layered database maps **500**. The layered database maps **500** are preferably based on a terrain map of the agricultural field **108**. Each map layer contains a portion of the terrain map characterizing unique features of the field, such as weed condition data **502**, obstacles **504**, irrigation data **506**, rainfall data **508**, fertilizer data **510**, yield data **512**, node locations **514**, and elevation data **516**. The map layers shown in FIG. **5** are exemplary. Other map layers may be used as well.

In the preferred embodiment, the data in the layered database maps **500** is determined from the parameters **200** that are delivered to the first control system **202**, and from updates of the condition status at each node **406** as the agricultural machine **104** performs the desired operations at the nodes **406**.

It is noted that the concept of using layered maps to store and process data is well known in the art, and therefore will not be discussed further.

Referring now to FIG. **6**, a preferred method of the present invention is shown.

In a first control block **602**, data defining a plurality of parameters **200** is received at the first control system **202**.

In a second control block **604**, a plurality of nodes **406** located at the agricultural field **108** are determined by the first control system **202**.

In a third control block **606**, the condition status associated with each node **406** is determined. The condition status at each node **406** is determined as a function of the parameters **200**.

Control then proceeds to a fourth control block **608** and a fifth control block **610**. In the fourth control block **608**, data defining the nodes **406** is received by the second control system **206**. In the fifth control block **610**, data defining the condition status at each node **406** is received by the second control system **206**.

In a sixth control block **612**, the second control system **206** plans a path as a function of the nodes **406**.

In a seventh control block **614**, a desired work operation is determined by the second control system **206** relative to each node **406**. Preferably, the desired work operation is a function of the condition status at each node **406**.

Control then proceeds to an eighth control block **616**, where the machine controller **212** controls operation of the agricultural machine **104** and the work implement **106** to perform the desired work operation at each respective node **406**.

INDUSTRIAL APPLICABILITY

As an example of an application of the present invention, and with reference to FIG. **1**, agricultural machines **104** use a variety of work implements **106** to perform a variety of tasks. As examples, a tractor **104***b* may be used to pull a planter **106***b* to plant seeds. A harvester **104***a* may use a thresher **106***a* to harvest wheat or hay, and a truck **104***c* may use a sprayer **106***c* to spray fertilizer. In each of these examples, the work to be performed may vary over different portions of the agricultural field **108**.

The first control system **202** uses data from the parameters **200** received to determine nodes **406** throughout the field **108**, each of which is associated with a condition status of that portion of the field **108**. Layered database maps **500** containing this information is delivered to a respective second control system **206** located on each agricultural machine **104**. Each second control system **206** plans a path for the machine **104**, and determines a desired work operation for the machine **104** to perform at each node **406**.

In one embodiment of the present invention, the desired work operation is displayed on a display monitor **210** located on the agricultural machine **104** to allow an operator to responsively control the machine **104** and the work implement **106**. In another embodiment of the present invention, the desired work operation is communicated to the machine controller **212** to allow autonomous control of the agricultural machine **104** and the work implement **106**. In yet another embodiment of the present invention, control of the agricultural machine **104** and the work implement **106** is divided into varying degrees of manual and autonomous control.

Other aspects, objects, and features of the present invention can be obtained from a study of the drawings, the disclosure, and the appended claims.

What is claimed is:

1. A computer-aided farming system, comprising:

a first control system adapted to receive data defining a plurality of parameters and responsively determine a plurality of nodes located at an agricultural field, the first control system being further adapted to determine a condition status associated with each of the nodes, the condition status at each node being a function of the parameters;

a second control system located on an agricultural machine and adapted to receive data defining the nodes and the condition status at each node, the second control system being further adapted to plan a path as a function of the nodes and to determine a desired work operation relative to each node, the desired work operation being a function of the condition status at each node; and

a machine controller located on the agricultural machine and adapted to control the agricultural machine to perform the desired work operation at each respective node.

2. A system, as set forth in claim **1**, wherein the path is planned by determining a plurality of segments, each segment connecting two nodes.

3. A system, as set forth in claim **2**, wherein the machine controller is adapted to control navigation of the agricultural machine to traverse the path.

4. A system, as set forth in claim **1**, wherein a parameter is historical yield data.

5. A system, as set forth in claim **1**, wherein a parameter is soil data.

6. A system, as set forth in claim **1**, wherein a parameter is historical prescription application data.

7. A system, as set forth in claim **1**, wherein a parameter is a terrain map having characteristics of the field.

8. A system, as set forth in claim **7**, wherein a characteristic of the field is a contour of the field.

9. A system, as set forth in claim **7**, wherein a characteristic of the field is an obstacle in the field.

10. A system, as set forth in claim **7**, wherein a characteristic of the field is an area of discontinuous contour of the field.

11. A system, as set forth in claim **7**, wherein a characteristic of the field is an area of non-tillable terrain in the field.

12. A system, as set forth in claim **1**, wherein a parameter is the location of the agricultural machine.

13. A system, as set forth in claim **1**, wherein a parameter is rainfall data.

14. A system, as set forth in claim **1**, further including a work implement connected to the agricultural machine.

15. A system, as set forth in claim **14**, wherein a parameter is a characteristic of the work implement.

16. A system, as set forth in claim **15**, wherein the machine controller is further adapted to control the work implement to perform the desired work operation at each respective node.

17. A system, as set forth in claim **16**, wherein the machine controller is adapted to control a rate of application of the work implement.

18. A system, as set forth in claim **16**, wherein the machine controller is adapted to control an elevation of the work implement.

19. A system, as set forth in claim **16**, wherein the condition status associated with each node is updated in response to the agricultural machine performing the desired work operation at the node.

20. A system, as set forth in claim **19**, wherein the first control system is adapted to store the condition status in at least one of a plurality of layered database maps.

21. A system, as set forth in claim **20**, wherein a layered map contains historical yield data.

22. A system, as set forth in claim **20**, wherein a layered map contains data defining locations of obstacles in the field.

23. A system, as set forth in claim **20**, wherein a layered map contains fertilizer data.

24. A system, as set forth in claim **20**, wherein a layered map contains data defining locations of the nodes in the field.

25. A system, as set forth in claim **20**, wherein a layered map contains elevation data of the field.

26. A system, as set forth in claim **20**, wherein a layered map contains data defining a condition of weeds in the field.

27. A system, as set forth in claim **20**, wherein a layered map contains rainfall data.

28. A system, as set forth in claim **20**, wherein a layered map contains irrigation data.

29. A system, as set forth in claim **16**, further including a display monitor located on the agricultural machine and electrically connected to the second control system.

30. A system, as set forth in claim **29**, wherein the desired work operation relative to each node is displayed on the display monitor to enable an operator of the agricultural machine to responsively control at least one of the agricultural machine and the work implement.

31. A system, as set forth in claim **16**, wherein the desired work operation relative to each node is communicated to the machine controller to enable autonomous control of at least one of the agricultural machine and the work implement.

32. A system, as set forth in claim **1**, further including a communications system adapted to enable communications between the first control system and the second control system.

33. A system, as set forth in claim **32**, wherein the communications system is a wireless communications system.

34. A system, as set forth in claim **32**, wherein the communications system is a wired communication system enabled by electrically connecting the first control system to the second control system.

35. A system, as set forth in claim **32**, wherein the communications system is a data receptor connected to at least one of the first control system and the second control system, the data receptor being adapted to receive a data medium for communicating data.

36. A system, as set forth in claim **35**, wherein the data medium is a removable storage medium.

37. A system, as set forth in claim **1**, further including a position determining system located on the agricultural machine and electrically connected to the second control system.

38. A system, as set forth in claim **37**, wherein the position determining system includes a GPS receiver.

39. A system, as set forth in claim **1**, further including a display monitor electrically connected to the first control system.

40. A computer-aided farming method, including the steps of:

receiving data at a first control system, the data defining a plurality of parameters;

determining a plurality of nodes located at an agricultural field;

determining a condition status associated with each of the nodes, the condition status at each node being a function of the parameters;

receiving data defining the nodes at a second control system located on an agricultural machine;

receiving data defining the condition status at each node at the second control system;

planning a path as a function of the nodes;

determining a desired work operation relative to each node, the desired work operation being a function of the condition status at each node; and

controlling the agricultural machine to perform the desired work operation at each respective node.

41. A method, as set forth in claim **40**, wherein planning a path includes the step of determining a plurality of segments, each segment connecting two nodes.

42. A method, as set forth in claim **41**, wherein controlling the agricultural machine includes the step of controlling navigation of the agricultural machine to traverse the path.

43. A method, as set forth in claim **40**, further including the step of controlling a work implement connected to the agricultural machine to perform the desired work operation at each respective node.

44. A method, as set forth in claim **43**, wherein controlling a work implement includes the step of controlling a rate of application of the work implement.

45. A method, as set forth in claim **43**, wherein controlling a work implement includes the step of controlling an elevation of the work implement.

46. A method, as set forth in claim **43**, further including the step of updating the condition status associated with each node in response to the agricultural machine performing the desired work operation at the node.

47. A method, as set forth in claim **40**, further including the step of storing the condition status in at least one of a plurality of layered database maps.

48. A method, as set forth in claim **40**, further including the step of determining the position of the agricultural machine.

49. A method, as set forth in claim **40**, further including the step of displaying the desired work operation relative to each node on a display monitor located on the agricultural machine.

50. A computer-aided farming system, comprising:

a first control system adapted to receive data defining a plurality of parameters and responsively determine a plurality of nodes located at an agricultural field, the first control system being further adapted to determine a condition status associated with each of the nodes, the condition status at each node being a function of the parameters;

a second control system located on an agricultural machine and adapted to receive data defining the nodes and the condition status at each node, the second control system being further adapted to plan a path as a function of the nodes and to determine a desired work operation relative to each node, the desired work operation being a function of the condition status at each node;

a communications system adapted to enable communications between the first control system and the second control system;

a position determining system located on the agricultural machine and electrically connected to the second control system;

a work implement connected to the agricultural machine; and

a machine controller located on the agricultural machine and adapted to control at least one of the agricultural machine and the work implement to perform the desired work operation at each respective node.

* * * * *

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Davey

(10) **Patent No.: US 6,173,727 B1**
(45) **Date of Patent: Jan. 16, 2001**

(54) **REMOTE CONTROL SPRINKLER CONTROL SYSTEM**

(76) Inventor: **Donald Davey**, 1451 Churchill Downs Dr., Sandy, UT (US) 84092

(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) Appl. No.: **09/562,041**

(22) Filed: **May 1, 2000**

Related U.S. Application Data

(63) Continuation of application No. 09/073,330, filed on May 6, 1998, now abandoned.

(51) **Int. Cl.**[7] **F16K 31/02**
(52) **U.S. Cl.** **137/1**; 251/129.04; 700/264
(58) **Field of Search** 137/1; 251/129.04; 239/69; 700/284

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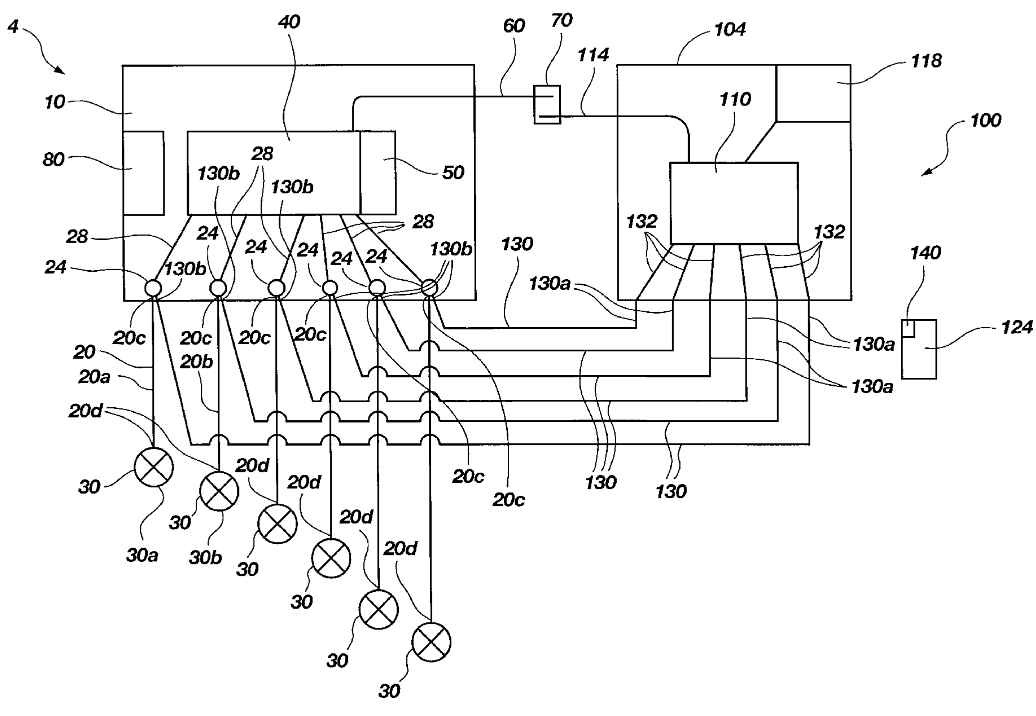
Primary Examiner—Kevin Shaver
Assistant Examiner—Eric Keasel
(74) *Attorney, Agent, or Firm*—Morriss, Bateman, O'Bryant & Compagni

(57) **ABSTRACT**

A remote control system for automatic sprinkler control systems includes remote conductor lines for attachment to an automatic sprinkler control system, a remote processor for selectively applying power through one or more of the remote conductor lines so as to activate a portion of the automatic sprinkler control system, and a remote control for controlling the processor. The remote control system enables the use to operate the automatic sprinkler control system independent of the processor of the automatic sprinkler control system, and allows the user to conduct such control from a location adjacent to the actual sprinkler stations, as opposed to the central control unit of the automatic sprinkler control system.

22 Claims, 5 Drawing Sheets



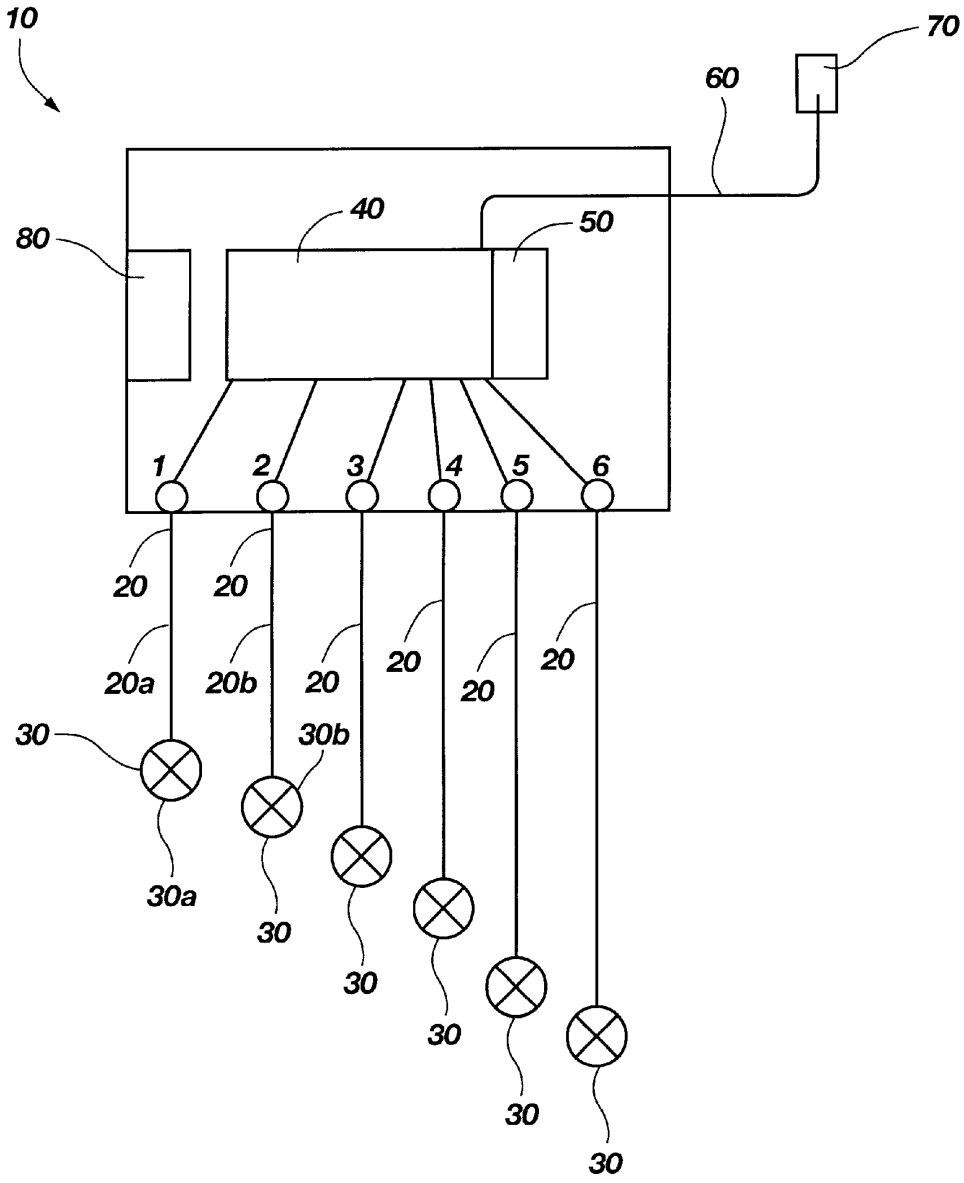
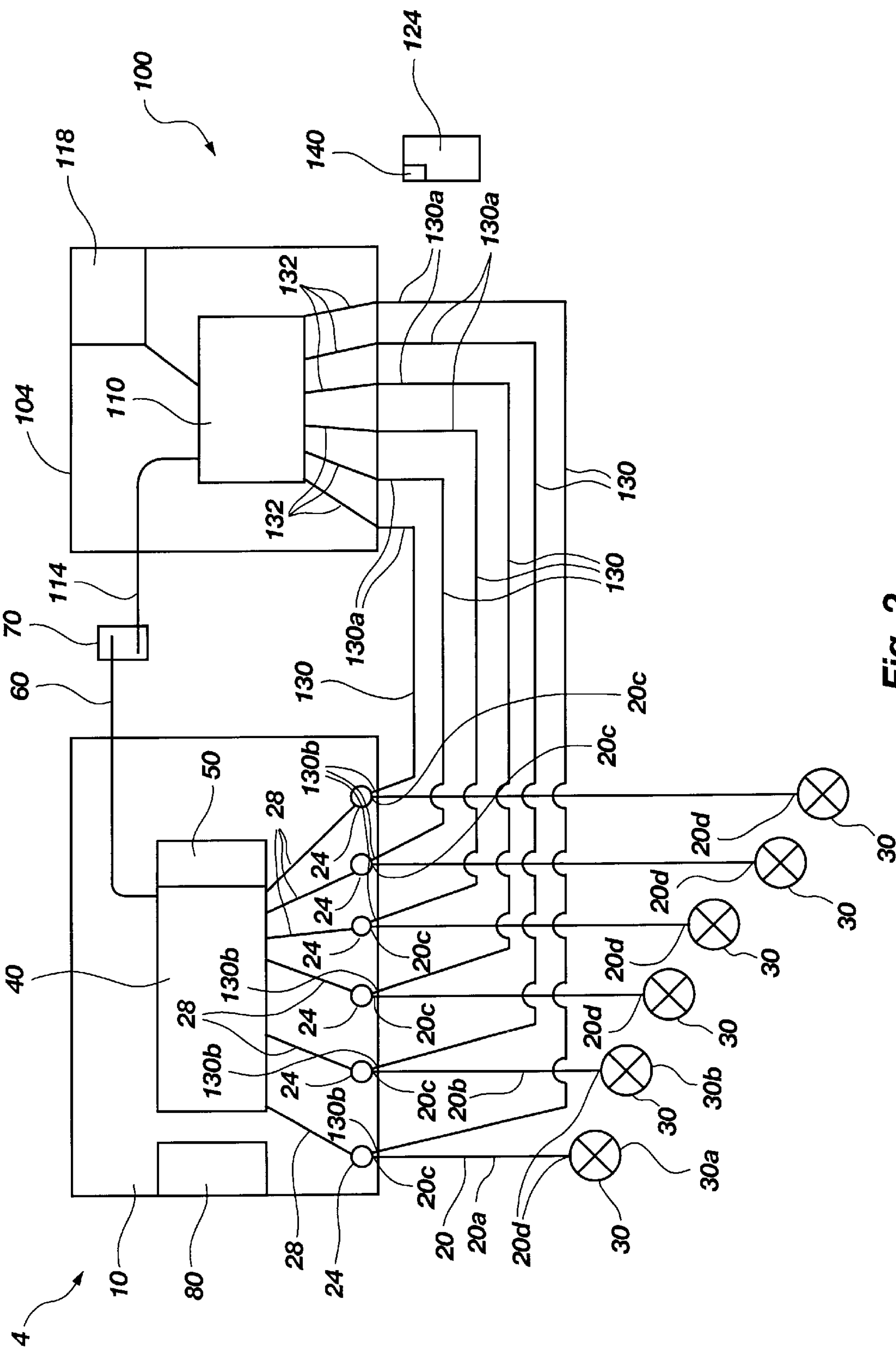


Fig. 1
(PRIOR ART)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124
118
140
130a
104
110
132
130
114
70
60
40
50
28
130b
24
20c
20d
30
20b
30b
30a
20
20a
4
10
80

Fig. 2

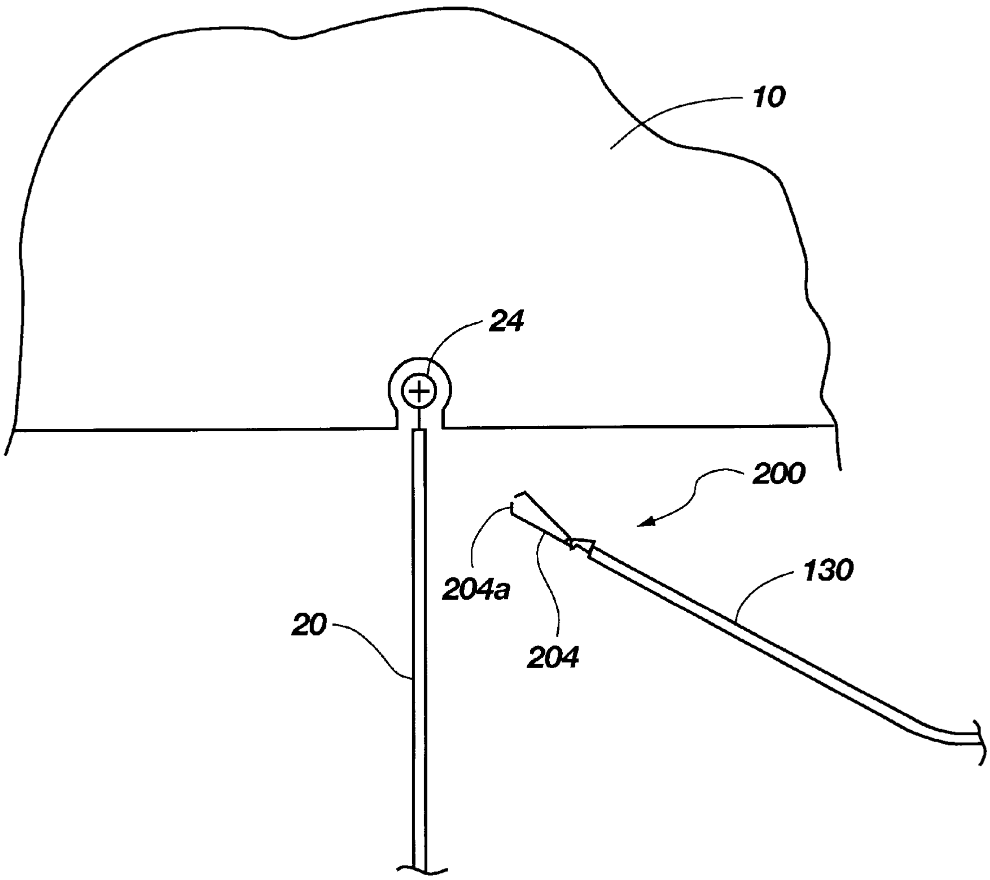

Fig. 3

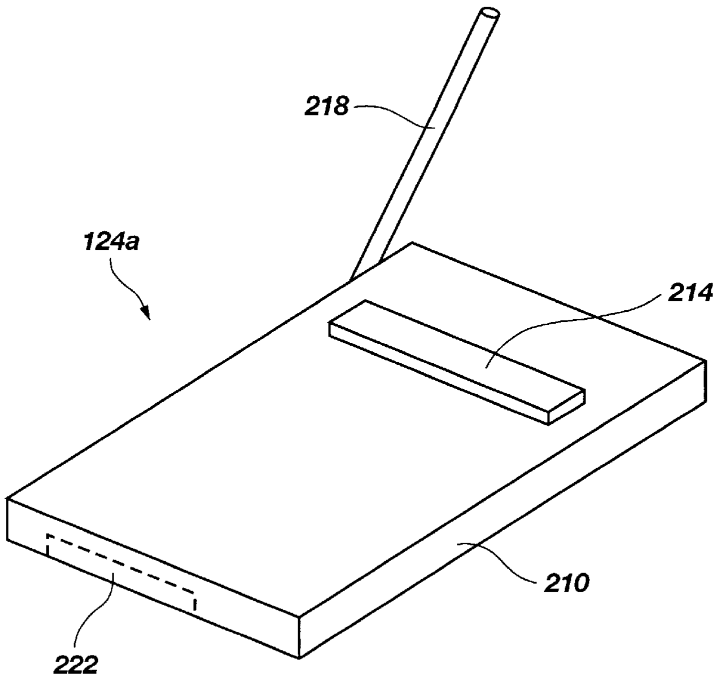
218
124a
214
210
222

Fig. 4

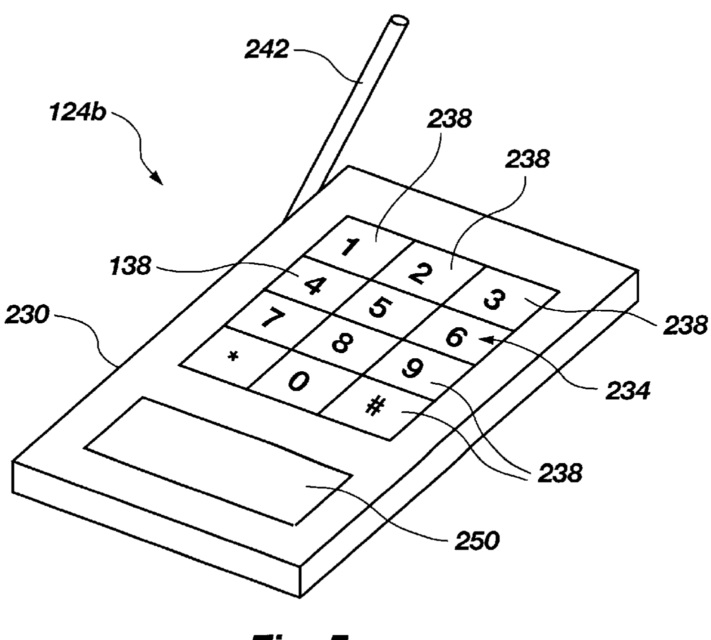
242
124b
238
238
1
2
3
138
4
5
6
230
7
8
9
*
0
#
238
234
238
250

Fig. 5

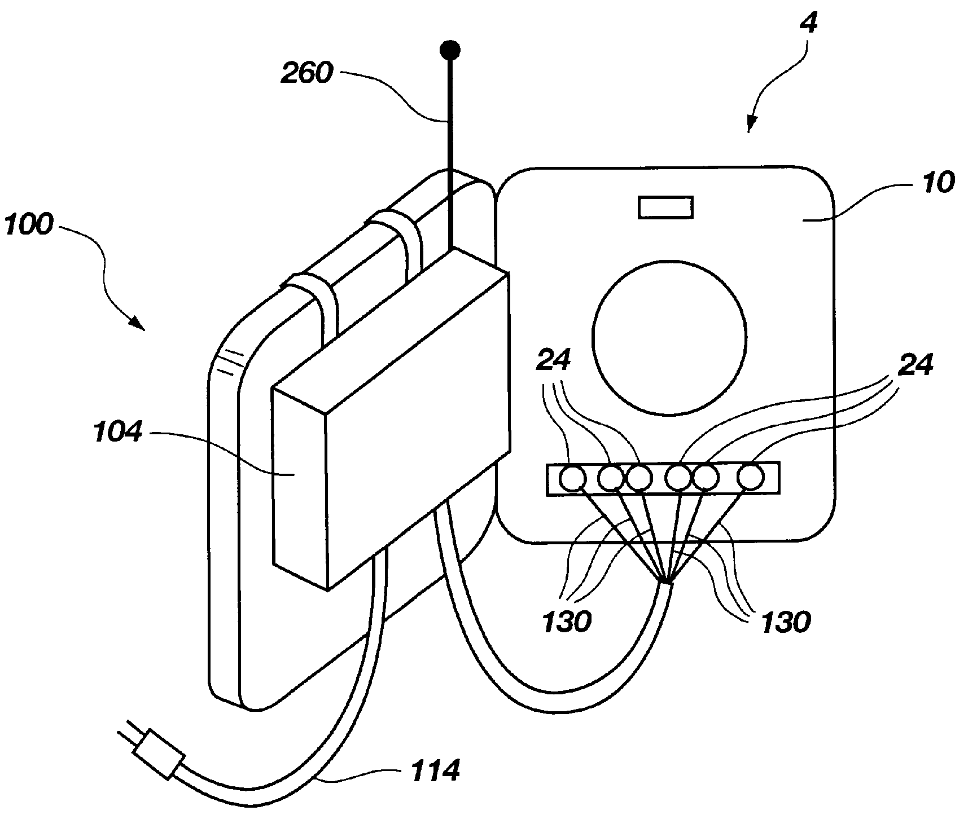

Fig. 6

REMOTE CONTROL SPRINKLER CONTROL SYSTEM

RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 09/073,330, filed May 6, 1998, now abandoned.

FIELD OF THE INVENTION

The present invention relates to an improved sprinkler control system. More particularly, the present invention relates to a remote control sprinkler system which enables the remote activation of various stations of an automatic sprinkler system to permit the user to selectively activate and monitor a given sprinkler or sprinkler station without need to return to the central control unit of the automatic sprinkler system.

STATE OF THE ART

The use of automated sprinkler systems for lawns and the like has increased significantly over the past twenty-five years. In a typical sprinkler system, conduit is attached to a water supply source and is run under the lawn, garden, shrubs, etc. which is to be watered. The conduit terminates in a plurality of sprinkler heads which are disposed adjacent the surface to be watered. When watering is desired, the water is released through the conduit to the sprinkler heads.

Because the amount of water available at any moment is limited, most lawns of any size will have the sprinkler heads grouped into a plurality of stations. Each sprinkler head in a station will generally be connected to a common main conduit, and a valve will be disposed along the main conduit so that water to each of the sprinkler heads in the station may be controlled from a common point.

To ensure proper water pressure and flow, irrigation through sprinklers usually is limited to one or two stations at a time. On large residential lots, it is not uncommon to have six to eight different stations.

In the early use of sprinkler systems, a key was provided by which the user would turn each of the valves on and off in a desired sequence to ensure that each station received the desired amount of water. While such sprinkler systems were a significant improvement over hand watering, they still required the user to be present at the start and stop of each cycle. As will be apparent to those familiar with irrigation, being present to start and stop water from six to eight stations can consume a fair amount of time and can be very inconvenient.

To alleviate these concerns, automated sprinkler systems were developed. Such systems generally include a plurality of solenoid valves which are disposed along the conduit leading to each station. Each of the solenoid valves is connected by a conducting wire to a central controller, such as the central control unit generally indicated at **10** in FIG. **1**. By supplying a current through the conducting wires, shown at **20**, the central control unit **10** is able to power the solenoid valve **30** from a normally closed position into an open position. In the open position, the solenoid valve **30** allows water to all of the sprinkler heads which are down stream—i.e. within that station.

The central control unit **10** is typically attached to four to eight conducting wires **20**, thus providing four to eight stations. The central control unit **10** also includes a central processor **40**, which typically includes a timing mechanism **50**. The central processor **40** receives power from a conductive line **60** which is typically plugged into a conventional wall electrical outlet **70**.

At the appropriate time, the central processor **40** sends power to one of the solenoid valves **30***a* through the conducting wire **20***a*. The power causes the solenoid valve **30***a* to move from a closed position to an open position to allow water to flow therethrough. Water flowing through the solenoid valve **30***a* is directed to the sprinkler heads of the station and is applied to the lawn, etc. adjacent the sprinkler heads. The central processor **40** maintains power to the solenoid valve **30***a* for a predetermined amount of time and then stops sending power to the valve **30***a* through the conducting line **20***a*. Once the power ceases, the valve **30***a* closes and irrigation through that station ceases. The central processor **40** may then start irrigation through another station by sending power through conductor line **20***b* to valve **30***b*.

Such an automated system allows the user to program the sprinkling system to water the lawn at a time which is least likely to interfere with water pressure needed for household functions. Thus, for example, a sprinkling system could be programmed to water the entire lawn before the occupants of the residence awake, or after they leave for daily activities.

One problem which commonly arises with automated sprinkling systems is that a sprinkler head will break due to being stepped on, run over by a lawn mower or other similar circumstance. The damage is usually noticed once the sprinkler system is used and abnormal watering is present. Due to advances in sprinkler technology, fixing the broken sprinkler head is relatively easy and usually requires only common hand tools. However, a recurrent problem is present. To ensure that the sprinkler was tested properly, the sprinkler station must be turned on to allow water to flow through the system under normal conditions.

Because the central control unit **10** of the automated sprinkler control system controls actuation of the solenoid valves **30**, the user must typically walk back to the central control unit to actuate the solenoid valve for the appropriate station. In most homes, the central control unit **10** is disposed in the garage or in the basement.

On a very small lot, the inconvenience required to leave the sprinkler head being repaired, to walk to the garage to actuate the sprinkler station and to return to the sight of the repair is relatively minor. This is, of course, except for those situations in which the sprinkler being repaired in on the opposing side of the sprinkler station from the garage. In such situations, the user must occasionally run through the sprinkler station to actuate or turn off the central controller.

Of course, the inconvenience increases in situations where several attempts are necessary to properly repair the damaged sprinkler, or to locate which of several sprinklers is damaged. In such a scenario, even a short distance between the sprinkler and the central controller can waste time and water.

The inconvenience involved with returning to the central control unit **10** is at its greatest on large pieces of property. In some cases, the user must walk forty or fifty yards to activate the sprinklers via the central control unit, and then immediately return to the sight of the repair. If the sprinkler is not properly repaired, the user must then walk back to central controller to stop water flow before any additional work is done on the sprinkler. In the mean time, the water flowing out of the sprinkler could cause soil erosion around the sprinkler, or may cause puddling or other problems which further complicate the repair process.

To remedy these concerns, there is a need for a mechanism which enables the user to control water flow to a sprinkler station from a remote location. Such a mechanism should preferably be adaptable to existing automatic sprinkler systems so as to enable remote control of the electrical signals being provided to the solenoid valves. Such a mechanism should also be configured to prevent interference with the normal functioning of the central control unit.

SUMMARY OF THE INVENTION

Thus, it is an object of the present invention to provide an improved system for actuating sprinkler stations of an automatic sprinkler control system from a remote location.

It is another object of the present invention to provide such a system which enables the user to monitor a repaired sprinkler head or conduit while actuating the station and/or terminating water flow to the station.

It is yet another object of the present invention to provide such a system which prevents feedback to the central processor when the system is in use, and thereby prevents damage to the central processor.

It is yet another object of the present invention to provide such a system which is both easy to install and easy to use.

The above and other objects of the invention are realized in specific illustrated embodiments of a remote control sprinkler control system including a remote processor disposable in communication with a power source, at least one remote conductor line for communication with the conductor lines of an automatic sprinkler system so as to enable the remote processor to power conductor lines of the automatic sprinkler system, and a remote communication mechanism for communicating with the remote processor.

In accordance with one aspect of the invention, the remote processor includes a plurality of conductor lines which may be attached to the conductor lines of the automatic sprinkler system to enable remote powering of the conductor lines of the automatic sprinkler system and thereby allows the user to cycle through the stations, or to choose any desired station for actuation.

In accordance with another aspect of the invention, the remote processor and the conductor lines connected thereto are configured to enable powering of the conductor lines of the automatic sprinkler system while the central processor of the automatic sprinkler system is turned off. Thus, the remote processor is able to selectively actuate the stations of the automatic sprinkler system while minimizing or preventing feedback to the central processor. This, in turn, minimizes risks to the central processor due to power surges and the like.

In accordance with another aspect of the present invention, the remote communication mechanism is a hand held transmitter with one or more touch keys. When the one or more touch keys are pressed, they selectively power conductor lines of the automatic sprinkler system. In a simplified embodiment of the invention, the transmitter can have a single touch key. Each pressing of the touch key causes the remote processor to actuate the next sprinkler station. Thus, the user need merely press the touch key a sufficient number of times to cycle through the sprinkler stations until the desired sprinkler station is actuated. To turn the automatic sprinkler system off, the user continues pressing the touch key once after the remote processor has actuated the last sprinkler station.

In another embodiment of the invention, the hand held transmitter is provided with a plurality of touch keys—preferably one for each sprinkler station. When the user desires to actuate the sprinklers of a particular station, he or she need only press the touch key which is associated with that station and the solenoid valve on that station is opened without the need to cycle through the other sprinkler stations. Once the test, etc., is complete, the sprinkler station can be closed by once again pressing the same touch key.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings in which:

FIG. **1** is a diagram of an automatic sprinkler control system including a central processor, a plurality of solenoid valves, and conducting wires for connecting the central processor and the solenoid valves in accordance with the teachings of the prior art;

FIG. **2** is a diagram of an automatic sprinkler control system made in accordance with the present invention;

FIG. **3** shows a close-up view of a connector as might be used to connect the conductor lines of the remote processor to the conductor lines of the automatic sprinkler system.

FIG. **4** is a perspective view of a remote communication mechanism made in accordance with the principles of the present invention;

FIG. **5** shows a perspective view of an alternate embodiment of a remote communication mechanism in accordance with the present invention;

FIG. **6** shows a perspective view of the remote processor mechanism and the central control of the an automatic sprinkler control system.

DETAILED DESCRIPTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numeral designations and in which the invention will be discussed so as to enable one skilled in the art to make and use the invention. It is to be understood that the following description is only exemplary of the principles of the present invention, and should not be viewed as narrowing the pending claims.

Referring again momentarily to FIG. **1**, there is shown a diagram of the control mechanisms of a prior art automatic sprinkler system, generally indicated at **4**. The central control unit **10** provides power through the conductor lines **20** (hereinafter referred to as the central conductor lines) to the solenoid valves **30** which are disposed along the conduits (not shown) carrying water to the sprinkler heads so as to define sprinkler stations. If the user desires to turn a station on or off, he or she must use a keypad **80** or other data entry device to actuate the desired sprinkler station. However, repeatedly returning to the sprinkler control unit **10** wastes a considerable amount of time and can cause damage to the lawn, etc., if there is a major brake in a sprinkler head or portion of the conduit. Thus, the present invention provides a mechanism to allow remote control of the stations of the automatic sprinkler control system.

Turning now to FIG. **2**, there is shown a diagram of an automatic sprinkler system of the prior art, and a remote control sprinkler control system formed in accordance with the principles of the present invention. The automatic sprinkler system, generally indicated at **4**, includes a central control unit **10** and a plurality of central conductor lines **20** which are attached at a first end **20***c* to the central control unit. Typically, the connection between the central conductor lines **20** and the central control unit **10** is made by a conductive screw **24**. The first end **20***c* of the central conductor lines **20** typically wraps around the screw which threadedly engages a conductor **28** in the central control unit **10**.

An opposing end **20***d* of each of the central conductor lines **20** is attached to a valve **30**. Typically, the valves **30** are solenoid valves configured such that when power is maintained through one of the central conductor lines **20**, the valve **30** which is associated with that conductor line opens. opening of the valve **30** allows water to flow to the sprinkler station (not shown) which is downstream from that valve. Once the power through the central conductor line **20** is terminated, the solenoid valve **30** closes. Thus, the valves **30** are in a fail closed configuration.

The central processor **40** and a timing mechanism **50** control when each of the central conductor lines **20** is powered to open the respective valves. Power to the central processor **40** is provided by a power line **60** which connects to conventional outlet **70**. If changes to the timing of the sprinklers are desired, a keypad **80** or other data entry method is used to modify the operational timing and sequencing of the system.

Disposed adjacent to the central control unit **10** is a remote control unit, generally indicated at **100**. The remote control system **100** is configured to enable the user to control the functions of the sprinklers independent of the central processor **40**, and from a remote location. The remote control system **100** includes a remote unit **104**, which contains a remote processor **110**. The remote processor **110** is powered by a power line **114**. For reasons which will be discussed in detail below, it is preferable for the power line to be plugged into the same wall outlet **70** as is used by the central processor **40** of the central control unit **10**.

The remote processor **110** is disposed in communication with a receiver **118** which receives signals from a remote communication means **124** which is discussed in detail in FIGS. **4** and **5**. The remote communication means **124** and the receiver **118** allows for remote control of the remote processor **110** to thereby enable remote control of actuation of the various sprinkler stations.

The remote processor **110** is also disposed in communication with a plurality of conductor lines **130** (hereinafter referred to as remote conductor lines). The remote conductor lines **130** are attached to conductors **132** of the remote processor **110** at a first end **130***a*, and are configured at a second end **130***b* for attachment to the screws **24** of the central control unit **4**.

In use, the remote conductor lines **130** of the remote processor **110** are configured to carry power to the central conductor lines **20** to thereby actuate the solenoid valves **30** independent of the central processor **40**. Preferably, the central processor **40** is turned off prior to use of the remote processor **110**. By turning off the central processor **40**, there is a reduced likelihood that the central processor **40** may be damaged by feedback from the power supplied by the remote processor **110** through the remote conductor lines **130** and the central conductor lines **20**.

To use the remote processor **110**, one or more of the conductor lines **130** are disposed in electrical communication with the central conductor lines **20** extending from the central processor **40**. Typically, this will be accomplished by attaching the remote conductor lines **130** to the screws **24** which anchor the central conductor lines **20**. Attachment may be made by clips, such as that shown in FIG. **3**, or by conventional adapters.

Once the remote conductor lines **130** are attached to the central conductor lines **20** and the power line **114** is plugged into the wall electrical outlet **70**, the remote processor **110** is ready for use. A signal is sent from the remote control means **124** through a transmitter **140** contained therein. The signal is received by the receiver **118** and passed to the remote processor **110**. The remote processor **110** interprets the signal received from the remote control means **124**, and selectively provides power to one the remote conductor lines **130**. The power is conveyed through the remote conductor line **130** and passed to the central conductor line **20** to which the remote conductor line is attached. The power is conveyed to the solenoid valve **30** disposed at the end of the central conductor line **20**, thereby opening the valve. The valve **30** will remain open as long as power is supplied by the remote processor **110** through the remote conductor line **130** and the central conductor line **20**. Once power is terminated through the central conductor line **20** and the remote conductor line **130**, the solenoid valve **30** will automatically close.

By using the remote control means **124**, the user is able to actuate the valve controlling any particular station while standing adjacent that station. Thus, the user is able to more rapidly determine the location of a broken sprinkler head or conduit. Additionally, the user is better able to test repairs without repeatedly returning to the central control unit. For example, if a user were to walk onto his or her back lawn and notice puddling on the lawn, the user may know that, due to the location of the puddle, a sprinkler was broken in either station **1** or station **2**.

Without the remote control system **100** of the present invention, the user would have to return to the garage, turn the automatic sprinkler system **4** into the manual mode and send power through the first central conducting line **20***a* to the solenoid valve **30***a* for the first station. The user must then walk back to the location of the first station's sprinkler heads and look for any malfunction which may be causing the puddling. If a problem is not observed, the user must then return to the garage and modify the central control unit **10** so that power is supplied to the second central conductor **20***b* and the second solenoid valve **30***b*. The user must then return to the location of the second sprinkler station and look for any malfunctioning sprinkler heads, etc.

If the defective part is observed, the user must then return to the garage to terminate the power and thereby close the second sprinkler station. The user must then return to the second sprinkler station to fix the defective part. Once fixed, the user must return to the garage to activate the second solenoid valve **30***b* again. The user must then return to the second sprinkler station to ensure that the repaired part is functioning properly, and then terminate water flow to the second sprinkler station. As will be appreciated, on a large piece of property the time spent walking between the sprinkler station and the central control unit **10** of the automatic sprinkler system can be more than the time required to make the actual repair. Similar time problems are raised by those who install sprinkler systems, as they must test each station once the installation has been completed.

The present invention solves these concerns by providing a remote control system **100** which avoids the numerous trips to the central control unit **10**. Specifically, under the scenario discussed above, the user would preferably make a first trip to the central control unit **10**. The remote conductor lines **130** would be connected to the central conductor lines **20**, the central control unit **10** would be turned off and the remote control system **100** would be plugged into the wall outlet **70**. Of course, a user could leave the remote control system **100** plugged in and the remote conductor lines **130** attached to the central control lines **20**. While such would save the initial trip to the central control unit **10**, it increases the chance the central processor **40** could be damaged by feedback from the remote conductor lines **130**. Plugging the central control unit **10** and the remote control system **100** into the same outlet **70** helps to avoid such problems by eliminating the risk of power damage caused by the alternating current being out of phase.

Once the remote control system **100** is plugged in and the remote conductor lines **130** are attached to the central conductor lines **20**, the user need merely carry the remote control means **124** to the first station. The user presses a touch key (not shown in FIG. **2**) on the remote control means **124**. The remote control means sends a signal through the transmitter **140** to the receiver **118** of the remote control system **100**. The receiver **118** conveys the signal to the remote processor **110**. The remote processor **110**, in turn, provides power through the remote conductor line **130***a* and the central conductor line **20***a* to open the solenoid valve **30***a*.

Without leaving the first sprinkler station, the user is able to observe if there are any defective sprinkler heads, etc. By pressing the touch key again, the user sends another signal through the transmitter **140** to the receiver **118**, which communicates with the remote processor **110**. The second signal causes the remote processor **110** to terminate power being supplied to the remote conductor line **130***a* and the central conductor line **20***a*. Without power, the solenoid valve **30***a* closes, terminating water flow to the first station.

Terminating the power to the solenoid **30***a* can be accomplished in two different ways depending on the sophistication of the device. In a simplified version, each signal from the remote control means **124** causes the remote processor **110** to supply power to the next remote conductor line **130**. Thus, as shown in FIG. **2**, sending a second signal to the remote processor **110** causes the remote processor to terminate power to remote conducting line **130***a* and to send power to the next remote conducting line **130***b*. Therefore, each use of the remote control means **124** simply advances water flow to the next station. After each station has been activated, the next use of the remote control means causes the remote processor to provide power to none of the remote conductor lines **130**. The cycle may then be repeated.

In more sophisticated versions of the remote control means **124** and the remote processor means **110**, the user can selectively use the remote control means **124** to turn on and terminate power to any one of the stations without requiring any of the other stations to be activated. Those familiar with automatic sprinkler control systems will appreciate the different circuitries which are available or which may be constructed to accomplish such tasks.

Referring again to the above example, if the user discovers a malfunctioning sprinkler head in the first station, he or she terminates power to the valve **30***a* and proceeds to repair the defective device. Once the repair has been completed, the remote control means **124** is again used to cause the remote processor **110** to send power through the remote conductor line **130***a* and the central conductor line **20***a*. The power causes the valve **30***a* to open, and allows the user to determine if the repair was effective without requiring the user to leave the station.

If the user does not discover a malfunctioning sprinkler head in the first station, he or she can activate the second station to determine if there is a defective sprinkler at that location. While checking two stations would require four or five trips back to the central control unit **10** with a conventional automatic sprinkler system **4**, the present invention allows everything to be done while standing adjacent the stations being tested. Such a system is particularly beneficial when adjusting sprinkler heads to obtain optimal irrigation patterns. Numerous adjustments can be made without leaving the vicinity of the sprinklers.

In use, the circuitry associated with the remote processor **110** processes the **120** vac power received from the power outlet **70** into a 24 vac with sufficient current to provide approximately 0.3 amps inrush and 0.19 amps holding current. These currents are sufficient, respectively, to actuate movement of the solenoid valves **30** and to maintain the valves in an open configuration

Turning now to FIG. **3**, there is shown a close-up view of a connector, generally indicated at **200**. The central conductor lines **20** (only one of which is shown in FIG. **3**) are attached to the central control unit **10** by the screw **24**. Thus, by attaching the remote conductor lines **130** (only one of which is shown in FIG. **3**) to the screw **24**, the remote conductor lines are disposed in electrical communication with the central conductor lines **20**.

To facilitate ease of attachment to the screw **24**, the remote conductor lines **130** may be provided with a connector **200** in the form of a spring biased clip **204**. Squeezing the clip **204** slightly allows a distal end **204***a* of the clip to open sufficiently to fit over the head of the screw **24**. Releasing the clip **204** causes the clip to grip the screw **24** and places the remote conductor line **130** in electrical communication with the central conductor line **20**. Once the remote control system **100** is no longer needed, the clip **204** can be easily removed by simply squeezing the clip and pulling away from the screw **24**.

The ease of attachment provided above is ideal for several applications. For the typical home owner, the connector **204** allows for easy disconnection of the remote conductor lines **130**, and thus encourages removal of the remote conductor lines when the remote control system **100** is no longer needed. Thus, the user is encouraged to terminate the connection and prevent electrical feedback during use of the automatic sprinkler system **4**.

For commercial applications, the ease of attachment and removal of the remote control system **100** is particularly beneficial. For example, those installing sprinkler systems can take the remote control system to each installation job. Once the initial installation is completed, the remote control system **100** can be attached in less then two minutes and allows full testing of the system. Once the newly installed sprinkler system has been tested, the remote control system **100** can be removed in an equally short amount of time.

Turning now to FIG. **4** there is shown a perspective view of a simplified version of the remote control means, indicated as **124***a*. The remote control means **124***a* includes a housing **210** configured for being holdable in one's hand. Disposed in communication with the housing is a touch key **214** which may be pressed by the user. When the touch key **214** is pressed, a transmitter in the housing (such as transmitter **140** in FIG. **2**) sends a signal through an antenna **218** to the receiver **118** (FIG. **2**). While the antenna **218** could be housed within the housing, a longer antenna is preferable to ensure proper transmitting even on large pieces of property.

In using the remote control means **124***a* shown in FIG. **4**, the user would simply press the touch key **214** repeatedly to cycle through the stations until reaching the station desired. Thus, if station six of an eight station automatic sprinkler control system **4** needed to be actuated to check for a damaged sprinkler, the user would press the touch key **214** six times to cycle through to the sixth station. The processor means **110** would send the appropriate power to the solenoid valve **30** (FIG. **2**) associated with the sixth sprinkler station. Once finished, the touch key would be pressed three more times to cycle through the seventh and eighth stations, and to return to the off position.

The remote control means **124***a* will typically be powered by conventional batteries—typically a pair of AA batteries. The batteries can be placed within the housing through a small door **222** on one end thereof.

Turning now to FIG. **5**, there is shown yet another embodiment of a remote control means, generally indicated at **124***b*. The remote control means **124***b* includes a housing **230** and a touch pad **234** in the form of a plurality of touch keys **238**. Preferably, there will be at least 8 touch keys, and more preferably at least 10. The touch keys **238** can be used to activate the valve **30** of a particular sprinkler station without requiring the remote processor to cycle through any other stations. Thus, for example, if a sprinkler head in station six was potential defective, the sprinklers of station six could be turned on and off without affecting any of the other sprinkler stations.

Once the user presses a desired station number and an enter key (i.e. the # sign), transmitter inside the housing **230** would send a signal through the antenna **242** to the receiver **118** (FIG. **2**) to the remote processor **110** (FIG. **2**). The remote processor **110** would power the appropriate remote conductor line **130** and central conductor line **20** to actuate the appropriate valve. Pressing the same touch key **238** again and hitting the enter key would cause the remote processor **110** to terminate power to the valve and thereby terminate flow.

The same remote control means **124***b* could also be utilized with a more advanced remote processor to control a much larger number of stations. For example, while a typical yard may have only six or eight stations, a large park or golf course could easily have as many as seventy or even one hundred sprinkler stations. By selecting a combination of two numbers, the user of the remote control means **124***b* of FIG. **5** could activate **100** stations from the touch pad **234**. Thus, the grounds crew of a golf course could selectively activate any sprinkler station required while on the course. By avoiding having to return to the central control unit to turn the stations on or off, considerable time can be saved.

To further facilitate use of the system **100**, a display screen **250** could be disposed in the housing. The display screen **250** would let the user see what station had been entered. When working with a large number of stations, an indicator of which stations are active would be very beneficial. Thus, the number of the last entered sprinkler station may be retained on the display screen to assist the user.

Turning now to FIG. **6**, there is shown a perspective view of the remote processor housing **104** and the central control unit **10** of an automatic sprinkler control system **4**. The remote control system **100** includes the power line **114**, and the remote conductor lines **130** which connect the screws **24** of the central control unit **10** to the remote processor (not visible).

Also shown in FIG. **6** is an antenna **260** which extends from the remote control system housing **104** to receive signals from the remote control means **124** (not shown in FIG. **6**). When a signal is received from the remote control means **124**, the remote processor sends power through the remote conductor lines **130** to provide power to the valves **30** (not shown in FIG. **6**) which control water flow through the sprinkler system. Once the remote control system **100** is no longer needed, the remote conductor lines **130** are simply removed from the screws **24**.

Thus there is disclosed an improved remote control system **100** for automatic sprinkler control systems. Those skilled in the art will appreciate numerous modifications which can be made without departing from the scope and spirit of the present invention. The appended claims are intended to cover such modifications.

What is claimed is:

1. A method for remotely controlling an automatic sprinkler control system having a processor, a plurality of conductor means disposed in electrical communication with the processor, and a plurality of valves, each valve being disposed in electrical communication with one of the conductor lines such that when the processor sends electrical power through the conductor line, the valve associated with that line is open, the method comprising:

(a) providing a remote control system having at least one remote conductor line, a remote processor, a remote control means, and a power line independent of the automatic sprinkler control system;

(b) attaching at least one remote conductor line to one of the conductors of the automatic sprinkler control system; and

(c) actuating the remote processor to supply electrical energy through the at least one remote conductor and one of the conductors of the automatic sprinkler control system to open the valve associated with said conductor of the automatic sprinkler control system.

2. The method according to claim **1**, wherein the method further comprises actuating the remote processor by sending a signal from the remote control means.

3. The method according to claim **1**, wherein the method comprises, more specifically, providing a plurality of remote conductor lines, each being in electrical communication with the remote processor, and attaching each of the remote conductors to a conductor of the automatic sprinkler control system.

4. The method according to claim **3**, wherein the method further comprises using the remote control means to control the remote processor and thereby select to which remote conductor lines power is supplied.

5. The method according to claim **1**, wherein the remote control means comprises at least one touch key, and wherein the method comprises using the at least one touch key to control the remote processor, and thereby send power to the at least one remote conductor line.

6. The method according to claim **1**, wherein the conductor lines of the automatic sprinkler control each control a station of sprinkler heads, wherein the at least one remote conductor line comprises a plurality of remote conductor lines, each being disposed in electrical communication with a conductor line of the automatic sprinkler control station independent of the processor of the automatic sprinkler control system, and wherein the method further comprises cycling through the sprinkler stations by repeatedly actuating the remote control means.

7. The method according to claim **1**, wherein the conductor lines of the automatic sprinkler control each control a station of sprinkler heads, wherein the at least one remote conductor line comprises a plurality of remote conductor lines, each being disposed in electrical communication with a conductor line of the automatic sprinkler control station, and wherein the method further comprises selectively activating a desired sprinkler station by actuating the remote control means and thereby causing power to flow through one of the remote conductor lines.

8. The method according to claim **7**, wherein the remote control means comprises a housing with a plurality of touch keys disposed thereon, and wherein the method comprises selecting a touch key associated with a desired sprinkler station.

9. The method according to claim **1**, wherein the method comprises, more specifically, utilizing the remote control system while the processor of the automatic sprinkler system is off.

10. A remote control system for remotely operating an automatic sprinkler control system having a processor means, a plurality of valves and a plurality of conductors operationally connecting the processor means and the valves, the remote control system comprising:

a plurality of remote conductor lines attachable to at least one conductor of the automatic sprinkler control system;

a remote processor disposed in communication with the remote conductor lines for selectively supplying power to one or more of the conductors through the at least one remote conductor; and

remote control means in communication with the remote processor for controlling the remote processor to selectively apply power to at least one of the at least one remote conductor lines; and

wherein the plurality of remote conductor lines each further comprise a clip means for attachment to the conductors of the automatic sprinkler control system so as to place the remote conductor lines in electrical contact with the conductor lines of the automatic sprinkler control system.

11. A remote control system for attachment to an automatic sprinkler control system having a processor, a plurality of valves and a plurality of conductors for communicating electricity between the processor and the plurality of valves, the remote control system comprising:

a plurality of remote conductor lines for carrying electrical energy, the remote conductor lines having a means for attachment to the conductors of the automatic sprinkler control system;

a remote processor for selectively providing electrical energy to the remote conductor lines and the conductors independent of the automatic sprinkler control system; and

a remote control means for controlling the remote processor and for selecting which of the remote conductor lines receives power.

12. A remote control system for remotely operating an automatic sprinkler control system having a processor means, a plurality of valves and a plurality of conductors operationally connecting the processor means and the valves, the remote control system comprising:

at least one remote conductor line disposable in communication with at least one conductor of the automatic sprinkler control system;

a remote processor disposed in communication with the at least one remote conductor for selectively supplying power to one or more of the conductors through the at least one remote conductor independent of the processor means of the automatic sprinkler control system;

a power supply for supplying power to the remote processor and remote conductor line independent of the automatic sprinkler control system; and

remote control means in communication with the remote processor for controlling the remote processor to selectively apply power to at least one of the at least one remote conductor lines.

13. A remote control system for remotely operating an automatic sprinkler control system having a processor means, a plurality of valves and a plurality of conductors operationally connecting the processor means and the valves, the remote control system comprising:

at least one remote conductor line disposable in communication with at least one conductor of the automatic sprinkler control system;

a remote processor disposed in communication with the at least one remote conductor for selectively supplying power to one or more of the conductors through the at least one remote conductor independent of the processor means of the automatic sprinkler control system; and

remote control means in communication with the remote processor for controlling the remote processor to selectively apply power to at least one of the at least one remote conductor lines.

14. The remote control system according to claim **13**, wherein the automatic sprinkler system operates on 120 vac and wherein the remote control system operates on 120 vac.

15. The remote control system according to claim **13**, wherein the at least one remote conductor line comprises a plurality of remote conductor lines, each of said remote conductor lines being disposable in electrical communication with a conductor of the automatic sprinkler control system.

16. The remote control system of claim **15**, wherein the automatic sprinkler control system comprises a plurality of screws for anchoring the conductor lines of the automatic sprinkler control system, and wherein the plurality of remote conductor lines each comprise attachment means for attachment to the screws.

17. The remote control system of claim **13**, further comprising a transmitter disposed in the remote control means and a receiver disposed in communication with the remote processor.

18. The remote control system of claim **13**, wherein the at least one remote conductor line comprises a plurality of conductor lines, and wherein the remote control means comprises data input means for selectively actuating the remote processor to provide power to a selected one of the remote conductor lines.

19. The remote control system of claim **18**, wherein the data entry means comprises at least one touch key.

20. The remote control system of claim **19**, wherein the data entry means comprises a plurality of touch keys, each key being configured to actuate the remote processor to provide power to a different remote conductor line.

21. The remote control processor of claim **13**, wherein the remote processor is configured to provide sufficient power through the at least one remote conductor line and the conductor line of the automatic sprinkler control system to independently actuate a valve attached to a conductor line of the automatic sprinkler control system.

22. The remote control processor of claim **13**, wherein the remote control means comprises a housing, and means for wireless communication between the housing and the remote processor when the remote processor is disposed in a remote location from the housing.

* * * * *

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(12) **United States Patent**
Conkright et al.

(10) **Patent No.: US 6,236,332 B1**
(45) **Date of Patent: *May 22, 2001**

(54) **CONTROL AND MONITORING SYSTEM**

(75) Inventors: **Gary W. Conkright**, Naperville; **Robert M. Beckman**, West Chicago, both of IL (US); **Todd Clark**, Valpraiso, IN (US)

(73) Assignee: **Profile Systems, LLC**, Merrillville, IN (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/955,808**

(22) Filed: **Oct. 22, 1997**

(51) **Int. Cl.**[7] **G05B 23/02**; G08C 19/16; G08C 17/00

(52) **U.S. Cl.** **340/825.06**; 340/825.06; 340/825.08; 340/825.17; 340/870.01; 340/870.28

(58) **Field of Search** 340/825.06, 825.08, 340/825.17, 825.22, 825.54, 825.69, 825.72, 870.01, 870.12, 870.13, 870.28; 364/328.11; 379/102.01, 102.05, 106.03

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Primary Examiner—Michael Horabik
Assistant Examiner—M. Phan
(74) *Attorney, Agent, or Firm*—Cook, Alex, McFarron, Manzo, Cummings & Mehler Ltd.

(57) **ABSTRACT**

A two-way wireless communications system for permitting the control, monitoring and collection of data from electrical apparatus includes a host computer, control and monitoring units remotely located from the host computer, and subscriber software for establishing communication protocol with each unit. The host computer includes a customer interface gateway which handles communications from the subscriber software to the host system, a wireless service gateway which handles all communications with the remotely located units, and a product data processor for processing data obtained from either a customer via the subscriber software or a particular remote unit. The subscriber software permits customers to have desktop control of their electrical apparatus associated with a remote unit. Each remote unit contains a motherhood, power supply, and modem. Each unit is capable of real-time monitoring and control of the electrical apparatus associated with the unit.

16 Claims, 7 Drawing Sheets

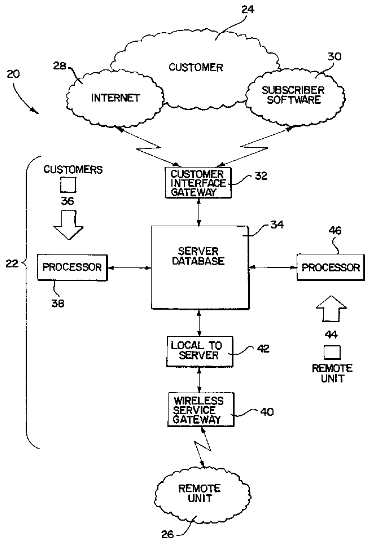
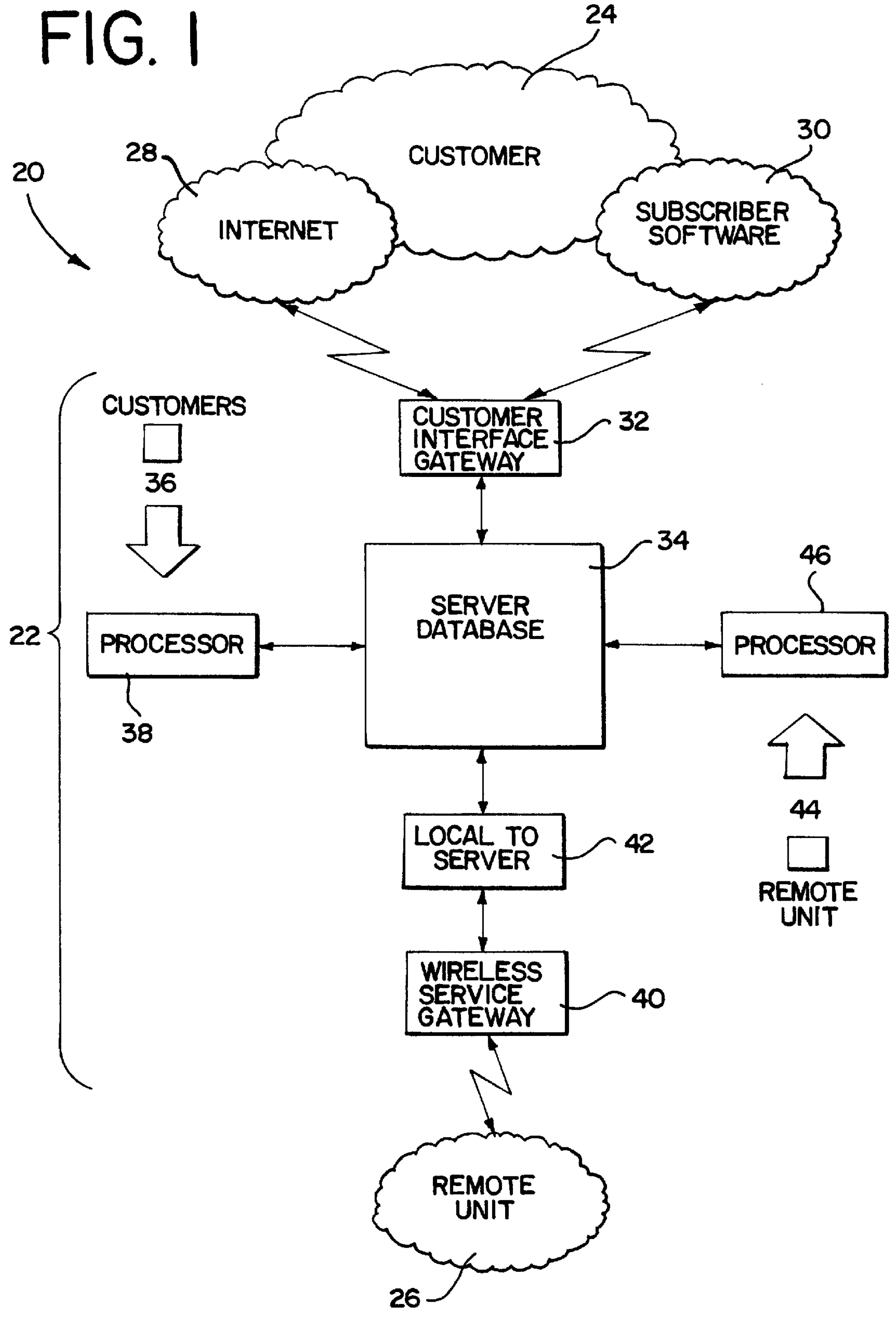


FIG. 1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SUBSCRIBER SOFTWARE
CUSTOMERS
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CUSTOMER INTERFACE GATEWAY
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22
PROCESSOR
SERVER DATABASE
PROCESSOR
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LOCAL TO SERVER
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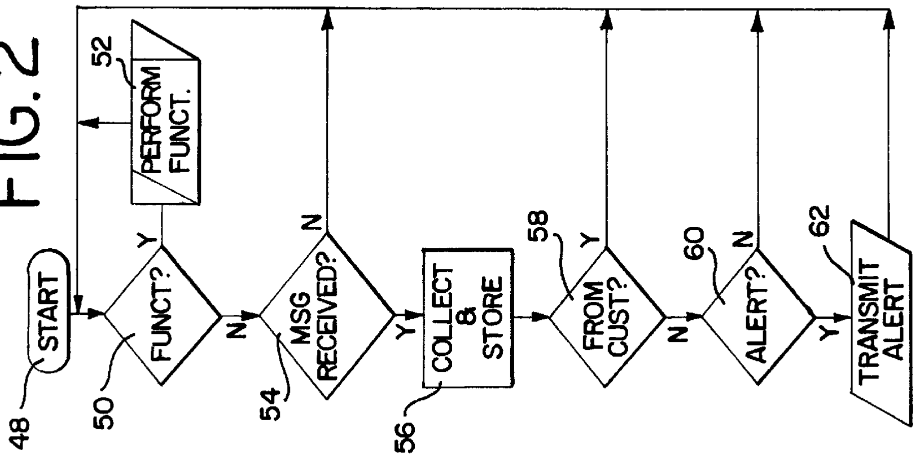
REMOTE UNIT
WIRELESS SERVICE GATEWAY
40
REMOTE UNIT
26

FIG. 2


START
FUNCT?
PERFORM FUNCT.
MSG RECEIVED?
COLLECT & STORE
FROM CUST?
ALERT?
TRANSMIT ALERT
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50
52
54
56
58
60
62

FIG. 3

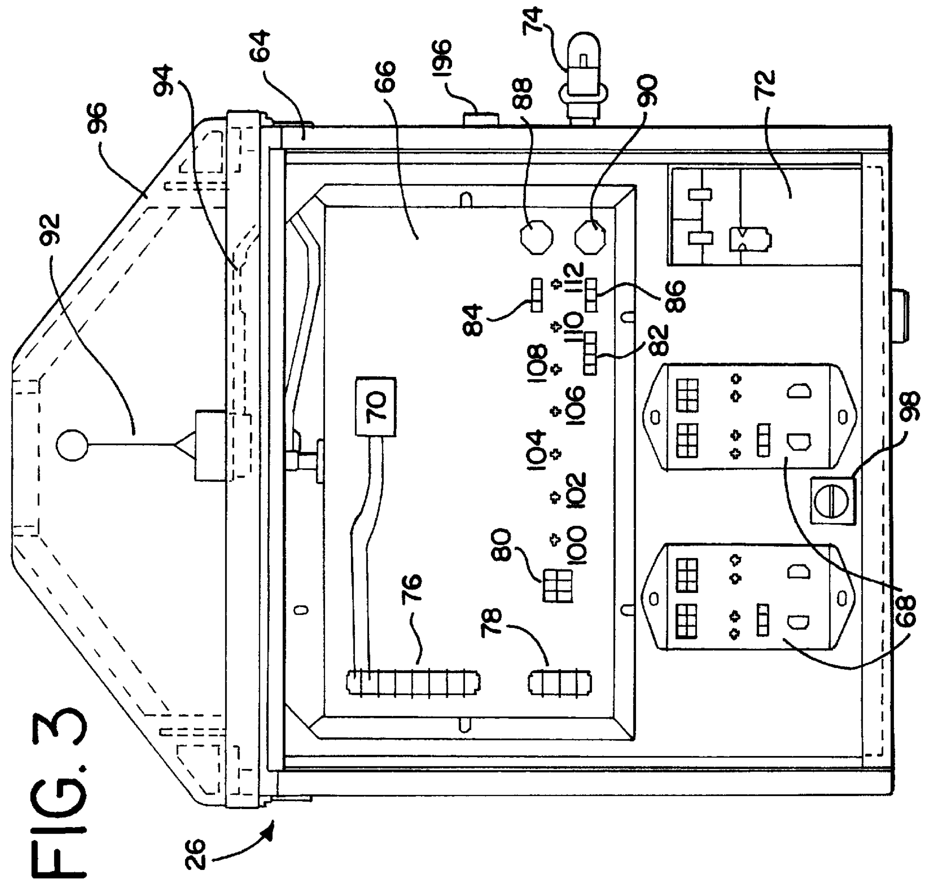
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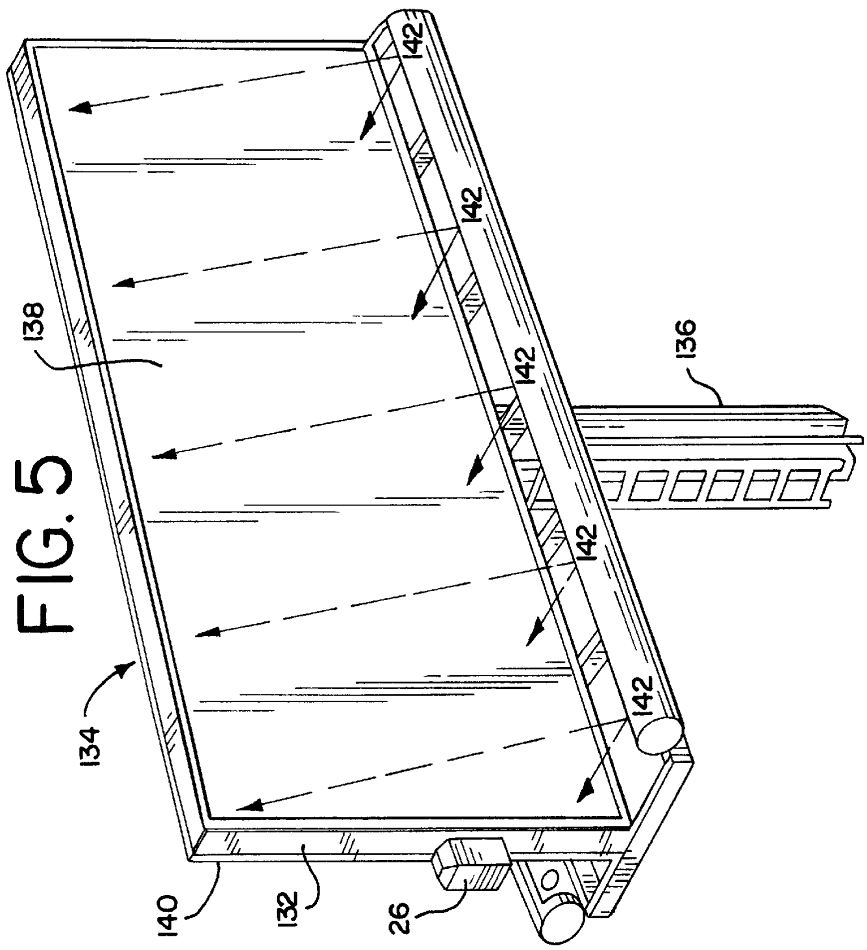
FIG. 5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142
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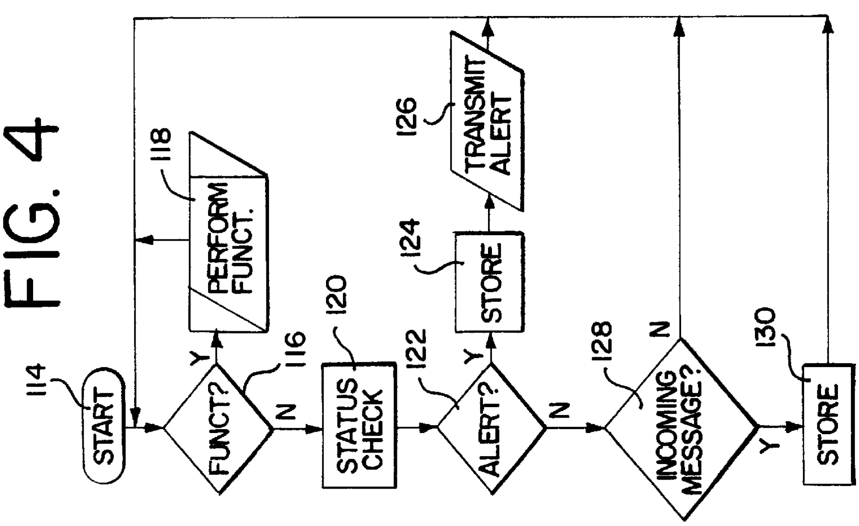
142

FIG. 4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STATUS CHECK
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STORE
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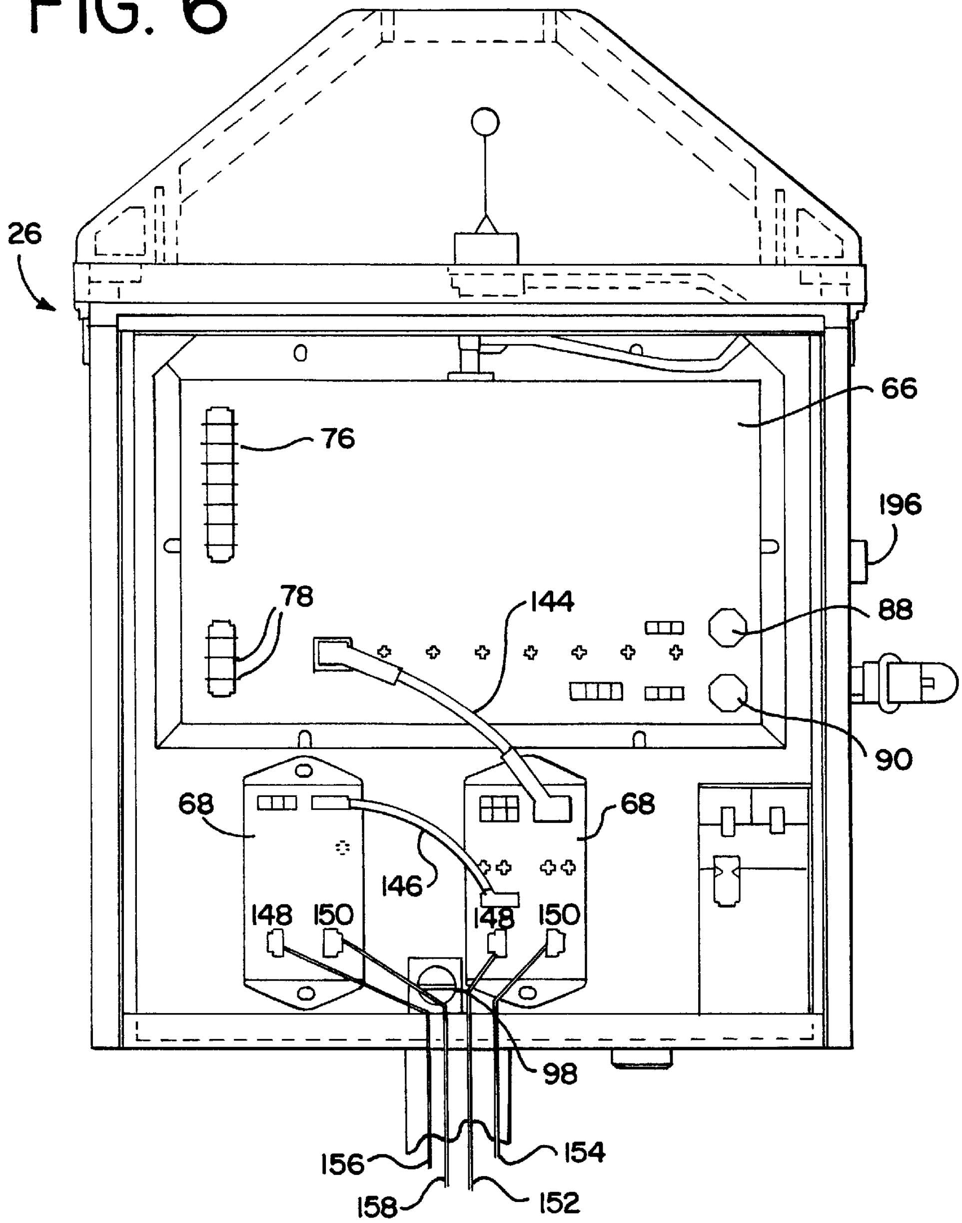
TRANSMIT ALERT
128
INCOMING MESSAGE?
Y
N
130
STORE

FIG. 6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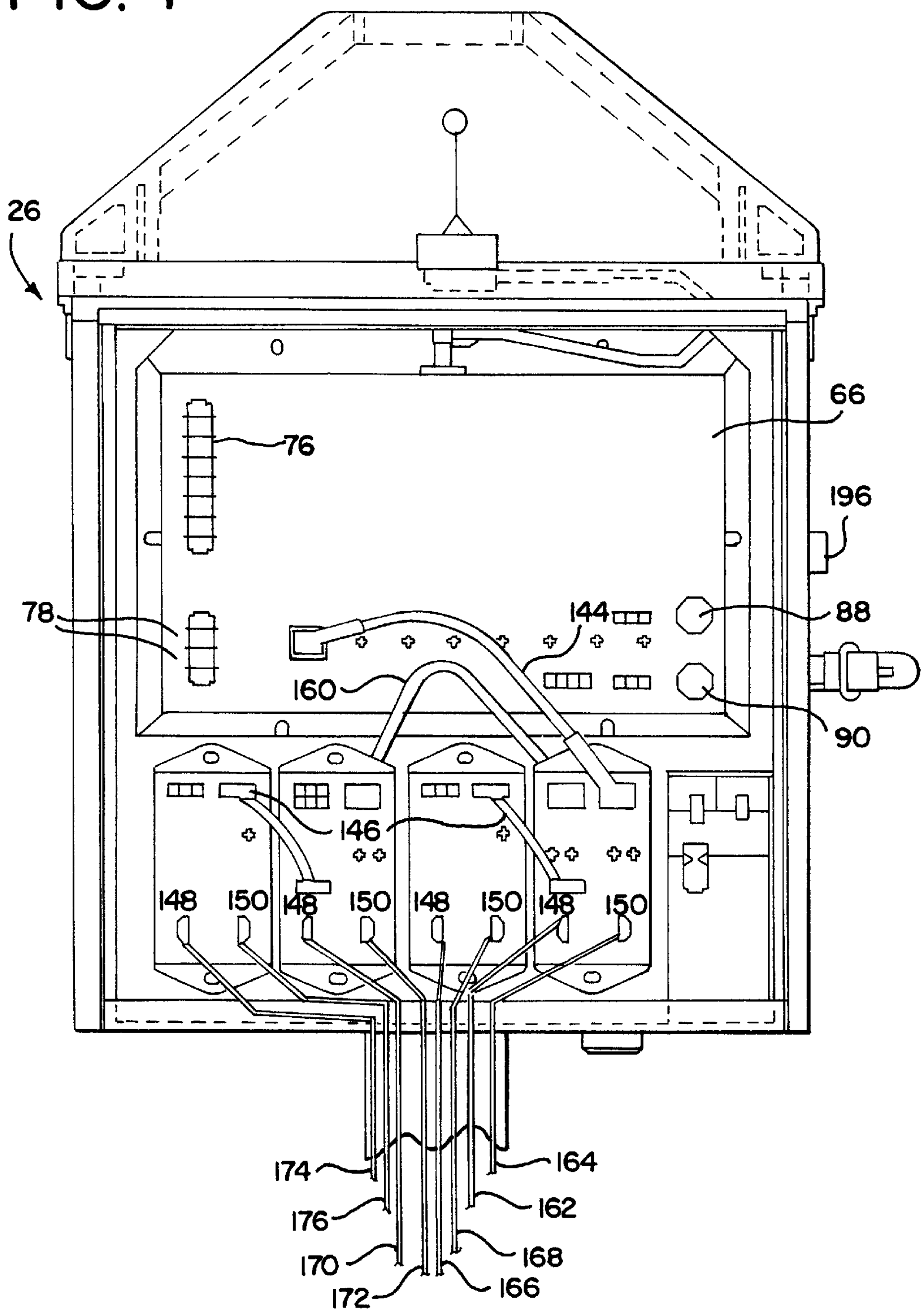
158
152

FIG. 7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172
166

FIG. 8

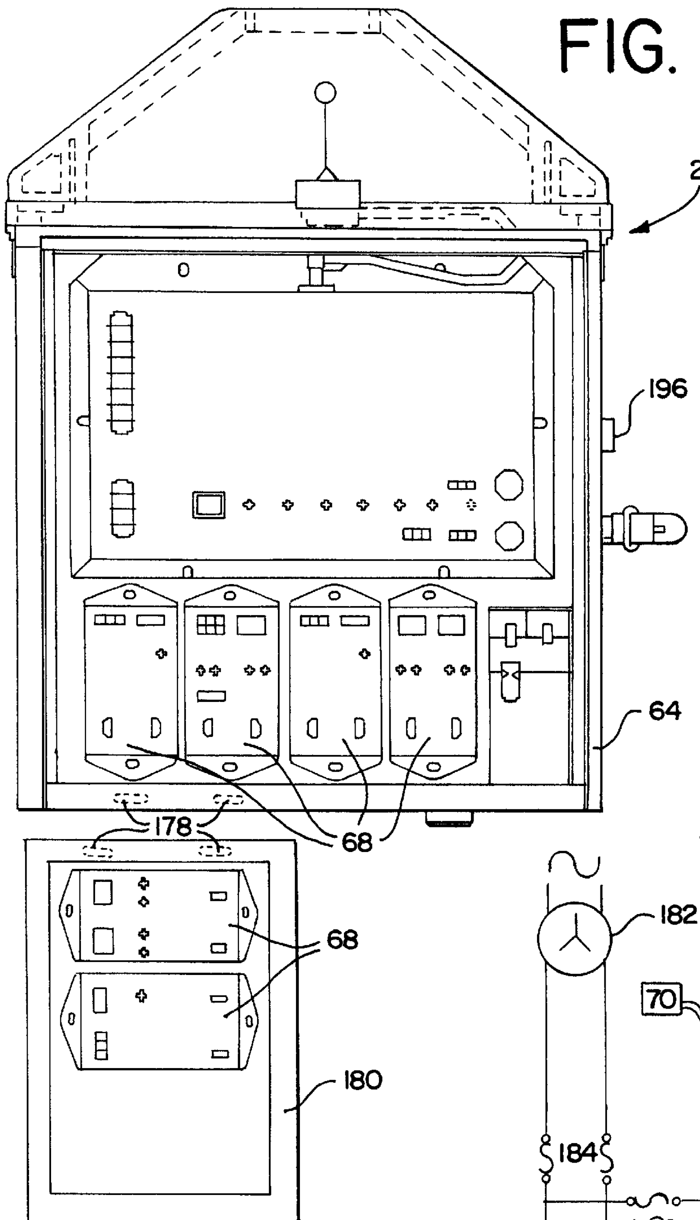


FIG. 9

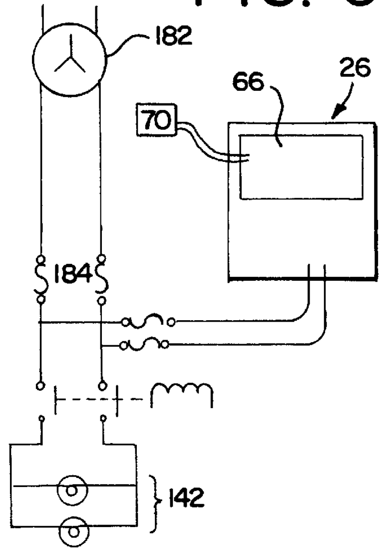


FIG. 10

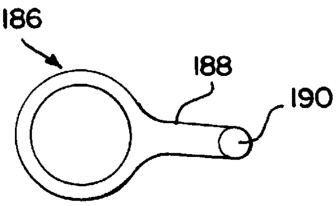


FIG. 11

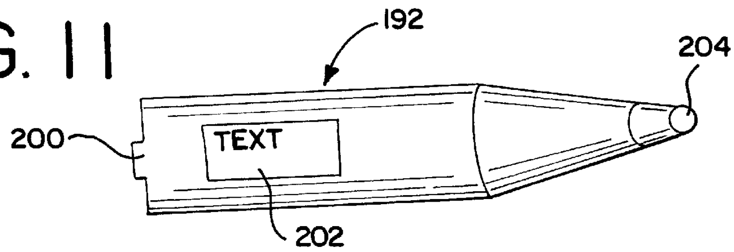


FIG. 12

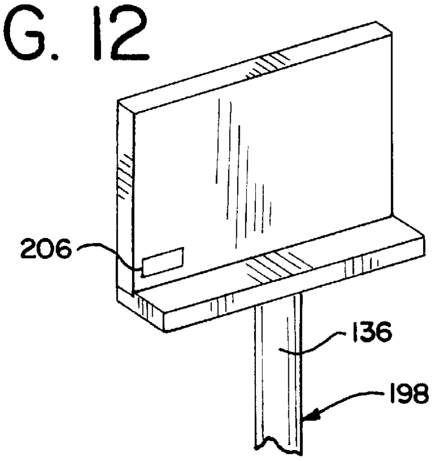
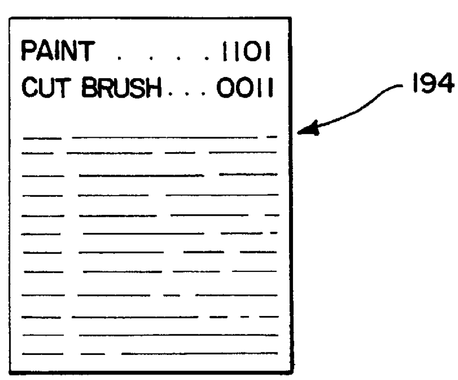


FIG. 13



CONTROL AND MONITORING SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates generally to a system for controlling and monitoring electrical apparatus and, more particularly, to a system which utilizes two-way wireless communications to control, monitor and collect data from electrical apparatus.

The present manual methods used for controlling and monitoring electrical apparatus are expensive and time consuming. For example, a person or business having remotely located electrical apparatus typically needs to manually check on such apparatus to determine whether the apparatus is operating properly. This gets particularly expensive when the electrical apparatus is located at geographically diverse positions. Frequently, in such situations, employees are hired to travel between each apparatus site to examine each apparatus and report on the status of the apparatus.

A control and monitoring system capable of not only controlling such diversely located apparatus, but also of monitoring and collecting data from the apparatus, would obviate the need for such field inspections. Also, such a control and monitoring system has the potential of optimizing the efficiency of the network of apparatus and significantly reducing energy consumption. There are many applications which would benefit from the use of such a control and monitoring system, and although the present invention is described in the context of several particular applications, the invention should not be construed as being limited to these applications.

One application for which the present invention could be advantageously used is the monitoring of utility systems. The conventional method of monitoring and collecting electrical energy consumption is to manually read a meter located at a site by sending personnel to that site. The present invention provides for a remote reading of the monthly electrical consumption at a particular site, thereby eliminating the need to manually read the meter at each site. The invention is also capable of discontinuing service to a utility customer when so commanded by the utility company.

Another application for the present invention is monitoring traffic through a so-called automobile drive-through line of a fast food type restaurant. In particular, certain data such as the time spent by each customer waiting for his/her order, could obtained at a central monitoring facility.

Another potential application for the present invention is the monitoring of the quality of gasoline at fuel stations. Again, the conventional method has been to send personnel to each station to test each gasoline holding tank. The present invention provides for quality, and quantity testing of a holding tank from a remote location. Again, cost and time are saved.

Another use of the present invention is the monitoring of the remaining capacity of a remotely located trash compactor. From such a reading, the invention is capable of activating and deactivating the compactor, as desired.

Other applications for the present invention include lighting systems, climate control systems, irrigation systems, and traffic control systems. The lighting applications include the control and monitoring of household and business lights, airport runway lights, and signboards, such as those typically utilized for advertising goods and services. These include triface signboards, mechanical signboards, and multiple face signboards, among others.

Accordingly, it is a general object of the present invention to provide a control and monitoring system which establishes two-way wireless communication between a host computer and a control and monitoring unit located at a site remote from the host computer.

It is a more specific object of the present invention to provide a system which establishes two-way wireless communications for controlling and monitoring an electrical apparatus remotely located from a host computer.

It is still another object of the present invention is to provide remote control and monitoring units which are stand-alone units and are independently capable of controlling and monitoring electrical apparatus.

Still another object of the present invention is to provide a system which establishes two-way wireless communications and permits collection of data regarding the operating conditions of electrical apparatus.

These and other objects, features and advantages of the present invention will be clearly understood through a consideration of the following detailed description.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a system for controlling, monitoring, and collecting data from electrical apparatus. The system comprises a host computer having a memory for storing data regarding the operating conditions of the electrical apparatus, a processor for processing such data and input/output ports which allow the host computer to communicate with peripherals and a plurality of controlling and monitoring units remotely located from the host computer. The system further includes the control and monitoring units, each unit being associated with electrical apparatus for controlling, monitoring and collecting data from the same. The control and monitoring units communicate with the host computer over a wireless network while performing those functions.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with the further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. **1** is a simplified functional block diagram of the control and monitoring system of the present invention showing the communication links between the host computer, the customer, and the control and monitoring units;

FIG. **2** is a simplified logic diagram of the operation of the host computer of the control and monitoring system of the present invention;

FIG. **3** is a front elevational view of a remotely located control and monitoring unit used with the control and monitoring system of the present invention;

FIG. **4** is a simplified logic diagram of the operation of the remote unit of the control and monitoring system of the present invention;

FIG. **5** is a perspective view of a dual face signboard showing the remote unit of FIG. **3** positioned to illuminate the sides of the signboard, as desired;

FIG. **6** is a front elevational view of the remote unit of FIG. **3** shown wired to control and monitor a single face signboard;

FIG. **7** is a front elevational view of the remote unit of FIG. **3** shown wired to control and monitor a dual face signboard;

FIG. **8** is a front elevational view of the remote unit shown with an auxiliary relay cabinet used to permit control and monitoring of electrical apparatus comprising a relatively large electrical load;

FIG. **9** is a simplified schematic diagram of the alternating current sensor module preferably used with each remote unit of the present invention;

FIG. **10** refers to a personal identification data button for use in conjunction with the control and monitoring system of the present invention;

FIG. **11** refers to a service wand for use in conjunction with the control and monitoring system of the present invention;

FIG. **12** refers to a load located at a remote unit site for use in conjunction with the control and monitoring system of the present invention;

FIG. **13** refers to a work order for use in conjunction with the control and monitoring system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the Figures, and particularly to FIG. **1**, there is shown a control and monitoring system generally designated by reference numeral **20** which utilizes two-way wireless communications in accordance with the principles of the present invention. FIG. **1** depicts this control and monitoring system **20** and shows the data communication links between a host computer **22**, customers **24**, and each remote unit **26** of the present invention. Each customer **24** is capable of communicating with the host computer **22** through the Internet **28**, subscriber software **30**, or through other communication media including, but not limited to, a direct dial-up phone line, facsimile, paging, e-mail, or even human-to-human contact. The subscriber software **30** is adapted for each application (e.g., monitoring utilities, monitoring traffic flow, monitoring lighting, etc.), and the customers **24** install the software on a personal computer (PC) at their home or office. This gives the customers desktop control of their applications and allows the customers to create a database on their computers for each remote unit within their particular application. Data is preferably transmitted between each customer's computer and the host computer **22** via telephone lines and modems.

A customer interface gateway **32** permits full duplex communication between the customer and host computer **22**. When data is sent from the customer to the host computer, the data is stored in a server database **34**. Inbound messages **36** from customers may also be routed through a customer interface gateway product data processor **38**. This processor **38** processes data received from a customer **24** and periodically scans the data for commands from the subscriber software **30**.

Each remote unit **26** communicates with the host computer **22** via the wireless service gateway **40**. This gateway **40** permits communication with the local server database gateway **42**. Inbound messages **44** received from the remote unit **26** may also be transmitted through a wireless service gateway product data processor **46** to host computer **22**. This processor **46** processes data received from the remote unit **26** and periodically scans the data for inbound messages from the remote unit for processing. Auxiliary components of the host system **22** then relay data to the appropriate end receivers,.and provide for a notification routine which may be, for example, conducted through e-mail, facsimile, or paging networks.

The host computer **22** is on line, runs continuously, and includes auxiliary power units for back up power supply. Computer **22** activates and deactivates the customer applications and stores "Alert" notification signals, as necessary. Computer **22** also sends commands to each remote unit **26**. Computer **22** further communicates with the remote units **26** regularly, and can poll them to inquire if any "Alert" signals have been generated, or if any other performance problems are present within the system. Computer **22** also scans and processes new commands and communicates with the remote units **26** through a wireless paging network, for example.

When a paging network is used for these purposes, the commands are preferably sent in a protocol consisting of serially transmitted frames. Two different protocol may be used for sending and receiving information, each having two layers. One layer is application independent and defines the type of interaction between each remote unit **26** and computer **22** at the application level. The second layer of protocol is application dependent and defines additional information. The protocol is structured so that many types of information can be sent in the same packet of data. Each frame contains different information such as customer identification bits, product identification bits, remote unit **26** identification bits, electrical apparatus identification bits, etc.

Referring now to FIG. **2**, the operation of computer **22** is shown in logic diagram form. The operation of the computer begins at terminal block **48**. The computer then determines, at block **50**, whether it needs to perform a particular function. The function to be performed can be, for example, transmitting a command signal to a remotely located control and monitoring unit **26** (see FIG. **1**), thereby commanding that remote unit to activate or deactivate its associated electrical apparatus. While making this determination at block **50**, computer **22** is in its so-called comparison mode.

If computer **22** needs to perform a function, it does so at block **52** and then reenters its comparison mode. If not, computer **22** determines, at decision block **54**, whether it has received a message from an external source. If not, the computer reenters its comparison mode. If so, the computer receives the message, processes it and stores it in its memory unit at block **56** so that the data can be accessed at a future time.

Thereafter, computer **22** determines at decision block **58**, whether the message was sent by a customer or from a different source (such as a remote unit **26** or service personnel at a job site). If the received message was sent by a customer, no alert notification subroutine need be performed and the computer reenters its comparison mode. However, if the received message was not sent by a customer, the computer determines, at decision block **60**, whether it needs to perform an alert notification subroutine. If the computer needs to perform an alert notification subroutine, it does so at block **62** and then returns to its comparison mode. If not, the computer returns immediately to its comparison mode.

A remote unit **26** of the type preferably used with the system of the present invention is shown in FIG. **3**. As shown, the unit **26** is self-contained and includes a housing **64**. A control or logic box **66**, two relay/sensor modules **68**, AC line sensors **70**, and a back up power supply in the form of a battery **72** are all preferably included within housing **64**. Although not shown in FIG. **3**, a cover or door is preferably included as a portion of housing **64**. This cover is secured by an assembly or latch **74** when it is closed and the latch includes a locking mechanism of a type well known in the art. As will be apparent, the cover or door assembly protects the components of remote unit **26** from the outside environment.

The control or logic box **66** contains a processor board, a power supply, and a two-way radio/modem. An AC sensor terminal strip **76** and AC power feed terminal strip **78** are also preferably included within control box **66**. As shown, the top portion of housing **64** contains a relay/sensor module port **80**, a battery port **82**, a port **84** for a push button, and a service switch port **86**. There are also two push button switches **88**, **90**. Switch **88** is labeled CAL and permits calibration of the system; switch **90** is labeled SVC and permits service of the electrical apparatus associated with unit **26**.

An antenna **92** is preferably mounted on housing **64** in a manner well known in the art. Antenna **92** permits control box **66** to transmit and receive electromagnetic signals, as desired. Antenna **92** is electrically connected to the processor board of control box **66** by a transmission line shown in the form of coaxial cable **94**. Antenna **92** is protected from the outside environment by a plastic shroud **96**. A ground bolt **98** is also provided within housing **64** to enable the remote unit **26** to be properly grounded.

Included as part of the circuitry within logic box **66** are seven verification light-emitting diodes (LEDS) **100**–**112**. LED **100** comprises a transmit indicator and is normally off. When it flashes, LED **100** indicates that the remote unit **26** is receiving or transmitting data across the wireless network. LEDS **102**, **104** indicate the status of first and second alternating current power lines, respectively, during use of the AC line sensors **70**. Each LED **102**, **104** is illuminated while AC power is present on its respective line, and it will turn off during a power failure condition. LED **106** comprises a calibrate LED and illuminates whenever service personnel depress push-button calibration switch **88**. LED **108** comprises a network contact LED switch and will illuminate throughout the interval of time when there is sufficient radio contact with the wireless network. LED **110** comprises a battery test indicator and will illuminate at all times except during the time interval that the unit **26** performs a battery test. While the unit **26** performs a battery test, LED **106** will flash. LED **112** comprises a power indicator and remains illuminated while AC power is applied to unit **26**.

Referring now to FIG. **4**, there is shown the operation of a control and monitoring unit **26** in logic diagram form. The operation of the remote unit **26** begins at block **114**. The remote unit first determines, at decision block **116**, whether it needs to perform one of its many available functions. At this point, remote unit **26** is in its comparison mode. If the remote unit needs to perform a function, it does so at block **118** and then reenters its comparison mode.

It not, remote unit **26** performs an internal status check at block **120** to determine both its own operating condition and that of its associated electrical apparatus. Thereafter, the remote unit determines, at decision block **122**, whether it has detected an alert condition based on the status check performed at block **120**.

If so, remote unit **26** stores the alert signal data in its internal memory at block **124** and then transmits an alert notification signal to the host computer **22** at block **126** before reentering its comparison mode.

If no alert condition is detected, the remote unit determines, at block **128**, if it has received an incoming message. If so, it collects and stores the message in its internal memory at block **130** before reentering its comparison mode. If not, it simply reenters its comparison mode.

As previously discussed, the remote unit **26** of the present invention can be used in a number of applications and may control, monitor and collect data from a number of associated electrical apparatus. The preferred control and monitoring system has been generally described above and it should be apparent that the system may be used in a wide variety of controlling and monitoring applications. Nevertheless, in the following description, the system will be described as being used to control, monitor and collect data from remotely located lights, in particular signboard lights. It will be understood that the following description is for illustrative purposes only and while it does embody the principles of the present invention, this invention is in no way limited to a single application.

Referring now to FIG. **5**, there is shown the control and monitoring system **20** in an embodiment adapted to control, monitor and collect data from signboard light sources. The remote unit **26** is shown mounted to the side **132** of a signboard **134**. The illustrated signboard **134** includes a pole **136**, a first or front face **138**, and a second or back face **140**. Faces **138**, **140** are each illuminated by five light sources **142**. Each light source **142** illuminates a proportional share of its respective face.

The logic box **66** of the remote unit **26** is programmed to accurately keep track of Greenwich Mean Time on its internal clock while it also automatically calculates and makes the required adjustments for daylight Savings Time and the Diurnal Cycle (dusk/dawn). This is accomplished in part because the unit knows its location, namely, its latitude and longitude coordinates, and has those locations stored in its internal memory. Because the unit **26** knows the exact time based on its location, the customer **24** can program and thereby control and monitor the electrical apparatus associated with the unit. For instance, the customer **24** can command unit **26** to activate its associated electrical apparatus at a first desired time and later deactivate it at a second desired time. The first and second desired times may be based on standard clock time (e.g. 6:54 a.m. EST—on; 8:23 p.m. EST—off, for example), the diurnal cycle, or any combination of the two.

Referring now to FIG. **6**, the remote unit **26** is shown as being wired to control and monitor a single face signboard. In this case, two relay/sensor modules **68** are used. A communication cable **144** connects the logic box **66** to the first relay/sensor module and an auxiliary cable **146** connects the first relay/sensor module to the second relay/sensor module, as shown. As shown, each relay/sensor module **68** includes a line receptacle **148** and a load receptacle **150** to receive electrical lines and thereby establish electrical connection with an associated AC power line and the associated electrical apparatus (e.g., signboard light source **142**), respectively. For a single face signboard set-up, the line receptacle **148** of the first relay is connected with an electrical line **152** and circuit breaker (not shown) of the second AC power line. The load receptacle **150** of the first relay is connected by an electrical line **154** to the electrical apparatus (not shown) associated with the first relay. Similarly, the line receptacle **158** of the second relay is connected by an electrical line **148** and a circuit breaker (not shown) for the first AC power line. The load receptacle **150** of the second relay is connected with an electrical line **158** and the electrical apparatus (not shown) associated with the second relay.

If the remote unit **26** is used to control a dual face signboard, the wiring diagram shown in FIG. **7** will preferably be used. As shown, the wiring arrangement for a dual face signboard is somewhat similar to the arrangement for a single face signboard. A communication cable **144** connects the logic box **66** to a first relay, and auxiliary cables **146** connect the first and second relays for each face. The difference lies in the use of a separation cable **160** which connects the first relay of the first face of the signboard to the first relay of the second face of the signboard. As is described in further detail, the separation cable **160** permits designation of relay sets for each face of a signboard. This is particularly advantageous during system set-up and operation.

In the dual face signboard arrangement, the line receptacle **148** of the first relay is connected with an electrical line **162** and a circuit breaker (not shown) for the first AC power line. The load receptacle **150** of the first relay is connected with an electrical line **164** for the electrical apparatus (not shown) associated with the first relay. The line receptacle **148** of the second relay is connected with an electrical line **166** and a circuit breaker (not shown) for the second AC power line. The load receptacle **150** of the second relay is connected with an electrical line **168** for the electrical apparatus (not shown) associated with the second relay. The line receptacle **148** of the third relay is connected with an electrical line **170** for a circuit breaker (not shown) for the second AC power line. The load receptacle **150** of the third relay is connected with an electrical line **172** for the electrical apparatus (not shown) associated with the third relay. The line receptacle **148** of the fourth relay is connected with an electrical line **174** for a circuit breaker (not shown) for the first AC power line. The load receptacle **150** of the fourth relay is connected with an electrical line **176** for the electrical apparatus (not shown) associated with the fourth relay.

More than four relays **68** may be required for some applications. In signboard applications, each face of the signboard typically requires two relays, depending on the electrical load of the light sources, so in multi-face signboard applications with signboards having three or more faces, an expansion cabinet may be needed to house additional relays. FIG. **8** shows an embodiment of the present invention implementing a relay expansion cabinet. The housing **64** of the remote unit **26** preferably includes a number of conduit punch-out portions **178** which enable conduit to connect the housing with an expansion cabinet **180**. The expansion cabinet **180** is also equipped with conduit punch-out portions **178** to permit this connection. The wiring scheme for the relays **68** contained in the expansion cabinet **180** is identical to the connections previously described to provide a robust system.

Additional novel features of the present invention will now be discussed as they pertain to the use of the system in a signboard application. Again, it will be understood that such features are not intended to be limited to only a signboard application, but they may be used in other applications as well.

During set-up of the remote unit **26** at an established signboard site, the system **20** will automatically determine the number of signboard faces that the remote unit is to control and monitor. To achieve this feature, the host computer **22** polls each of the relays **68** associated with a particular remote unit **26**. During the preferred polling scheme, the host computer **22** polls each remote unit **26**. The first relay of the polled remote unit **26** responds to the poll by initiating an answer back routine. Upon receipt of an answer signal, the host computer **22** again polls the remote unit **26**. If additional relays **68** are present, they each respond to their respective polls by initiating answer back routines. Each successively polled relay responds through the previously polled relays and indicates whether it is connected to a previously polled relay through an auxiliary cable **146**, to another relay through a separation cable **160**, directly to the logic box **66** through a communication cable **144**, or any combination of the foregoing. Each successively polled relay **68** will initiate an answer back routine in this fashion. When the last relay **68** answers back, the host computer **22** stores data regarding the number of relays, the number of faces, and number of electrical apparatus controlled and monitored by the remote unit **26** at its site.

After this set-up routine is completed, the system **20** is ready to perform its calibration routine. The calibrate push-button switch **88** included within logic box **66** will activate the electrical apparatus associated with remote unit **26** for a predetermined period of time (approximately twenty minutes for the signboard application) so that the current drain of the connected apparatus (i.e., load) reaches its steady state operating condition. The steady state current drain is then measured and stored for later use during the monitoring of the electrical apparatus.

During monitoring of the operating conditions of its associated electrical apparatus, the remote units **26** periodically measure the current delivered to the apparatus. If the measured current differs from the stored steady state current drain for the apparatus by more than a threshold value, the remote unit **26** detects a failure condition. Alternatively, the host computer may periodically poll each remote unit **26** to command that unit to check for the occurrence of a failure condition of the electrical apparatus associated with the polled unit.

If a failure condition is detected, the level of current delivered to the electrical apparatus is continually monitored and measured throughout a predetermined period of time referred to as a validation period. The level of current may be measured by the remote unit **26** independently or by polling signals received from the host computer **22** commanding the unit **26** to conduct a measurement of that current level. If a failure is detected during each current measurement taken throughout the validation period, an alarm signal is transmitted to the host computer **22**, indicating that there has been at least a partial failure of the electrical apparatus. Measurement of the current then continues until the current level rises so that it is once again within the threshold range of the steady state value of the current drain. At that time, an alarm restore signal is transmitted to the host computer **22**, indicating remedy of the partial failure condition.

If any of the measurements during the validation period indicate that a failure condition is not present, the above-described alarm signal is not sent to the host computer **22** and periodic measurement resumes until the remote unit **26** detects a subsequent failure condition.

The present invention is also capable of distinguishing failure conditions indicating low current or partial failure from those indicating no current or total failure. A complete power failure will also trigger detection of a failure condition. A power failure may occur for any number of reasons, and because of this, each remote unit **26** is equipped with a back up power supply shown as battery **72**. In the case of such a failure, it would be advantageous to know, and the present invention provides for, a determination of whether the failure was due to power line failure or merely a tripped circuit breaker. If the outage is due to a tripped circuit breaker, service personnel can be dispatched to the outage site immediately so that the involuntary deactivation time of the electrical apparatus is kept to a minimum. By having the ability to determine the cause of a total failure condition, the condition may be remedied in a timely manner.

As shown in the Figures, the remote units **26** detect power failures by implementing an AC sensor module **70**. Referring now to FIG. **9**, the AC sensor module **70** is shown in schematic form. The AC sensor module **70** mounts between the meter **182** and a circuit breaker **184**. The logic box **66** sends current to the module **70** and measures the electrical field surrounding it. To obviate any fluctuation in the AC magnetic field, the preferred embodiment of the present invention measures this field six times over a set period of time. If the module **70** detects an electrical field during any of those measurements, then the failure condition was caused by a trip condition of the attached circuit breaker and service personnel may be sent to the site to remedy the failure. Otherwise, the failure condition was caused by a loss of power in the utility line and may involve more complicated problems.

In another feature of the present invention, when the back up power supply battery **72** loses its charge, a signal is sent to the host computer **22** indicating this failure. In this state, the logic unit **66** will typically have only enough power to keep its internal clock running, to maintain the data in its memory and to perform a few of its basic operating functions. Although the battery **72** continues to supply power for the unit, the unit does not respond to pages or communicate with the host computer. Nevertheless, based on the notification signal, service personnel may be dispatched to remedy the problem.

In another feature of the present invention, after a failure of an operating condition has been determined and located by the unit, such as an inoperative bulb in the case of use of the system in a signboard application, a worker or serviceman is sent to the site. Once there, he can press the service button **90**, causing all relays within the unit to close and activate the electrical apparatus for one hour. The serviceman can then determine which apparatus has failed and remedy the problem by opening the circuit breaker, replacing the apparatus, and then closing the breaker.

As another useful feature of the present invention, customers are able to know whether service personnel have performed work they have contracted to perform at the site in a timely manner. Quality control of service performance is often a concern of customers, particularly those in the signboard advertising industry. The present invention contemplates a fail-proof quality control feature. To ensure work is done as contracted for, or service has been completed, the present invention will relay such information back to the host computer **22** in real time. This is accomplished through the use of bar codes as well as data stored on a personal ID touch button and data readers. Typically, a signboard service provider will carry with him a personal ID data button as well as a wand that operates both as a bar code and a button data reader. When the service has been performed in accordance with the contract, the service provider transmits the encoded information on his personal button to the wand by touching the button to the wand. This encoded information is then temporarily stored in the wand. The service provider then touches the wand to a data button located at the work site. Upon doing so, information regarding the location of the work site is transmitted to the memory unit contained within the wand. That location information is encoded in each of the data buttons located at each of the work sites. After completing the job, the service provider then scans the bar code located on the sign with the wand to store the signboard information. Any additional information may also be read by the wand. Finally, the service provider touches the wand to the touch button **196** located on the remote unit **26**. The logic box **66** may then download this information to host computer **22** so that customers may be assured the work was performed according to the contract. All of this information is then sent to the host computer **22**.

This particular feature may be best understood by the use of an example in conjunction with FIGS. **10–13**. Service personnel carry with them a personal identification data button like that shown in FIG. **10** which holds all of their work related data. This information may include their name, ID number, and any other such information. Typically, this data button **186** may be integral with a tab **188** and loop **190** so as to easily attach to a keychain, for example.

When service needs to be performed at an electrical apparatus site, the service personnel are directed to such location and will bring the service wand **192** depicted in FIG. **11** as well as any other needed supplies such as the work order **194** shown in FIG. **13**. Each site will have at least two data buttons, one on the housing **64** of the remote unit **26** (data button **196**), and one at the site of the load (data button **198** on the pole **136** as in FIG. **12**, for example).

Examples for which wand **192** may be used in the signboard application include changing the sign on a particular signboard, cutting the grass around the pole of the signboard, and painting the pole. A serviceman will arrive at the site and touch his personal ID data button **186** to an end **200** of the service wand **192**. This transfers his personal data into the wand, and may be displayed in the text window **202** of the wand. The serviceman then touches the end **200** to data button **198** associated with the pole so as to transfer location data to the wand **192**. After the sign is changed, the tip **204** of the wand **192** reads the bar code **206** on the sign and transfers this data to the wand **192**. The serviceman then paints the pole and cuts the brush, and touches the tip **204** to the appropriate bar code placed on the work order **194** shown in FIG. **13**. This transfer of data need not be performed in this order, but may be performed in any order as long as all of the data eventually is read into wand **192**. Thereafter, the serviceman touches the end **200** of wand **192** to the data button **196** of the remote unit **26**, and all of the data is transferred to the unit. This data may then be transferred to the host computer **22** so that a customer is able to know when, where and by whom a work order was performed.

While particular embodiments of the invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made therein without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A system for controlling, monitoring, and collecting data from devices, comprising;

- a host computer including an internal memory for storing a plurality of protocols for a plurality of applications, said computer having means for selecting one of said protocols corresponding to one of said applications and further including means for sending a text message to remote units associated with each of said devices as determined by said selected protocol, said host computer further including means for receiving a text message;
- a customer interface capable of full-duplex communication with said host computer thereby having the ability to provide control of their applications and further having the ability to receive signals indicative of operational parameters of said devices;
- a remote unit associated with each of said devices for controlling, monitoring, and collecting data including said selected protocol, said unit further having means

for sending a text message to said host computer, said unit further including means for receiving a text message from said computer.

2. A system for the controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said means for sending a text message includes a protocol comprising a first and a second layer, said first layer being application independent and said second layer being application dependent.

3. A system for the controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said means for receiving a text message comprise a protocol having a first and a second layer, said first layer being application independent and said layer being application dependent.

4. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **3** wherein said unit includes a relay.

5. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **3** wherein said unit includes and AC current sensor.

6. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **3** wherein said unit included a stand-by battery.

7. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said unit includes a logic circuit which automatically calculates for changes in the diurnal cycle.

8. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said unit includes an antenna and a cover integral with said housing adapted to shield said antenna.

9. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said host computer polls said logic circuit current, said logic circuit current responds to said host computer and said host computer determines the status of said load for said device.

10. A system for the controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said logic circuit includes a calibration button for determining a maximum stable load current value.

11. A system for the controlling, monitoring, and collecting data from electrical devices as defined in claim **5** wherein said AC current sensor samples an electrical field between a meter and a circuit breaker associated with said device.

12. A system for the controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said logic circuit includes a service button for providing current to as associated load for a predetermined period of time.

13. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **1** wherein said housing includes a data port.

14. A system for controlling, monitoring, and collecting data from electrical devices as defined in claim **13** further including a data wand, said wand being capable of reading a bar code and a data port, said wand further being capable of transferring data to said data port on said housing.

15. A system for controlling, monitoring, and collecting data from devices, comprising;

a host computer including an internal memory for storing a plurality of protocols for a plurality of applications, said computer having means for selecting one of said protocols corresponding to one of said applications and further including means for sending a text message to remote units associated with each of said devices as determined by said selected protocol, said sending means includes a protocol comprising a first and second layer, said first layer being application independent and said second layer being application dependent, said host computer further including means for receiving a text message, said receiving means includes a protocol having a first and a second layer, said first layer being application independent and said second layer being application dependent;

a customer interface capable of full-duplex communication with said host computer thereby having the ability to provide control of their applications and further having the ability to receive signals indicative of operational parameters of said devices;

a remote unit associated with each of said devices for controlling, monitoring, and collecting data including said selected protocol, said unit further having said means for sending a text message to said host computer, said unit further including means for receiving a text message from said computer.

16. A system for the controlling, monitoring, and collecting data from electrical devices, wherein said unit includes a relay, on AC current sensor, and a stand-by battery.

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Abts

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(54) **SYSTEM FOR CONTROLLING AND MONITORING AGRICULTURAL FIELD EQUIPMENT AND METHOD**

(76) Inventor: **Gerald L. Abts**, 567 Steele St., Denver, CO (US) 80206

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 9 days.

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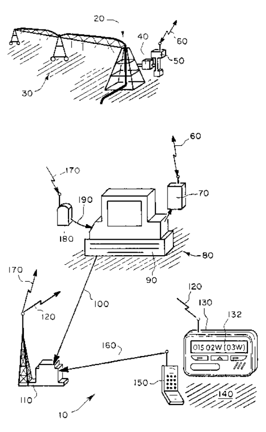
Primary Examiner—William Cumming
(74) *Attorney, Agent, or Firm*—Dorr, Carson, Sloan & Birney, P.C.

(57) **ABSTRACT**

A pager system for monitoring the operation of a plurality of controllers in each one of a plurality of agricultural field equipment in a group. A plurality of sensors are provided at each location of agricultural field equipment wherein a sensor connects through an isolation device to one of the controllers for issuing a status signal corresponding to the present status of the connected controller. Whenever the status of a controller changes, the remote terminal unit immediately transmits the changed status symbol as well as the status of the other sensors to a central control computer. The central control computer analyzes the transmitted status signals for generating a changed status paging message and delivers the changed status paging message, identifying the agricultural field equipment having the changed status, as well as the unchanged status messages from all remaining agricultural field equipment in the group. The paging messages are delivered to a pager held by an operator at a remote location with the changed status paging message marked so that the operator can identify which piece of agricultural field equipment had its status changed.

19 Claims, 7 Drawing Sheets



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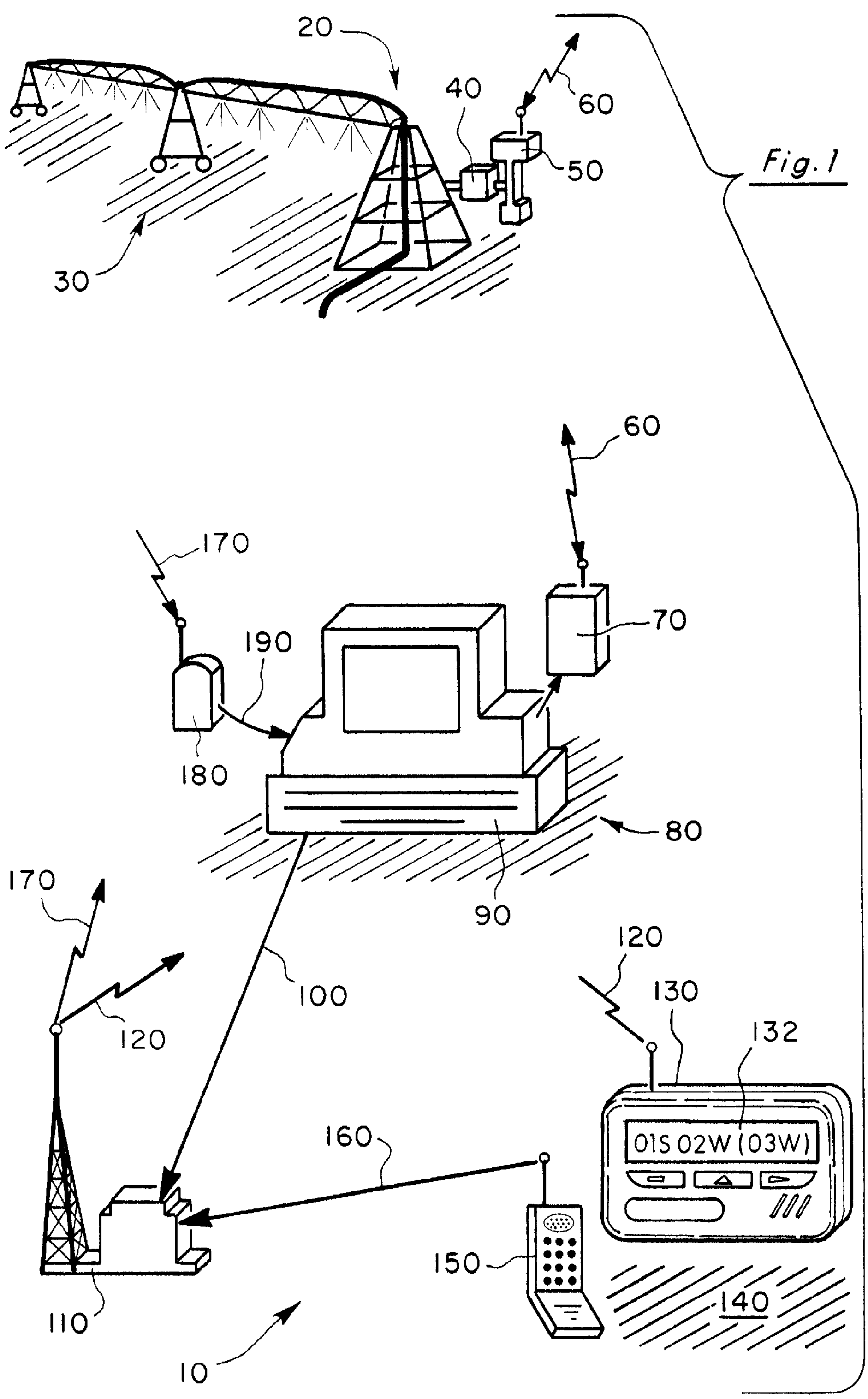

20
40
60
50
30
60
170
70
190
180
80
90
170
120
100
120
130
132
01S 02W (03W)
160
150
140
110
10

Fig. 1

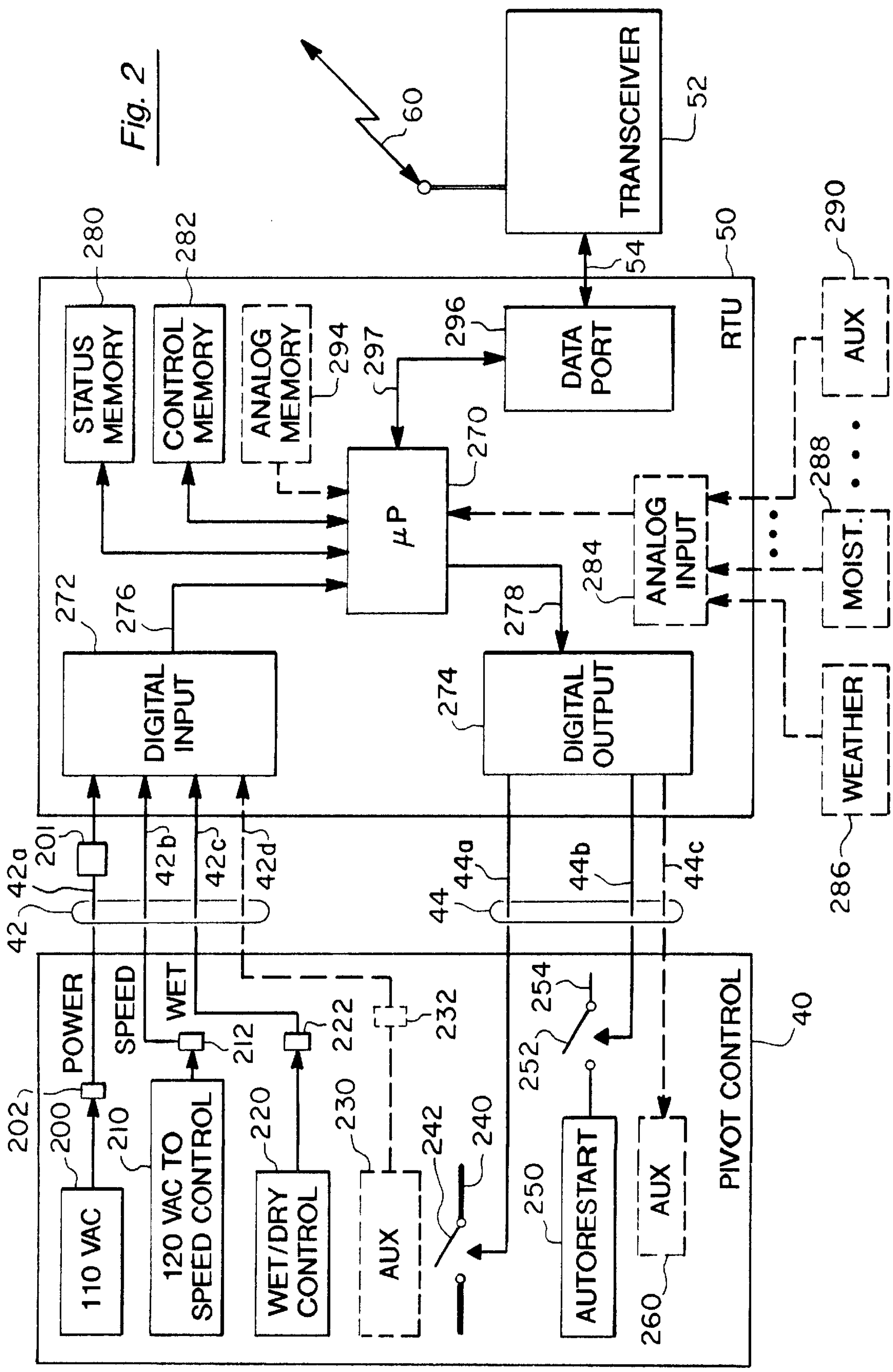

TRANSCEIVER
52
60
54
50
RTU
STATUS MEMORY
280
CONTROL MEMORY
282
ANALOG MEMORY
294
DATA PORT
296
297
μP
270
DIGITAL INPUT
272
276
DIGITAL OUTPUT
274
278
ANALOG INPUT
284
288
AUX
290
MOIST.
WEATHER
286
42
42a
201
42b
42c
42d
44
44a
44b
44c
POWER
SPEED
WET
110 VAC
200
202
120 VAC TO SPEED CONTROL
210
212
WET/DRY CONTROL
220
222
AUX
230
232
242
240
AUTORESTART
250
252
254
AUX
260
PIVOT CONTROL
40

Fig. 2

Fig. 3

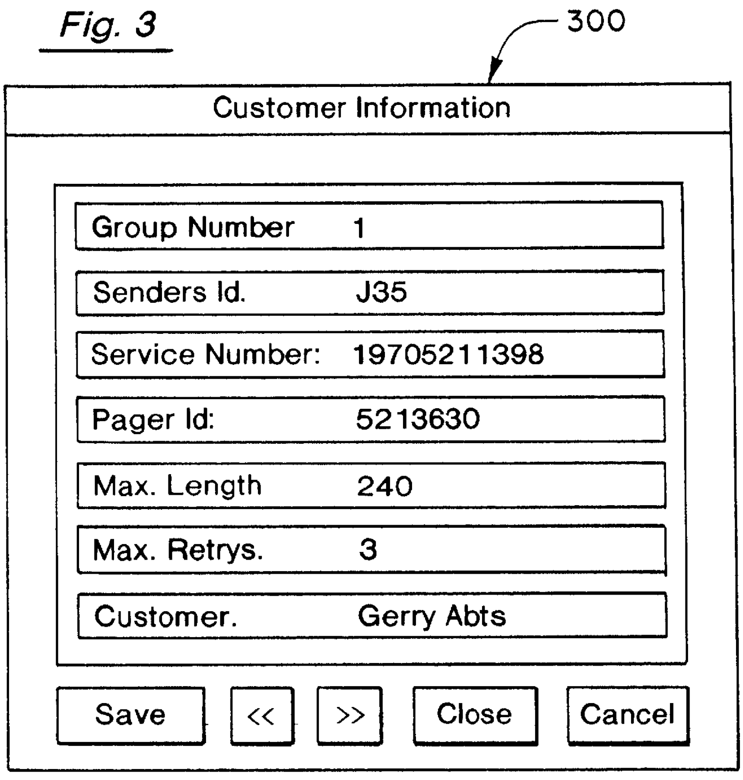

300
Customer Information
Group Number 1
Senders Id. J35
Service Number: 19705211398
Pager Id: 5213630
Max. Length 240
Max. Retrys. 3
Customer. Gerry Abts
Save
<<
>>
Close
Cancel

Fig. 4

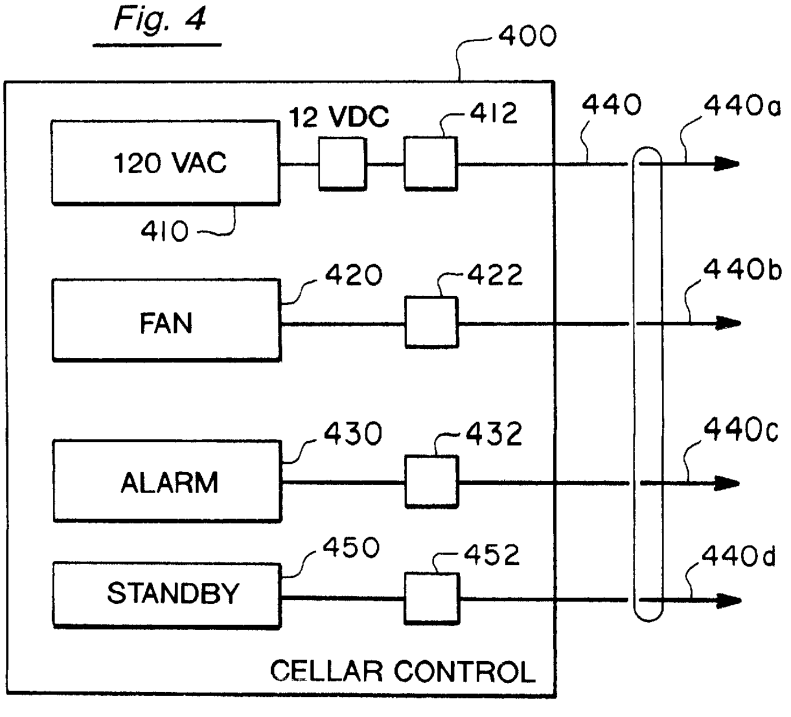
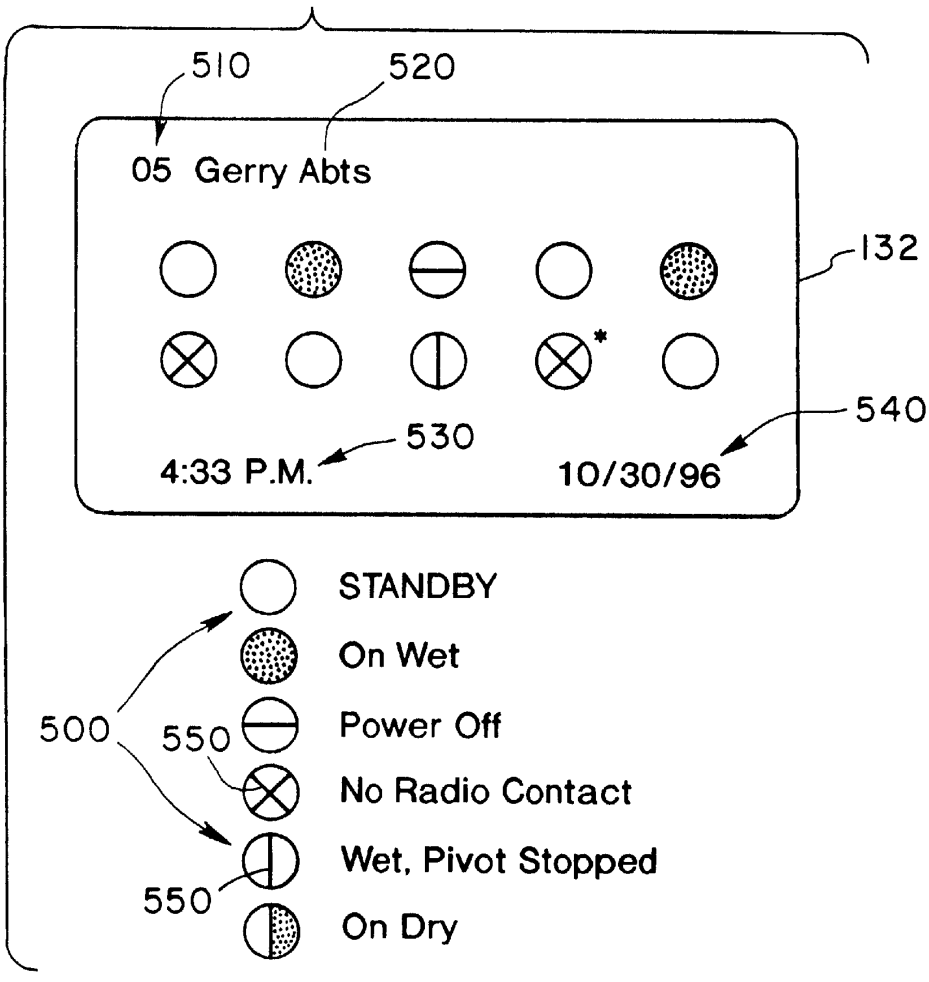

400
120 VAC
12 VDC
412
410
440
440a
FAN
420
422
440b
ALARM
430
432
440c
STANDBY
450
452
440d
CELLAR CONTROL

Fig. 5


510
520
05 Gerry Abts
132
*
530
540
4:33 P.M.
10/30/96
STANDBY
On Wet
Power Off
No Radio Contact
Wet, Pivot Stopped
On Dry
500
550
550

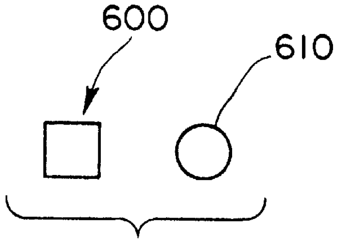

600
610

Fig. 6

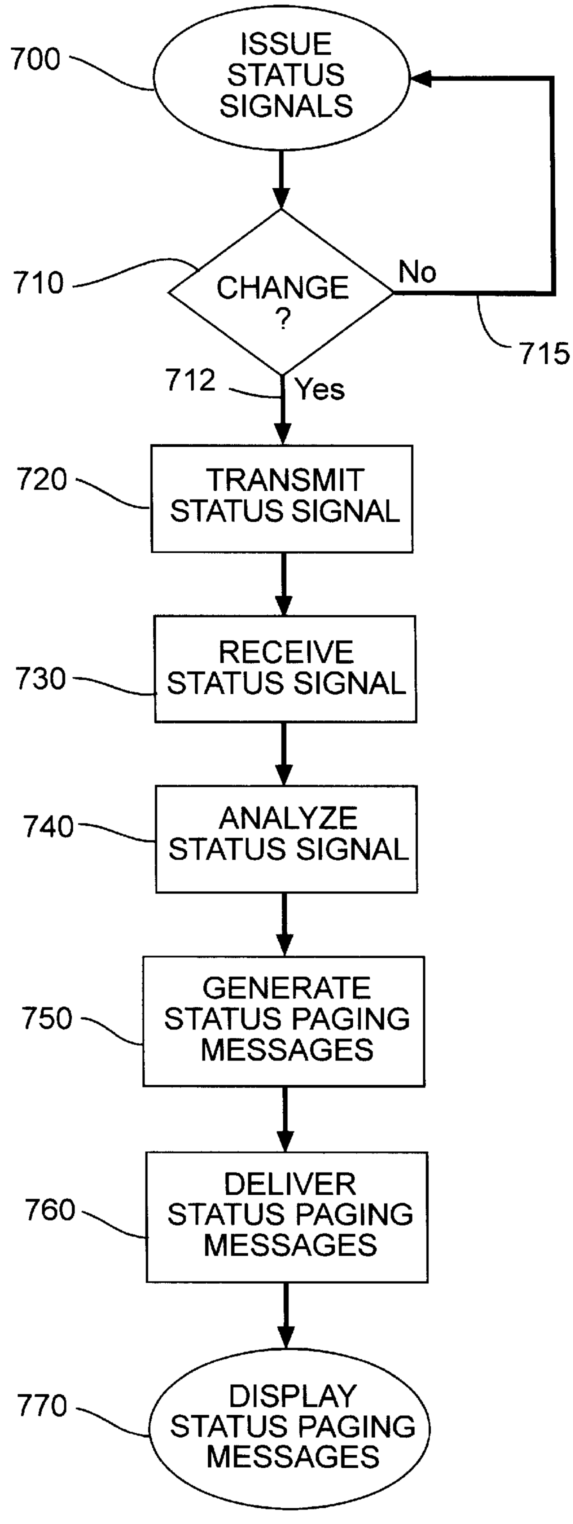

700
ISSUE STATUS SIGNALS
710
CHANGE ?
No
715
712
Yes
720
TRANSMIT STATUS SIGNAL
730
RECEIVE STATUS SIGNAL
740
ANALYZE STATUS SIGNAL
750
GENERATE STATUS PAGING MESSAGES
760
DELIVER STATUS PAGING MESSAGES
770
DISPLAY STATUS PAGING MESSAGES

Fig. 7

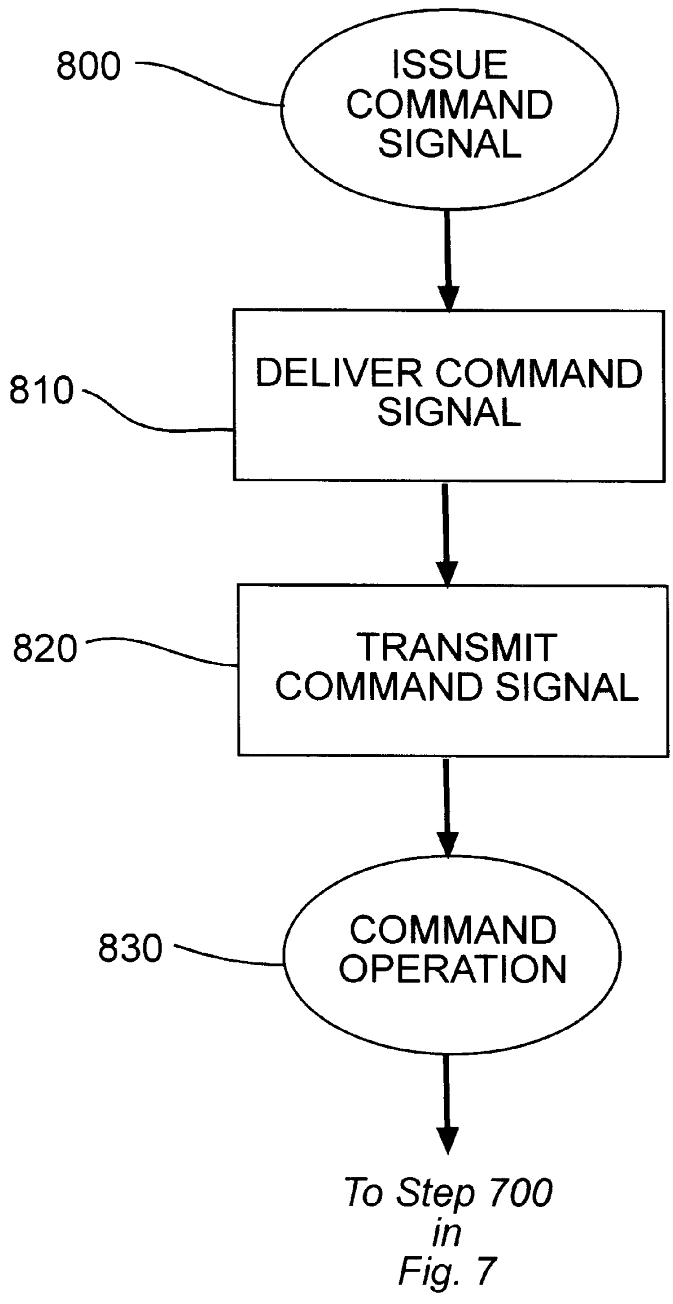

800
ISSUE COMMAND SIGNAL
810
DELIVER COMMAND SIGNAL
820
TRANSMIT COMMAND SIGNAL
830
COMMAND OPERATION
To Step 700 in Fig. 7

Fig. 8

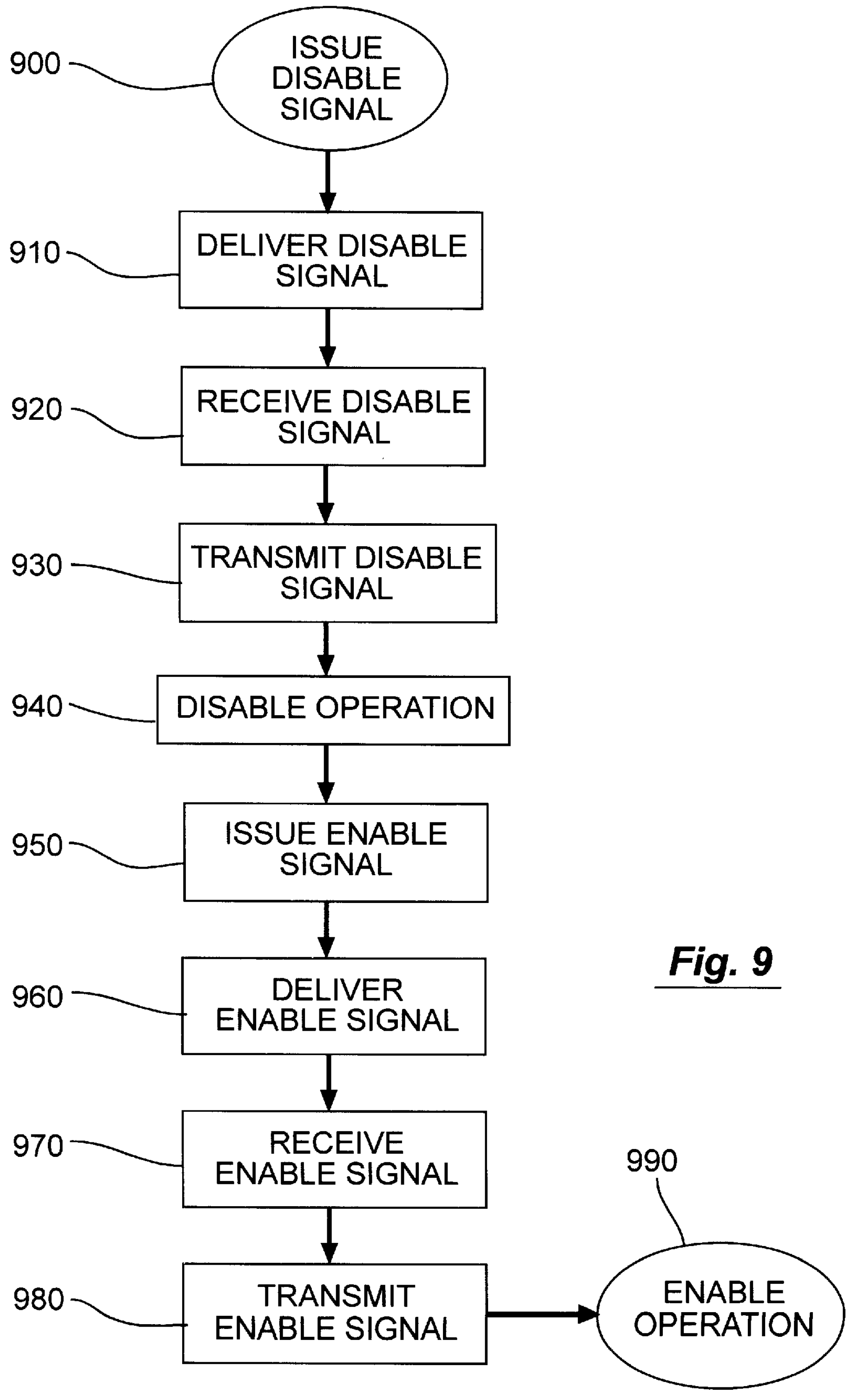

900
ISSUE DISABLE SIGNAL
910
DELIVER DISABLE SIGNAL
920
RECEIVE DISABLE SIGNAL
930
TRANSMIT DISABLE SIGNAL
940
DISABLE OPERATION
950
ISSUE ENABLE SIGNAL
960
DELIVER ENABLE SIGNAL
970
RECEIVE ENABLE SIGNAL
980
TRANSMIT ENABLE SIGNAL
990
ENABLE OPERATION

Fig. 9

SYSTEM FOR CONTROLLING AND MONITORING AGRICULTURAL FIELD EQUIPMENT AND METHOD

RELATED INVENTION

This application claims the benefit of "PivaTrac™ For Controlling and Monitoring Irrigation and Other Field Equipment Using Two-Way Radio Telemetry, Single Computers and Telephone Pagers," Disclosure Document No. 383437 filed Oct. 16, 1995, and claims the benefit of U.S. Provisional Application Ser. No. 60/030,272 filed Nov. 1, 1996.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to systems for controlling and monitoring agricultural field equipment such as irrigation pivots and potato storage cellars.

2. Statement of the Problem

A need exists to provide two-way remote communication between agriculture field equipment such as pivot irrigation systems and a mobile operator such as a farmer in a truck to report the status of the equipment and to provide command control over it. This is especially true when a farmer (or pivot irrigator) manages a large number of pivots (e.g., with a 20-mile radius). Pivot irrigation systems require frequent setup changes in response to weather changes, and since breakdowns are common, to confirm that they are running. While many conventional systems provide a central control computer (or base station) to report on the status of the equipment and to execute command signals, a need exists to immediately provide similar information to a mobile operator (such as a farmer in a truck) remote from the central control computer.

A number of prior patented approaches exist in the pivot irrigation technology. U.S. Pat. No. 4,396,149 (Hirsch) discloses an irrigation control apparatus using soil moisture sensors connected to a radio transmission apparatus located on the upper portion of the irrigation mast for continuously transmitting data concerning the status of soil moisture. A farmer obtains reports from a telephone or radio. The data from the moisture sensors (or a weather station) are delivered to a remote computer such as through radio transmission, which processes the data and in turn communicates it to the farmer.

U.S. Pat. No. 4,899,934 issued to Krisle sets forth a sensor on a pivot irrigation system for monitoring stoppage of the pivots. When stoppage is detected, a radio transmitter at the pivot delivers a signal to a remote receiver or beeper carried by the farmer. When stoppage of the pivot or angular displacement of sections of the pivot occurs, a signal is generated which is delivered to a radio transmitter at the pivot for transmitting a signal to a detached signal receiver or beeper carried by the farmer.

U.S. Pat. No. 4,856,047 issued to Saunders teaches an automated remote telemetry paging system where operators carrying remote pagers are notified of alarms at a specific site location. The operator carrying the pager can take appropriate repair or corrective action to remedy the alarm situation. In the '047 patent, the status of the monitored functions is continuously monitored every 26 microseconds. The input status values are compared against a reference field stored in memory and if a deviation occurs, an alarm is issued to the remote pager identifying the location with the alarm.

U.S. Pat. No. 4,962,522 issued to Marian provides a pager at each pivot to receive command signals from a remote phone to control activities at the pivot. A farmer at a phone in a vehicle calls a paging station and enters an identification code and a message. The message is delivered to the pager at the irrigation site, is decoded, and causes a function to occur at the site (such as to increase watering or to decrease watering).

U.S. Pat. No. 5,255,857 issued to Hunt sets forth use of a master control computer at each pivot, which communicates to a central computer. The central computer monitors the pivot and allows the operator to program the system. The computer at the pivot may be controlled by a radio device such as a VHF transmitter or a cellular telephone system. Hunt provides an operational personal computer-based irrigation network facility so as to provide complete irrigation management. This allows management from any location on the farm or elsewhere. The personal computer displays the current status of all pivots in the network and allows any settings to be changed.

U.S. Pat. No. 4,626,984 issued to Unruh discloses a central computer for monitoring control in a number of pivots. In an alternate embodiment of Unruh, a portable base unit could be separately transported by the farmer to input and monitor each intelligent remote unit. Hence, a farmer can, through a portable base unit, directly control and monitor the intelligent remote control at a pivot or pivots.

U.S. Pat. No. 5,146,216 to DeLuca et al., permits a pager to receive a graphic address command to display on the pager a desired graphic.

A number of prior commercially available systems for managing irrigation pivots are also available. Valmont Industries, Inc. sells a computer-aided management system, which includes a radio telemetry package, located at the irrigation pivot to provide two-way communication via a radio link to a remote central computer. The remote central computer enables the farmer to change all system operations from his office. Up to 100 pivots operate from one remote computer. The remote computer is interrogated by the central computer to obtain status changes for direction, running condition (run/stop), speed, water depth, and whether chemical is being applied. Communication range is a line of sight communication up to 15 miles and provides monitoring and control 24 hours per day. In the case of an alarm, an auto-dialer for the farm's two-way radio can be used to alert remote individuals. Valmont offers the Valley Remote Link which provides 24 hour control via a cellular phone, business band radio, or touch-tone phone. This allows the farmer to direct pivot functions from a remote location.

Lockwood Corporation provides an automated panel located at each pivot to allow the user to have computerized control over a particular pivot. When something goes wrong with a pivot, the Lockwood system will attempt to correct the problem at the remote central control and if unable to correct it, it will call a preprogrammed list of numbers until the farmer is reached.

T-L Irrigation Company provides a computer control for a hydrostatic drive pivot.

Reinke Manufacturing Company provides an automated management system having control panels at each pivot which may communicate with a remote computer control via a radio link.

Lindsey Manufacturing Company provides an automated irrigation management system which provides remote control and monitoring via a telemetry network with corresponding controls at each pivot. Lindsey provides a remote monitor alarm and control system that links the farmer with a pivot over the business band radio or cellular phone. It permits the farmer to poll any pivot and to provide the farmer with an instant report of operating conditions including an automatic trouble alarm. The farmer can start, stop, change direction and perform other control functions from the remote location. This system utilizes a UHF or VHF business band radio. A code is keyed on the microphone tone pad of the business band radio or cell phone. A code is keyed on the microphone tone pad of the business band radio telephone. This is received at the pivot and the pivot will respond with its call letters and unit number. The farmer then keys in the proper code to bring up one of hundreds of voice message combinations to obtain the exact operating status of the pivot system. These are status reports. The remote monitor alarm system will also automatically broadcast alarm messages such as when the pump shuts down prematurely.

Sensing and Control, Inc. also provides a computerized control at each pivot. However, a communications package provides communications to a remote central computer via a spread spectrum radio or telephone modem.

K&S Systems, Inc. provides a control display panel at each pivot and a two-way radio communications system link with a remote computer command system.

Dexter Fortson Associates, Inc. provides a control panel at each pivot. The control panel upon detecting a change in status immediately reports this to a remote base station. The base station computer can be set up to request updates such as every ten minutes from each control panel. The system interfaces with hand-held computer and telephone voice or digital to multi-frequency (DTMF) tone pad interface units to enable the farmer to monitor and control functions from vehicles, tractors, or homes within the radio range or from any touch tone telephone.

A need exists to provide a pager at the central control computer to receive remote commands from a mobile farmer to perform a function at an individual pivot managed by the central control computer. After the remote commands are performed, a need exists to provide feedback verifying the completion of the function to the farmer in the form of status signals displayed in a pager held by the farmer. Finally, a need exists for the farmer to be immediately paged whenever a change in the status of any one pivot occurs and to be updated on the status of all pivots with changes in status clearly marked. The Hirsch, Hunt and Unruh patents and the Valmont, Lockwood, Lindsey, and Dexter systems all teach providing a computer at each pivot in communication with a central computer and a portable unit (phone, radio, or computer) carried by the farmer for communication to the computer at the pivot, or in the case of Dexter, to the central computer. Saunders and Krisle teach providing equipment at the pivot for directly reporting status information to a pager carried by a farmer. Marian teaches sending commands from a phone carried by a farmer to a pager at the remote pivot. However, none of these approaches provide a solution to all of the above three needs.

A need also exists to continuously monitor the status of the AC power being delivered to each pivot, to continuously monitor whether each pivot is dry or wet, to monitor whether a pivot is moving or not, and to monitor the status of fertilizer and chemical injection equipment being operated at a pivot site.

A need further exists to issue a status signal when the central control computer has not communicated with a pivot for a predetermined period of time.

A need also exists to monitor the status of the "AC power interruption device" often used by rural power providers to "load manage" their power distribution systems. Running pivots are "shed" for periods of time in order to reduce power consumption at peak periods. There is a need to alert irrigators to these status changes, particularly to advise when power interruption is curtailed.

A need also exists to permit the farmer at a remote mobile location to control the pivot by "killing" a particular pivot by stopping the pivot from moving and delivering water. For example, when a thunder and lighting storm is nearby a pivot, it is often desirable to stop the operation of the pivot and the need exists for a kill control to remotely stop the pivot from operation.

A need also exists to have the farmer review all paged statuses for all pivots delivered to the pager during a past predetermined number of page transmissions.

A need also exists for the continuous updating of time and date stamped records of each monitored pivot's status to the central computer. These data base records are to facilitate the reporting of text and graphic reports of changes to pivot status over time. Selected summary reports can also be "paged."

In addition to pivot management, there is a similar need to remotely monitor status and control process functions of grain and produce conditioning and storage facilities such as potato cellars. These facilities are often scattered and remote to the central headquarters of a farm operation. Knowing the status of the ventilation, drying, and stirring equipment is critical to establishing and maintaining the optimal environmental conditions for stored crops.

3. Solution to the Problem

The system of the present invention for controlling and monitoring agricultural and storage field equipment provides a solution to all of the above-described needs. The system of the present invention provides a pager at a central control to receive remote commands from any of a plurality of mobile farmers in order to enable a function to occur at an individual pivot monitored by the central control. The performance of the commanded function is detected at the pivot and delivered back to the central control in the form of a status value. The change in status at the commanded pivot is then converted to a status "symbol" and delivered along with the status of all of the other pivots to the respective farmer via a hand-held pager that the farmer can clearly view. The pivot having the change (or the pivots having the changes) are clearly marked so that the farmer can instantly verify, in real time, the change in status as well as the status of all other pivots. Hence, with each page, the status of all pivots is delivered to the farmer at a remote location. Those pivots having a change in status are clearly marked. The farmer can, by viewing his pager, continuously monitor whether each pivot in the group of observed pivots is wet or dry or is moving or not or has lost AC power or has been "load shed" or is receiving chemical or fertilizer injection. Furthermore, the system of the present invention issues a status signal when the central control computer has not communicated with a pivot for a predetermined period of time (such as 45 minutes). The farmer needs to know of a failure in communication link at any pivot.

Furthermore, the system of the present invention enables the farmer at the remote location to control certain functions of the pivot such as "killing" a particular pivot by stopping the pivot from moving and delivering water, such as when a nearby thunderstorm or heavy rainstorm occurs.

Finally, the system provides storage in the pager at the farmer's remote location of a predetermined number of prior pages to enable the farmer to scan through such prior pages to review time tracked changes in status that have occurred in the past. The system provides a complete backup of status information and of all pages delivered and received for each piece of field equipment at the central computer.

SUMMARY OF THE INVENTION

A pager method system for monitoring the operation of a plurality of controllers in each one of a plurality of agricultural field equipment (i.e., a group) is disclosed. The pager method system of the present invention includes a plurality of isolation devices at each location of agricultural field equipment, such isolation relay devices providing optical isolation between the relay and the sensors and between the relay and the electronic circuitry of RTU **50**. A plurality of sensors are provided at each location of agricultural field equipment wherein a sensor connects through an isolation relay device to one of the controllers for issuing a status signal corresponding to the present status of the connected controller. For example, in the case of pivot irrigation equipment, a power sensor could be interconnected through an isolation device such as an optical isolator to wet/dry control switch. The sensor continuously monitors whether or not the wet/dry switch is on or off through the optical isolation relay device.

The sensors of the present invention are interconnected to a remote terminal unit. Whenever the status of a controller changes, the remote terminal unit transmits the changed status symbol as well as the status of the other sensors to a central control computer. The "inputs" to the remote terminal unit include appropriate time delays to prevent the reporting of intermittent or "spike" signals.

The central control computer receives the transmitted status signals from the transmitting remote terminal unit, identifies the field unit and the data with a defined group, and analyzes the status signals for generating at least one changed status paging message for the respective group of equipment. In noisy environments, several redundant messages are sent. The central control computer delivers the changed status paging message, identifying the group and the agricultural field equipment having the changed status, as well as the unchanged status messages from all remaining agricultural field equipment in the respective group. The changed status and the unchanged status paging messages are delivered to a paging terminal for redelivery to a pager (or group of pagers) held by an operator of the defined group of equipment at a remote location. The pager notifies the operator of the page, and the operator views the displayed changed and unchanged status paging message. The pivot(s) with changed status is marked so that the operator can easily identify which piece of agricultural field equipment had its status changed for the current page.

The method of the present invention for monitoring the operation of a number of controllers and for commanding the operation of at least one power circuit in each one of the plurality of agricultural field equipment includes the following steps:

issuing a command signal for an identified agricultural field equipment in an identified group from a phone at a remote location,

delivering the issued commands by way of commercial paging services to a first pager located at a central control computer,

the central control computer transmitting by way of radio telemetry the delivered command signal to the power circuit (or other control points) at the identified agricultural field equipment,

commanding the operation of the power circuit at the identified agricultural field equipment,

issuing status signals corresponding to the changed and unchanged status of the plurality of controllers,

transmitting the issued status signals by radio telemetry to a central control computer whenever one status signal changes such as in response to the commanded operation,

receiving the transmitted status signals at the central control computer,

analyzing the received status signals at the central control computer,

generating a changed status paging message identifying the location and status of the agricultural field equipment having the one status signal change and including the unchanged status of the remaining agricultural field equipment locations in the group,

delivering the paging message to a second pager carried by a remote operator by way of commercial paging services,

displaying said changed and unchanged status paging message in the operator's pager, the changed status paging message being marked when displayed thereby marking the agricultural field equipment issuing the changed status paging message.

The same sequence of system events is carried out when an individual pivot has a change in status of a monitored input (event). The status signals corresponding to the changed and unchanged status of a plurality of controllers are immediately transmitted to the central computer so as to cause a new page message to the operator's pager displaying the changed and unchanged status of all pivots in the respective group.

The method of the present invention for monitoring the operation of a number of controllers also includes a means for each remote terminal unit to transmit a "self report" of current status of all inputs (control points being monitored) to the central computer. Such self reports provide a "backup" to any missed "event" reports. The frequency of self reports is adjustable. Self reports also verify continued radio functions.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is an illustration showing the various major components of the system of the present invention and their communication paths.

FIG. **2** is a block diagram of the remote terminal unit of the present invention at a conventional pivot.

FIG. **3** is the screen presentation at the central control computer for defining a group.

FIG. **4** is a block diagram of the potato cellar control of the present invention.

FIG. **5** is a pager display illustrating the status information as graphic icons.

FIG. **6** is an illustration where the shape of the graphical icon identifies the type of field equipment.

FIG. **7** is a flow chart illustrating a method to issue status messages to a pager.

FIG. **8** is a flow chart illustrating a method to command operation of a power circuit in the agricultural field equipment.

FIG. **9** is a flow chart illustrating a method to disable/enable an auto restart controller in the agricultural field equipment.

DETAILED DESCRIPTION OF THE INVENTION

1. Overview

In FIG. **1**, the system **10** of the present invention is generally shown. A center irrigation pivot **20** operates in a field **30**. Such pivot irrigation systems **20** are conventionally available from a number of sources. Pivots **20** are typically under control of control circuits **40** which control direction of the pivot, the rate of application (i.e., the speed by which the pivot **20** moves over the ground **30**), whether chemicals such as fertilizer are to be added, and other operational parameters. It is to be expressly understood that the pivot control **40** and the pivot **20** in operation on a field **30** is conventional.

The present invention interfaces with a remote terminal unit (RTU) **50** which provides a radio link **60** to a transceiver **70** at a central location **80**. The transceiver **70** is connected to a central computer **90** by means of a conventional radio modem (not shown) and provides a two-way communication link **60** between the central control computer **90** and the remote terminal unit **50**. The central control computer **90** can receive status signals from the RTU **50** concerning the status of the various operational parameters of the pivot **20** and can deliver control signals from the central control computer **90** over the link **60** to the RTU **50** for controlling certain operational functions of the pivot **20**. Again, the provision of a RTU **50** with the capabilities of two-way transmission **60** to a central control computer **90** is conventional and can be found in, for example, the Valmont system discussed above. However, under the teachings of the present invention and as will be explained later, particular status signals and control signals are provided and delivered over the two-way communication link **60** in accordance with the teachings of the present invention.

Central control computer **90**, under the teachings of the present invention, is capable of establishing a communication link **100** to an alpha port paging terminal **110** through a telephone modem (not shown). The communication link **100** may be a standard telephony link over phone lines connected to the central control computer **90**. Again, communication path **100** and paging terminal **110** are conventional. The paging terminal **110** transmits a paging signal **120** which is received by a pager **130** at a remote location **140**. Remote location **140** could be a truck moving along a road many miles away from locations **30** and **80**. This communication link **120**, under the teachings of the present invention, delivers the current status of all pivots **20** in a defined group, when a status of any one pivot in the group has changed, and displays **132** all the statuses of the group in the pager **130**.

Under the teachings of the present invention, a cellular or touch-tone phone **150** is used to transmit control signals over a communication link **160** which is delivered through conventional telephony channels to the paging terminal **110** for retransmission as paging signal **170** to the control pager **180** located at the central computer **90**. The control pager **180** has a serial connection **190** to the central control computer **90**.

In operation, as illustrated in FIG. **7**, and assuming there are three center pivots **20** (only one of which is shown in FIG. **1**), the RTU **50** continuously monitors in steps **700**, **710** and **715** the status of select operational parameters on the pivot **20**. These status signals are delivered in step **700** through the communication channel **60** into the transceiver **70** for processing by the central control computer **90**. Whenever a monitored input has a change in status (e.g., off to on) **712** the RTU immediately sends a "data packet" of all monitored status to the computer **90** in steps **720** and **730**. When the central control computer **90** detects a change in the status of one pivot in step **740**, computer **90** assembles the status signals of all units in the group of three in step **750** and delivers all of them in a group as a page message over the communication link **100** marking the unit that has changed in step **760**. Also in step **760**, the paging terminal **110**, in turn, redelivers the status signals as a page over communication links **120** to the remote pager **130** and displays **770** them as a page message in the display **132**.

For example, in FIG. **1**. "01s" in the display **132** indicates to the operator of the pager **130** that pivot "01" is in a standby (or "stopped") mode "s." The pager display **132** also indicates to the holder of pager **130** that the second pivot "02" is wet "w" indicating it is moving and sprinkling the field **30** and that the third pivot "03w" is also in the wet status stage. The parenthesis ( ) around "03w" indicates to the operator that the status of pivot **3** just changed and was the cause of the current page message.

Under the teachings of the present invention, the status of all pivots in a defined group are delivered in the paging signal to the pager **130** whenever the status of one pivot in the respective group changes. The system of the present invention can handle any number of pivots in a small group although the preferred number is up to 30. Multiple groups for one irrigator are provided, enabling hundreds of pivots to be monitored on a single pager. The system also provides for any one pivot status to be simultaneously sent as part of multiple groups to multiple pagers carried by different individuals. The various types and forms of status signals being determined and sent will be explained in the ensuing.

As shown in FIG. **8**, the operator of the pager **130** can use a cellular phone **150** or touch-tone telephone to issue a command signa in step **800** by conventionally calling the paging terminal **110** and to deliver **810** a coded page message over communication link **170** to control pager **180**. The central control computer **90** upon receiving a page from control pager **180** over interface **190** processes the paged control commands and delivers **820** them over communication link **60** to the RTU **50** to cause the pivot control **40** to perform the requested operational functions in step **830**.

The operator of the pager **130** can thereupon observe the performance of the function since the actual performance of the function commanded will be detected by the RTU **50** and delivered back to the pager **130** in the manner described above with respect to FIG. **7** to show the changed status of that particular pivot. For example, a pivot can go from the "s" standby status to the "w" wet status with the farmer issuing a control command to start the pivot from any cell phone or touch-tone telephone.

Under the teachings of the present invention and without traveling to the field **30**, an operator of the present invention at a remote location **140** can view the status of any pivots and can effectuate changes in the status of any pivot in the group and then have feedback verifying the occurrence of the change.

For example, should a storm suddenly appear or approach the field **30**, the farmer can cause the pivot **20** to shut down until the storm passes to avoid possible lightning damage to the pivot **20** or its control **40** or an over-application of water in case of a large rain.

It is to be expressly understood that the pivot **20** comprises agricultural field equipment, but that the agricultural field equipment may also include other types of irrigation systems or, for example, equipment for storing crops such as potato cellars or grain bins.

The present invention combines the use of a central control computer **90**, telephone pagers **130** and **180**, cell phone **150** (or touch-tone telephone), and two-way telemetry **60** to remotely control equipment functions and to record in real-time the status of the equipment and/or other field sensors among a plurality of remote locations such that certain changes in the operating status of remote equipment (e.g., pivots **20**) or sensor readings being monitored are immediately and automatically reported to the operators by means of standard text pagers carried by the operators. The system of the present invention recognizes and records status changes in the field equipment **20** received by the central control computer **90** over the radio or telemetry **60** from individual RTUs **50** each monitoring inputs (either digital or analog or both) that define the operation of the field equipment.

The system automatically creates discreetly addressed (group and unit I.D.) "data packets" of the status signals for each piece of field equipment (i.e., each pivot **20**) in a defined "group" (such as, for example, 30 pivots) using specific "protocols" acceptable to a paging terminal **110**. Each pivot can be assigned to any of a plurality of groups such that the status change of a single pivot is reported in a plurality of groups and in turn paged to multiple pagers. The system of the present invention provides an automatic connection and communication of these "data packets" through a modem and over telephony lines **100** from the central control computer **90** to one or more paging terminals **110** which in turn automatically transmits the "data packet" containing the status signals to the individual operator's pager **130**. Each change in status on a single piece (e.g., pivot **20**) of monitored equipment in a defined group results in an immediate and complete report being sent to the pager **130** of the status of monitored set points of all field equipment in the respective group of field equipment.

The operator, at the remote location, can use standard touch tone telephones **150** to dial into the paging terminal **110** and enter passwords, equipment ID numbers and discrete digital commands to change the function of a discrete piece of remote field equipment (i.e., pivot **20**) either immediately or to be performed at a future time. The operator can also create and store date and time page messages on any PC computer and use a phone modem connection to automatically send a controlled "data packet" to the paging terminal **110** immediately or at a future date and time. Upon receipt of the "data packet" (from either a touch tone phone or a computer and phone modem), the paging terminal **110** transmits the digital command "data packet" to the "control pager" **180** at the central control computer **90**. The "data packet" received by the pager at the central control computer site **80** is automatically delivered **190** to the central control computer **90** through a conventional serial port. As the "data packets" are received by the central control computer **90** from the control pager **180**, a central control computer **90** verifies password, equipment ID numbers and control commands and retransmits the control command signals to the RTU **50** at the location **30** of the field equipment **20** over telemetry path **60**.

Alternatively, the date and time can be assigned to the data packet, immediately downloaded to the "control pager" **180**, and passed to the control computer **90**, which will transmit the signal to the RTU **50** at a future time corresponding to the date and time included in the page message sent to the control pager **180**, as will be subsequently discussed.

The present invention, upon execution of a remote control change to the operating function of the field equipment (for example, pivot **20** being turned "on to off" or "off to on"), causes the RTU **50** at the location **30** of the field equipment **20** to report the digital change "event" back to the central control computer **90** over the telemetry path **60**. The central control computer **90**, in turn, keys up a phone modem connection over path **100** and automatically dials the paging terminal **110** and transmits a "data packet" of the new status. In turn the paging terminal **110** automatically transmits a page message reporting the new "data packet" on the respective piece of field equipment **20** as well as the latest status on all other pivots in the group to the operator's pager **130**.

Thus the system of the present invention provides a "closed loop" between the execution of an on-site or remote control command and the reporting of the resulting equipment status changes to pagers **130** carried by those operators managing or executing the control changes. Via pager messages, the field equipment operators would have real-time status of the selected operating set points of digital inputs and values of any analog inputs for each field unit and for a group of field units.

While FIG. **1** shows a single pivot **20**, single RTU **50**, single control computer **80**, single paging terminal **110**, single pager **130**, and single telephone **150**, it is to be expressly understood that FIG. **1** is an illustration and does not limit the present invention. For example, a farming operation may have a large number of pivots **20** and RTUs **50** (e.g., 50 to 100), one or several computers **80**, due to the geographical spread of the pivots **20**, and a number of terminals **110**, and a number or pagers **130** and phones **150** for each terminal **110** could be utilized.

2. Details of the Remote Terminal Unit (RTU) **50**

In FIG. **2**, the components of the remote terminal unit **50** are shown. The RTU **50** is connected to a transceiver **52** which issues the two-way radio signal **60**. The RTU **50** is connected to the transceiver **52** over communications link **54**. Transceivers **52** are conventionally available.

The RTU **50** is also connected to a pivot control **40** over status input lines **42** and control output lines **44** through isolation input circuits and control relays. The pivot control **40** can be any conventional pivot control apparatus such as those described in the background of prior art section.

a. Power Status Input

Each pivot control **40** has a source of control power **200** such as 120 VAC for powering the internal electromechanical or electronic control circuitry for the pivot control **40**. The present invention provides a pick-off lead **42*a*** and 12 VDC power supply **201** for converting the 120 VAC power to 12 VDC power and for sensing the presence of control power from the power source **200** through a battery charger **202**. The RTU includes a battery charger **202** connected to a source of AC power **200** that continually powers a resident battery, not shown, in the RTU. When the source of control power fails, the twelve volt battery stops charging and pick-off lead **42*a*** senses this occurrence.

b. Speed Status Input

In conventional control **40** there is also a circuit **210** that delivers power such as 120 VAC to the control relay of the drive circuit of the pivot **20** to cause it to move. In a typical pivot **20** operation, water is delivered at a constant rate and by varying the speed of the pivot **20**, the water rate application can be varied. By providing a pick-off lead **42*b*** from the 120 VAC circuit of a conventional "speed timer" to an optical isolator **212**, the delivery of power to the speed timer can be sensed and the status of whether or not the pivot **20** is moving is known. Whether it is moving in the clockwise or the counterclockwise direction is not important.

c. Status Input

Also found in conventional pivot controls **40** is a wet/dry control circuit **220**. The pivot control **40** has a circuit **220** that issues a signal to deliver water through the pivot **20** for delivery on the field **30**. The present invention provides a pick-off line **42***c* acting through an optical isolator **222** for sensing when pivot control **40** operates to deliver water. For example, this could also sense a dry contact closure of a pressure switch actually in the water line to sense when water pressure is there.

d. Auxiliary Status Inputs

The present invention is not limited to the above status inputs, all of which are digital. Other digital status inputs from the pivot control **40** could be delivered through the auxiliary circuit (or circuits) **230**. For example, whether the pivot **20** is moving in the forward or reverse direction could be determined, whether the pivot **20** has injection equipment adding chemicals, whether a corner gun on the pivot **20** has been extended, whether load management circuitry has been activated by a power provider, etc. could be additional status inputs. These additional digital inputs from one or more auxiliary circuits **230** are delivered through corresponding optical isolators and over lines **42***d*.

e. Kill Control Command

Likewise, the pivot control **40** can be controlled by the RTU **50** over control lines **44**. At the pivot control **40** exists a conventional "safety" line **240**. This safety line **240** is essentially a closed loop line that senses when any portion of the pivot **20** becomes out of alignment or the pivot stops moving, loses pressure, etc. For example wheels in a portion of the pivot **20** could become stuck causing misalignment of the pivot and a break in the closed loop safety line **240**. This is discussed above, for example, in U.S. Pat. No. 4,899,934.

The present invention places a switch **242** in the safety line **240**. When a "kill" control signal is delivered over control line **44***a,* the switch **242** opens. The opening of the safety line **240** causes the pivot control **40** in a conventional fashion to shut down. This turns off the power to the wheels of the pivot and typically opens the wet/dry control stopping the means of water delivery. Hence, switch **242** is normally closed in operation.

In operation, the farmer at location **140** can call the paging terminal **110** and key in a code for "kill." The paging terminal **110** delivers this "kill" code to pager **180** which, in turn, communicates the "kill" code to computer **90**. Computer **90** thereupon issues a "kill" command from transceiver **70** over link **60** to transceiver **52** where it is delivered to RTU **50** and into memory **282**. The microprocessor **270** causes the switch **242** to open for a predetermined period of time, such as five seconds, so as to open the safety line **240**. The pivot **20** and water control are then stopped.

f. Power On/Off Output Command

Although not conventionally part of a pivot control **40** the operator of a pivot can add an auto restart circuit **250** to pivot control **40**. The auto restart circuit **250** is used in the pivot **20** to detect main power interruptions. When a power interruption is detected in the main AC source of power to the pivot **20**, circuit **250** conventionally operates to prevent power from reactivating the pivot control **40** for a predetermined period of time such as five to twenty minutes. An operator conventionally sets the predetermined time. Hence, when a power interruption such as a momentary loss of power long enough to "break the safety circuit" occurs, the pivot stops. This is detected on the AC power line to the auto restart device **250**, and the auto restart circuit **250** will prevent the redelivery of restart control power back to the pivot **20** for a sufficiently long period of time to prevent damage to the pivots such as providing enough time for the water to drain from the pump column or line pipes and pivot so as to prevent hydrostatic pressure damage.

The present invention adds a switch **252** in the sensing line **254** of the auto restart circuit **250** to fake a power outage by opening solid state switch **252** and a moment later reclosing switch **252**. When this open-and-close sequence is executed on a pivot in standby mode "s," the auto restart circuit **250** will restart the pivot as if a power interruption had occurred. Switch **252** is under control of control line **44***b*. Under the teachings of the present invention, a control signal on line **44***b* opens switch **252** which emulates a power interruption to the auto restart circuit **250**. It is to be understood that the placement of switch **252** does not interrupt the power to the pivot control **40** or to the pivot **20** and that only the power in the line **254** to the conventional auto restart circuit **250** is interrupted. Hence when switch **252** is opened, the auto restart circuit **250** is deactivated though main power to the rest of the pivot **20** is still being delivered. When the switch is closed (activated), the restart process as controlled by the auto restart circuit **250** is started. If the pivot is already running the command is moot. If the pivot is in standby mode, it will start and run. Control of switch **252** provides a means to not only remotely initiate an auto restart, but also a means of remotely "deactivating" the function of the auto restart circuit **250** by latching the switch "open." This would be beneficial during a period of multiple main power interruptions such as result during lightning storms, because repeated start/stop operation of a pivot experiencing multiple power interruptions could be avoided. Short periods of on/off operation of a turbine pump in a well can greatly increase the amount of sand or gravel drawn into the well casing.

The remote control of an auto restart circuit **250** located in farm field equipment is an important feature of the present invention, as shown in FIG. **9**. For the reasons stated above, farmers and operators are reluctant to install auto restart circuits **250** into their field equipment such as pivots because of the continuous starting and stopping of the field equipment during a thunder and lightning storm. This command feature of the present invention enables a farmer to issue a disable signal from his remote location in step **900**, which is delivered to the pager **180** located at the central control computer **90** in step **910**. The central control computer **90** receives the disable signal in step **920** and transmits **70** it to the RTU **50** in step **930** to disable the auto restart circuit **250** in step **940**, as discussed above. The farmer can simply leave the auto restart circuit **250** disabled during the thunder and lightning storm and then issue an enable signal from the remote location to enable the auto restart circuit **250** in steps **950** to **990** similarly to that discussed above with respect to disabling the auto restart circuit **250**. It is important, once again, to underscore that disabling the auto restart circuit **250** does not affect the operation of the pivot **20** as discussed above. What it prevents is the operation of the auto restart circuit **250** numerous times during a thunder and lightning storm which would, in fact, affect the operation of the pivot **20** and perhaps cause damage such as increasing the amount of sand or gravel drawn into the well casing.

g. Auxiliary Outputs

It is to be expressly understood that other control signals could be delivered over additional control leads such as **44***c* to control other auxiliary functions **260** of the pivot control **40**.

In FIG. **2**, the RTU **50** has a microprocessor **270**, a digital input circuit **272** and a digital output circuit **274**. The digital input circuit **272** communicates with the microprocessor **270** over lines **276** and the digital output circuit **274** communicates with the microprocessor over lines **278**. Also found in the RTU **50** is a status memory **280** and a control memory **282**. The microprocessor **270** periodically reads the status signals on status inputs **42** from the digital input circuit **272** and stores them in a status memory **280**. Likewise, the microprocessor **270** stores control functions in the control memory **282** for delivery over line **278** through the digital output circuit **274** and over control lines **44** to the pivot control **40**.

Also shown in FIG. **2** is an optional analog input circuit **284** which can receive various analog inputs from analog sensors **286**, **288** and **290**. For example, various analog inputs could be derived at by sensors **286** such as temperature, humidity, or wind speed and direction. Analog sensors **288** could sense the temperature and moisture in the soil and other auxiliary analog inputs from circuits **290** could be delivered through the analog input circuit **284** to the microprocessor. These could be stored digitally in the analog memory **294** by the microprocessor **270**. Additional signal conditioning of analog instruments could include cumulators, prescalers and counters to measure water flow, rainfall, wind speed, etc. The data associated with these sensors and other input devices could be sent to the control computer as an addendum to the "data packet" described above. The values of instruments and sensor readings could be processed by software at the central computer and delivered as alarms or as "mail drop" messages to the same pagers **130** carried by managers and operators for the purpose of monitoring equipment status.

Finally, there is a data port **296** which provides two-way communication **297** between the data port **296** and the microprocessor **270**.

i. Future Commands

The command/status structure of the present invention enables its operator to program the performance of commands to occur in the future.

As discussed earlier, the farmer (or operator) can generate date and time controlled page messages from a personal computer and phone modem connection for delivery of a "data packet" to paging terminal **110**. The farmer may also program central control computer **90** to execute a command at a predetermined date in the future. The central control computer **90**, having a real time clock, will cause the command to be generated in transceiver **70** for delivery over link **60** to the RTU **50**. The RTU **50** will cause the command to operate on the pivot **20**. Hence, the farmer at the central control computer **90** could program the "kill" command, discussed above, to operate on a designated pivot **20** three days into the future at 1:00 p.m. The computer **90**, upon sensing the real time clock, would cause the "kill" command to be delivered to the pivot **20** when the pre-set time actually occurs. Of course, the performance of this command will cause a status signal change to be immediately delivered by the RTU **50** back to the computer **90** which, in turn, will transmit a paging message marking the change in status for that pivot as well as providing the unchanged status signals for all other pivots in the group to the farmer.

Rather than actually go to the central control computer **90**, the farmer can use the telephone **150** to key in a future preselected time at which to cause the command to be executed by the central control computer **90**.

3. Central Computer

In FIG. **1**, the central computer **90** receives the status signals from the RTU **50** over the transceiver connection **52** and **70** as shown by radio link **60**. It is immaterial to the teachings of the present invention as to the protocols and design of the transceivers **52** and **70** and the nature of the data transmitted on link **60**. Suffice to say that the RTU **50** periodically delivers from the status memory **280** the status of the signals appearing on lines **42**. Likewise, in an optional environment, analog input signals can also be delivered from analog memory **294** to the central computer **90**. The RTU **50** delivers the status periodically (such as every 15 minutes) to the central control computer **90** unless a change in status occurs whereupon an immediate delivery occurs. The microprocessor **270** in the RTU **50** accesses a real-time clock, not shown, to periodically transmit through data port **296** the statuses stored in memory **280**. Any suitable time period such as five to 500 minutes could be used. Whenever a change occurs and holds for a five-second period on one of the leads **42**, it serves as an interrupt causing the microprocessor **270** to immediately act on the change, to update memory **280**, and to transmit the changed status (and the remaining unchanged statuses) from memory **280** through data port **296** to transceiver **52**.

EXAMPLE

12:00 a.m.	Transmit status of signals on lines 42 as stored in memory 280.
12.02 a.m.	Power status on lead 42a changes. Interrupt occurs, after 5-second continuous changed status on lead 42a, memory 280 updated and transmission occurs of changed and unchanged statuses.
12:15 a.m.	Transmit status of signals on lines 42 as stored in memory 280.

In the above example, the normal periodic transmission (self report) from the RTU **50** to the central control system is every fifteen minutes and is illustrated to occur at 12:00 a.m. and 12:15 a.m. However, two minutes after the 12:00 a.m. periodic transmission, the status on power line **42*a*** suddenly changes, causing an interrupt to occur in the RTU **50**. The interrupt is sensed by the microprocessor **270**, which updates the status memory **280** and, if the updated status holds for 5 seconds, assembles a status message for immediate delivery through the data port **296** by means of the transceiver **52** to the central control computer **90**. Then, at 12:15 the next periodic transmission occurs which, of course, includes the changed status signal on lead **42*a***. While this transmission protocol would seem to be redundant, it serves an important role under the teachings of the present invention. One purpose of the present invention is to immediately transmit information concerning the status change at the field equipment **20** to the remote operator at location **140**. Each digital input event is recorded and the data packet is sent immediately, followed by three more redundant transmissions spaced randomly in time over 90 to 180 seconds. This provides a higher success of reporting status changes and, in the event of a "general" power outage affecting multiple pivots **20**, provides a method of spacing repeated event reports to the control computer **90**. Without multiple, randomly spaced event reports, a power outage would cause all remote units to report in the same few seconds, and some reports could be lost or scrambled due to interference and unavailable radio receivers. The 12:02 transmission accomplishes that. The periodic transmission is also important so that the central control computer **90** can continually maintain transmission capabilities with the RTU

50. As will be explained later, should that transmission characteristic fail for a predetermined number of times, the operator at location **140** will be immediately notified. In addition, it is possible that one or more of the transmissions from the RTU **50** to the central control computer **90** may not occur or may occur with errors in place. This is especially true in a region of interference, especially in stormy weather. If, for example, the 12:02 a.m. transmission was not properly received by the central control computer **90**, then the next periodic transmission will carry the changed status information, which will then be processed by the central control computer **90**. The RTU **50** also receives from the central control computer **90** control commands through transceiver **52** and data port **296** which are stored in control memory **282** for subsequent redelivery through the digital output **274** over lines **44** to the pivot control **40** to perform an operational function.

The central control computer **90** hardware is a standard computer and similar to that used in the Valmont system discussed above. The software implements the logical flow and analysis discussed herein for the system and method of the present invention.

The central control computer **90** receives the status inputs and generates status signals which are set forth in Table 1 below.

TABLE 1

STATUS	PAGE ALPHA CHARACTERS			
	STATUS INPUT SIGNALS			
SIGNALS	POWER	SPEED	WET	AUX
p	OFF	OFF/ON	OFF/ON	OFF/ON
s	ON	OFF	OFF	OFF
d	ON	ON	OFF	OFF
m	ON	OFF	ON	OFF
w	ON	ON	ON	OFF
e	ON/OFF	OFF	OFF	ON
X	No radio response (50 min.)			

where p = pivot power off
s = pivot on standby
d = pivot on dry
w = pivot on wet
m = pivot off, water on
e = pivot off and load managed
x = no communication from pivot

In the preferred embodiment, the RTU **50** transmits **60** new status input signals every 15 minutes. Immediately on receiving such transmissions, software in the central control computer **90** compares the reported status to the last reported status and, if different, processes the status input signals (i.e., power, speed, wet) according to the logic of Table 1 to product the page alpha characters defined in Table 1. If not different, no page message is assembled. The central control computer **90** maintains memory files on statuses reported. Central control computer **90** uses conventionally available software (FIELD VISION FOR WINDOWS manufactured by Automata, Inc., 16216 Brooks Road, Grass Valley, Calif.) to collect the status input signals from the transceiver **70** and uses custom software (PIVOTRAC, manufactured for PivoTrac, LLC, by Automata, Inc.) to process those signals according to the state table of Table 1. The PIVOTRAC software periodically scans the FIELD VISION database to detect changed status information. In turn, the PIVOTRAC software formats the data signals in page alpha characters of p, s, d, e, m, w, and x and into a proper paging format. The paging information is written to a specified "directory" in the storage disk of the PC for detection by SPAN•N software.

The present invention uses the conventional SPAN•N software developed by DCC, Inc., 10 Second Street, NE, Minneapolis, Minn. 55413, to send the page message. In the field **30**, when the pivot **20** changes it status (based on the status input signals) a digital event occurs. The central control computer **90** puts this information together according to Table 1 for a group of pivots and sends the new data as a paging signal to the operator at the remote location **140** directly into the operator's pager **130**. This allows the operator to monitor all pivots in the group even though the pivots are at different locations and even though only one pivot has experienced an "event." The central control computer **90** prepares a file based upon the following information: "Group" provides a file for the operator to list all pivots **20** that it desires to be sent in a group and to be included in a single page. For example, 30 pivots could be identified in a single group. "Sensor Time Out" is a field that the base station operator sets which in the preferred embodiment is 50 minutes. This is the upper limit of time allowed between communications between a pivot and the computer before an "x" code is assigned to that pivot's operating status. In the preferred embodiment, status signals in the central control computer **90** are updated every 15 minutes from each pivot **20**. Should any one pivot not report for three successive updates (i.e., forty-five minutes), then five minutes later the Sensor Time Out value in the field will time out. This is a logical operation at the central control computer **90** and is given a status "alpha character" of "x".

FIG. **3** shows the fields of a page file which includes the group number, the sender's ID, the paging terminal service number, the pager ID, the maximum length of the page message and the maximum retries. Each pivot (RTU **50**) is assigned to one or more groups. Each group has a pager ID number. RTUs **50** can be readily moved from one site to another and an internal cross reference table is changed to link the RTU **50** to a two-digit pivot number in a group. The customer name for the group is also provided. This data is used to create a "resolved" message in a file that is detected by the conventional Span•N paging software. These fields of information are needed by standard alpha ports (paging services) using conventional paging protocols. FIG. **3** is a computer screen **300** on the central control computer **90** and, as discussed above, can be selectively entered by means of the conventional keyboard or other input device. The central control computer **90** through a standard modem communicates the page message over link **100** to the paging terminal **110** for delivery into the operator's pager **130** at location **140** as shown in FIG. **1**.

When a page is sent it includes all the pivots in one group and their status. The page is only sent when a change in status occurs. The pager shows the operator's name followed by all the pivots by the group and their status. An example of this is shown in Table 2 below:

TABLE 2

DISPLAY PAGER
05 Jerry Abts 01x 02w 03w 09s 25d (89p) 90s 99w
06 Jerry Abts 01x 02w 03w 09s 25d (89s) 90s 99w
07 Jerry Abts 01x 02w 03w (09w) 25d 89s 90s 99w

This example shows that operator Jerry Abts in pager message "05" has eight pivots in this group. The first pivot number 01 shows that it has not communicated "x" either from the central control computer's **90** initial startup or from a time determined by the sensor time-out value in the station file field as shown in FIG. **3**. Pivots 02, 03, and 99 show that they are all wet "w," meaning that the pivots are running and that the water is on. Pivots 09 and 90 are in the standby (or stopped) mode "s" and are not running. Pivot 25 is running dry "d." Pivot 89 is the pivot that caused the page denoted by the parentheses around it. It had an AC power loss "p." The ( ) marks the location of the pivot whose status has changed. In the case of a power outage, the system of the present invention will wait five minutes before allowing another status to be sent for that pivot and only if the status has changed. An exception to this would be another pivot in the same group changing, in which case, all the statuses for that group will be sent with the new pivot enclosed in parentheses. In the preferred embodiment, the central control computer **90** provides a user defined delay (1–5 minutes) between calls to paging services which allows for multiple page messages to be delivered to a paging service on a single dial-up call.

In Table 2 above, the operator subsequently receives page "06" which indicates that pivot 89 changed status from "p" to "s." Later, the operator Jerry Abts receives pager message "07" indicating that pivot "09" changed status from "s" to "w." The pager of the present invention is capable of storing up to 20 such messages, thereby enabling the operator to scroll through the earlier messages to quickly review the history of the status changes, the changed status messages being marked with ( ). All stored pages include date and time of the page.

The present invention allows for a maximum of thirty groups to be defined. Each group can have up to 30 pivots.

In an alternate embodiment, the system of the present invention would incorporate various "graphic" displays of status on a pager developed and programmed for this purpose. As an example, Motorola markets "Sports Trax™," a graphic screen pager that displays the status of a baseball game. The 1-½" square LCD screen used in this application would serve as a basis to develop a special graphic display of center pivot status. For pivots this could be nothing more than columns and rows of "Cheerios"-size circles. The pivots would be numbered and a "solid" circle would be on; a pivot not running would be displayed by an "open" circle. Additional status could be coded graphically or displayed alphanumerically on the "main" screen or "sub" screen(s). This will be discussed in more detail later.

4. Command Operation

Table 3 sets forth the command operation for a pivot:

TABLE 3

COMMANDS

COMMAND	PIVOT FUNCTION	PAGETAP ™ PHONE COMMAND	RESULT
KILL	Open Safety Circuit 5 Seconds and close	0 (Kill Pivot)	Pivot is Stopped
AUTO-START	Open Auto Restart Circuit 5 Seconds & Close Auto Restart Circuit	1 (Open Switch & then Close Switch)	Pivot is Started (Need Auto Restart)
DISABLE AUTO RESTART	Open Auto Restart Circuit (latch open)	2 (Open & Leave Open)	Disables Auto-Restart
RESEND		3	Resend last page

The operator uses the phone **150** in FIG. **1** to send a command signal to the pager **180** at the central control computer **90**. The operator would first dial the number of pager **180** and the paging terminal **110** would answer and request a message. The operator would first touch-tone the identity of his group (PIN four to six digits) followed by the I.D. number (two digits) of the pivot to be commanded (e.g. "01"). The operator would then touch-tone the command to be performed (e.g. "0" for "kill"). The terminal **110** relays the paged command signal to pager **180** for delivery into the central control which, in turn, relays the command of "kill" to the identified RTU **50**. The RTU **50** receives the "kill" command and opens a solid state switch **242** in FIG. **2** to functionally stop the pivot **20**. The RTU **50** closes the switch **242** after five seconds. The pivot remains stopped.

When the operator inputs a PAGETAP™ phone command of "1," according to Table 3 and FIG. **2**, this command is then delivered to the RTU **50**, causing solid state switch **252** to open (thereby faking a power outage at the pivot and disabling the auto restart) and then to immediately (after 5 seconds) close. The closing of the solid state switch **252** enables the auto restart device and returns the pivot control **40** to its normal operation which, in this case, is the normal and conventional functioning of the auto restart circuit **250**. Hence, after a predetermined period of time (e.g., up to 30 minutes), the pivot control **40** auto starts the pivot **20**. Hence, if the pivot is stopped, the operator at a remote location can use the conventional auto restart circuit **250** and solid state switch **252** to start the pivot.

The central control computer **90** automatically performs the opening of solid switch state **252** by sending a first command to RTU **50** and the closing of solid state switch **252** by sending a second command a predetermined time later, such as ten seconds. It is important to keep in mind that, under the teachings of the present invention, power is always delivered to the pivot **20** but that PAGETAP™ phone command in Table 3 above for "1" starts the pivot by first opening and then closing switch **252**. If the pivot was already running when a "1" command is sent, the pivot would continue to run and there would be no change in reported status and, therefore, no new page message. If the pivot was off when a "1" command was issued (and assuming the pivot was otherwise set in a proper mode to be auto restarted), the pivot would start and a new page would issue.

The next PAGETAP™ phone command in Table 3 above is "2," which simply causes the solid state switch **252** to open and stay open. This disables the automatic restart circuit. The disabling of the auto restart function will not affect the operation of the pivot. Hence, if the pivot is running, it stays on. If the pivot is off, it stays off. This is an important command, since if the remote operator wants to ensure that the pivot does not auto restart, such as when storm conditions with lightning exist, he dials in "2." To simply start the pivot again, he later dials in a "1."

The last PAGETAP™ command is a "3." This signals the computer to "re-send" the last page for the group. This command is useful if the page message is not properly received by the pager or an operator has reason to believe he has missed a page message.

5. Potato Cellar Embodiment

The present invention could also be used for other field equipment such as, for example, a potato cellar.

A potato cellar control is shown in FIG. **4**. The potato cellar control **400** has a 120 volt AC power source **410** for controlling circuitry, a fan **420**, and an alarm circuit **430**. Again, these are all conventional control circuits found within a potato cellar ventilation system.

An optical isolator **412** is provided in the path sensing whether 12 volts DC is present from the power supply feeding off of the 120 VAC circuit **410**. The sensing path **440** delivers the signal to an RTU such as RTU **50** in FIG. **2**. Likewise, whether the fan **420** is operational is delivered through an optical isolator **422** and over lead **440***b* to the RTU **50**. Finally, whether an alarm (typically a "red" light on the outside of the cellar) has been generated is delivered through an optical isolator **432** and over sensing line **440***c* to RTU **50**.

Table 4 sets forth the assembly of the paging alpha characters by the central control computer **90**.

TABLE 4

PAGE ALPHA CHARACTERS			
STATUS	STATUS INPUT SIGNALS		
SIGNALS	POWER	FAN	ALARM
p	OFF	OFF/ON	OFF/ON
s	ON	OFF	OFF
f	ON	ON	OFF
a	ON	ON	ON
a	ON	OFF	ON
x	No radio response (50 min.)		

where p = cellar power off
s = cellar on standby
f = cellar fan on
a = alarm condition
x = no communication from cellar

The operation of the potato cellar is similar to that of the pivot. As shown above in Table 4, the status input signals for power (on line **440***a*), fan (on line **440***b*), and alarm (on line **440***c*) are detected and delivered into the RTU **50**. Periodically, such as every 15 minutes, these status input signals are, in turn, delivered to the central control computer **90**. In addition, whenever a signal input changes from one state to the other, the three status input signals for power, fan and alarm are also sent to the central control computer **90**.

The central control computer **90** then processes these three status input signals according to the logic of Table 4. The central control computer **90** generates the five alpha page characters. Cellar Power Off "p" is generated when the power in the 12 volt DC battery charging circuit **410** of FIG. **4** is off. Whether or not the fan or the alarm is on or off is immaterial. Likewise, the cellar is on standby "s" when the power to the 12 volt DC circuit **410** is on and the fan **420** is off and the alarm **430** is off. In other words, in the standby status state, power is available, but the fan and alarm are both off. When the cellar fan is turned on (such as to bring cooler air in from the outside), this is detected on lead **440***b*, and the central control computer **90** delivers the "f" alpha character, indicating the cellar fan is on when both the power is on and the fan is on. The alarm state is off.

Likewise, an alarm condition "a" is generated when the alarm circuit **430** is on and the power **410** is on. The status of the fan is immaterial under this logic. Finally, the page alpha character "x" is delivered when the central control computer **90** does not have a response from a particular potato cellar for a period of time, such as 50 minutes.

6. Graphic Display Embodiment

In FIG. **5**, a second embodiment for the display **132** is shown. This second embodiment utilizes graphical icons **500** to graphically display the status of each piece of field equipment (in this case, a pivot). An asterisk in the upper right-hand corner of the graphical icon **500** can indicate a change in status.

Hence, in FIG. **5**, the page number **510** is displayed along with the operator's name **520**. In FIG. **5**, ten pivots comprise a group (i.e., page number 5). The ninth pivot has an asterisk in the upper right-hand corner which indicates that the ninth pivot changed status and has no present radio contact. In the lower portion of the display is the time of the page **530** and the date of the page **540**.

Any suitable graphical icon **500** can be utilized to indicate the status signal for the display **132**.

Although FIG. **5** shows one page (i.e., page number 5), it is to be understood that a conventional pager can store up to 20 pages, thereby making it easy for the farmer or operator to page backward to prior pages to quickly review the history of the change in statuses of his pivots in one or more groups. The date and time are included on all stored pages.

7. Combinations of Field Equipment

In the two examples discussed above (i.e., pivots in FIG. **1** and potato cellars in FIG. **4**), it is to be understood that the present invention can report on the status of different field equipment within a group. For example, a farmer may have five pivots, two grain elevators, and three potato cellars. Under the teachings of the present invention, these various pieces of field equipment could be reported upon. For example, in FIG. **5**, pivots could use the circular icon **500**, whereas potato cellars could be designated with a square icon. Hence, the outer shape of the icon **500** could designate the type of field equipment. For example, in FIG. **6**, icon **600** is square and could be used to designate a potato cellar, whereas icon **610** is circular, and could be used to designate a pivot. As shown in FIG. **5**, the status indicators **550** indicate the status of the piece of field equipment.

The above disclosure sets forth a number of embodiments of the present invention. The present invention is not to be limited to field equipment such as pivots and potato cellars, but finds application in grain elevators, other irrigation and crop monitoring systems, and other similar agricultural farm equipment. Other arrangements or embodiments, not precisely set forth, may be practiced under the teachings of the present invention and as set forth in the following claims.

I claim:

1. A pager message system for monitoring the operation of a plurality of controllers in each one of a plurality of agricultural field equipment, said pager message system comprising:

a plurality of sensors at each of said plurality of agriculture field equipment, one of said plurality of sensors connected to one of said plurality of controllers for issuing a status signal corresponding to the status of said connected controller,

a plurality of remote terminal units, one of said plurality of remote terminal units connected to said plurality of sensors at each of said plurality of agriculture field equipment, said remote terminal unit transmitting status signals whenever one status signal changes and whenever a predetermined time period elapses,

a central control computer receiving said transmitted status signals from said transmitting remote terminal unit, said central control computer analyzing said transmitted status signals for generating at least one changed status paging message only when a changed status signal occurs,

a paging terminal, said central control computer delivering said at least one changed status paging message for all remaining agriculture field equipment in said plurality of agriculture field equipment to said paging terminal whenever one of said remote plurality of terminal units transmits said changed status signals,

at least one pager, said paging terminal delivering said delivered changed status paging messages to said at least one pager, said at least one pager displaying said changed status paging messages, said changed status paging message being marked when displayed.

2. The pager message system of claim **1** wherein said agricultural field equipment is pivot irrigation equipment.

3. The pager message system of claim 2 wherein said plurality of controllers at least includes control circuit power, speed control, and wet control and wherein said plurality of sensors at least includes a power control sensor, a pivot running sensor and a wet control sensor.

4. The pager message control system of claim 3 wherein said at least one changed status paging message is at least derived from the status signals from said power control sensor, said speed control sensor and said wet control sensor.

5. The pager message control system of claim 1 wherein said agriculture field equipment is potato cellar storage equipment.

6. The pager message control system of claim 5 wherein said plurality of controllers at least includes control circuit power, fan power, and an alarm, and wherein said plurality of sensors at least includes a power control sensor, a fan sensor, and an alarm sensor.

7. The pager message control system of claim 6 wherein said changed status is at least derived from the status signals from said power control sensor, said fan sensor, and said alarm sensor.

8. The pager message control system of claim 1 further comprising an isolation device between said one of said plurality of sensors connected to said one of said plurality of controllers.

9. The pager message control system of claim 1 wherein said central control computer generates a loss of communication changed status paging message whenever communication is lost with one of said plurality of field equipment for a predetermined period of time.

10. The pager message control system of claim 1 wherein said displayed changed status messages marks changed agricultural field equipment with a "( )".

11. The pager message control system of claim 1 wherein said displayed changed and unchanged status paging messages use graphical icons.

12. The pager message control system of claim 11 wherein the outer shape of the graphical icon defines the type of said agricultural field equipment and wherein the inner design of the graphical icon defines the status message.

13. A pager message system for monitoring the operation of a plurality of controllers in each one of a plurality of pivot irrigation equipment, said pager message system comprising:

a plurality of isolation devices at each of said plurality of pivot irrigation equipment,

a plurality of sensors at each of said plurality of pivot irrigation equipment, one of said plurality of sensors connected through one of said plurality of isolation devices to one of said plurality of controllers for issuing a status signal corresponding to the status of said connected controller,

a plurality of remote terminal units, one of said plurality of remote terminal units connected to said plurality of sensors at each of said plurality of pivot irrigation equipment, said remote terminal unit transmitting status signals whenever one status signal changes,

a central control computer receiving said transmitted status signals from said transmitting remote terminal unit, said central control computer analyzing said transmitted status signals for generating at least one changed status paging message for said transmitting remote terminal unit,

a paging terminal, said central control computer delivering said changed status paging message for all remaining pivot irrigation equipment in said plurality of pivot irrigation equipment to said paging terminal whenever one of said remote plurality of terminal units transmits said changed status signals,

at least one pager, said paging terminal delivering said delivered changed status paging message to said pager, said pager displaying said changed status paging messages, said changed status paging message being marked when displayed, said plurality of controllers at least includes power control, speed control, and wet control and wherein said plurality of sensors at least includes a power control sensor, a speed control sensor and a wet control sensor.

14. The pager message control system of claim 13 wherein said at least one changed status paging message is a least derived from the status signals from said power control sensor, said speed control sensor and wet control sensor.

15. A pager message system for monitoring the operation of a plurality of controllers in each one of a plurality of pivot irrigation equipment, said pager message system comprising:

a plurality of isolation devices at each of said plurality of pivot irrigation equipment,

a plurality of sensors at each of said plurality of pivot irrigation equipment, one of said plurality of sensors connected through one of said plurality of isolation devices to one of said plurality of controllers for issuing a status signal corresponding to the status of said connected controller,

a plurality of remote terminal units, one of said plurality of remote terminal units connected to said plurality of sensors at each of said plurality of pivot irrigation equipment, said remote terminal unit transmitting status signals whenever one status signal changes,

a central control computer receiving said transmitted status signals from said transmitting remote terminal unit, said central control computer analyzing said transmitted status signals for generating at least one changed status paging message for said transmitting remote terminal unit,

a paging terminal, said central control computer delivering said changed status paging message for all remaining pivot irrigation equipment in said plurality of pivot irrigation equipment to said paging terminal whenever one of said remote plurality of terminal units transmits said changed status signals,

at least one pager, said paging terminal delivering said delivered changed status paging messages to said pager, said pager displaying said changed status paging messages, said changed status paging message being marked when displayed, said central control computer generates a loss of communication changed status paging message whenever communication is lost with one of said plurality of pivot irrigation equipment for a predetermined period of time.

16. A pager message system for monitoring the operation of a plurality of controllers in each one of a plurality of pivot irrigation equipment, said pager message system comprising:

a plurality of isolation devices at each of said plurality of pivot irrigation equipment,

a plurality of sensors at each of said plurality of pivot irrigation equipment, one of said plurality of sensors connected through one of said plurality of isolation devices to one of said plurality of controllers for issuing a status signal corresponding to the status of said connected controller, wherein said plurality of controllers at least includes power control, speed control, and wet control and wherein said plurality of sensors at least includes a power control sensor, a speed control sensor and a wet control sensor,

a plurality of remote terminal units, one of said plurality of remote terminal units connected to said plurality of sensors at each of said plurality of pivot irrigation equipment, said remote terminal unit transmitting status signals whenever one status signal changes,

a central control computer receiving said transmitted status signals from said transmitting remote terminal unit, said central control computer analyzing said transmitted status signals for generating at least one changed status paging message for said transmitting remote terminal unit,

wherein said changed status paging message is at least derived from the status signals from said power control sensor, said speed control sensor and said wet control sensor and wherein said central control computer generates a loss of communication changed status paging message whenever communication is lost with one of said plurality of pivot irrigation equipment for a predetermined period of time,

a paging terminal, said central control computer delivering said changed status paging message for all remaining pivot irrigation equipment in said plurality of pivot irrigation equipment to said paging terminal whenever one of said remote plurality of terminal units transmits said changed status signals,

at least one pager, said paging terminal delivering said delivered changed status paging message to said pager, said pager displaying said changed status paging message, said changed status paging message being marked when displayed.

17. A method for monitoring the operation of a plurality of controllers in each one of a plurality of agricultural field equipment, said method for monitoring comprising the steps of:

issuing from a remote terminal unit status signals corresponding to the status of the plurality of controllers,

transmitting over a communication channel the issued status signals to a central control computer whenever one status signal changes,

receiving the transmitted status signals at the central control computer,

analyzing the received status signals at the central control computer,

generating at the central control computer at least one changed status paging message identifying the location of the agricultural field equipment having the one status signal change,

generating at the central control computer unchanged status paging messages identifying the location of the remaining agricultural field equipment,

delivering the changed status paging message and unchanged status messages to a least one pager,

displaying at said pager said changed and unchanged status paging messages, said changed status paging message being marked when displayed thereby marking the agricultural field equipment issuing the changed status paging message,

wherein the step of transmitting the issued status signals further includes the step of transmitting the issued status signals as radio frequency signals, wherein the step of delivering further comprises the steps of:

delivering the changed and unchanged status paging messages over a telephony link to a pager control system,

the pager control system delivering the changed and unchanged status paging messages over a paging link to at least one pager.

18. A method for monitoring the operation of a plurality of controllers in each one of a plurality of agricultural field equipment, said method for monitoring comprising the steps of:

issuing from a remote terminal unit status signals corresponding to the status of the plurality of controllers,

transmitting over a communication channel the issued status signals to a central control computer whenever one status signal changes,

receiving the transmitted status signals at the central control computer,

analyzing the received status signals at the central control computer,

generating at the central control computer at least one changed status paging message identifying the location of the agricultural field equipment having the one status signal change,

generating at the central control computer unchanged status paging messages identifying the location of the remaining agricultural field equipment,

delivering the changed status paging message and unchanged status messages to at least one pager,

displaying at said pager said changed and unchanged status paging messages, said changed status paging message being marked when displayed thereby marking the agricultural field equipment issuing the changed status paging message, wherein each unchanged status message is displayed in the form of:

location, status

and wherein the changed status message is displayed in the form of:

(location, status)

wherein the () marks the changed status message.

19. A method for monitoring the operation of a plurality of controllers and for commanding the operation of a least one power circuit in each one of a plurality of agricultural field equipment, said method for monitoring comprising the steps of:

issuing at least one command signal for an identified agricultural field equipment from a remote location,

delivering the issued at least one command signal to a first pager located at a central control computer,

the central control computer transmitting the delivered at least one command signal to the at least one power circuit at the identified agricultural field equipment,

commanding the operation of the at least one power circuit at the identified agricultural field equipment,

issuing from an RTU status signals corresponding to the status of the plurality of controllers, transmitting over a communication channel the issued status signals to a central control computer whenever one status signal changes such as in response to the commanded operation;

receiving the transmitted status signals at the central control computer,

analyzing the received status signals at the central control computer,

generating at a central control computer at least one changed status paging message identifying the location of the agricultural field equipment having the one status signal change,

generating at a central control computer unchanged status paging messages identifying the location of the remaining agricultural field equipment,

delivering said at least one changed status paging message and unchanged status messages to a second pager at the remote location,

displaying said at least one changed and unchanged status paging messages in the second pager, said changed status paging message being marked when displayed thereby marking the agricultural field equipment issuing the changed status paging message.

* * * * *

US006343255B1

(12) United States Patent
Peek et al.

(10) **Patent No.: US 6,343,255 B1**
(45) **Date of Patent: Jan. 29, 2002**

(54) **METHOD AND SYSTEM FOR PROVIDING WEATHER INFORMATION OVER THE INTERNET USING DATA SUPPLIED THROUGH THE INTERNET AND A WIRELESS CELLULAR DATA SYSTEM**

(76) Inventors: **Sanford Christopher Peek**, 1316 Lymric Way, Bakersfield, CA (US) 93309; **David P. Peek**, 13 Village Dr., Atkinson, NH (US) 03811

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/498,314**

(22) Filed: **Feb. 6, 2000**

(51) **Int. Cl.**[7] **G06F 19/00**
(52) **U.S. Cl.** **702/3**
(58) **Field of Search** 702/3, 4, 5; 342/26; 700/284; 709/218

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* cited by examiner

Primary Examiner—Donald E. McElheny, Jr.
(74) *Attorney, Agent, or Firm*—Timothy Thut Tyson

(57) **ABSTRACT**

A system and method for accessing and displaying weather information are shown. A weather station (**102**) collects weather information data from sensors (**108–114**) using a collection program and assembles the data as a data string in a memory. A station access system (**140**) is used to call the weather station through the Internet (**150**) and a wireless cellular digital packet data system (**154**). The weather station downloads the weather data string to a data base (**164**). A user contacts the access computer through the Internet using his personal computer (**170**) to ask for the weather information. The information is compiled from the data base and transmitted to the user's display (**172**) over the Internet. A user such as a farmer can also supply the system with his particular field and crop conditions and the system will apply the conditions to the weather information and return customized crop production and control information to the farmer over the Internet.

14 Claims, 13 Drawing Sheets

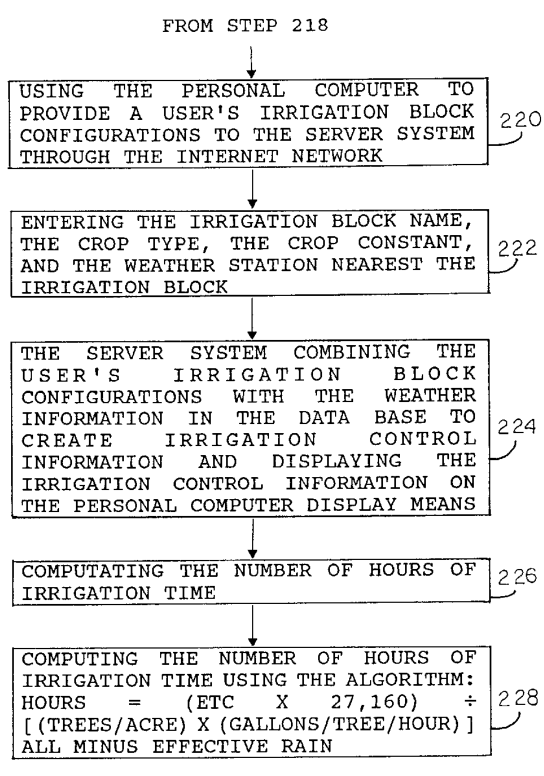
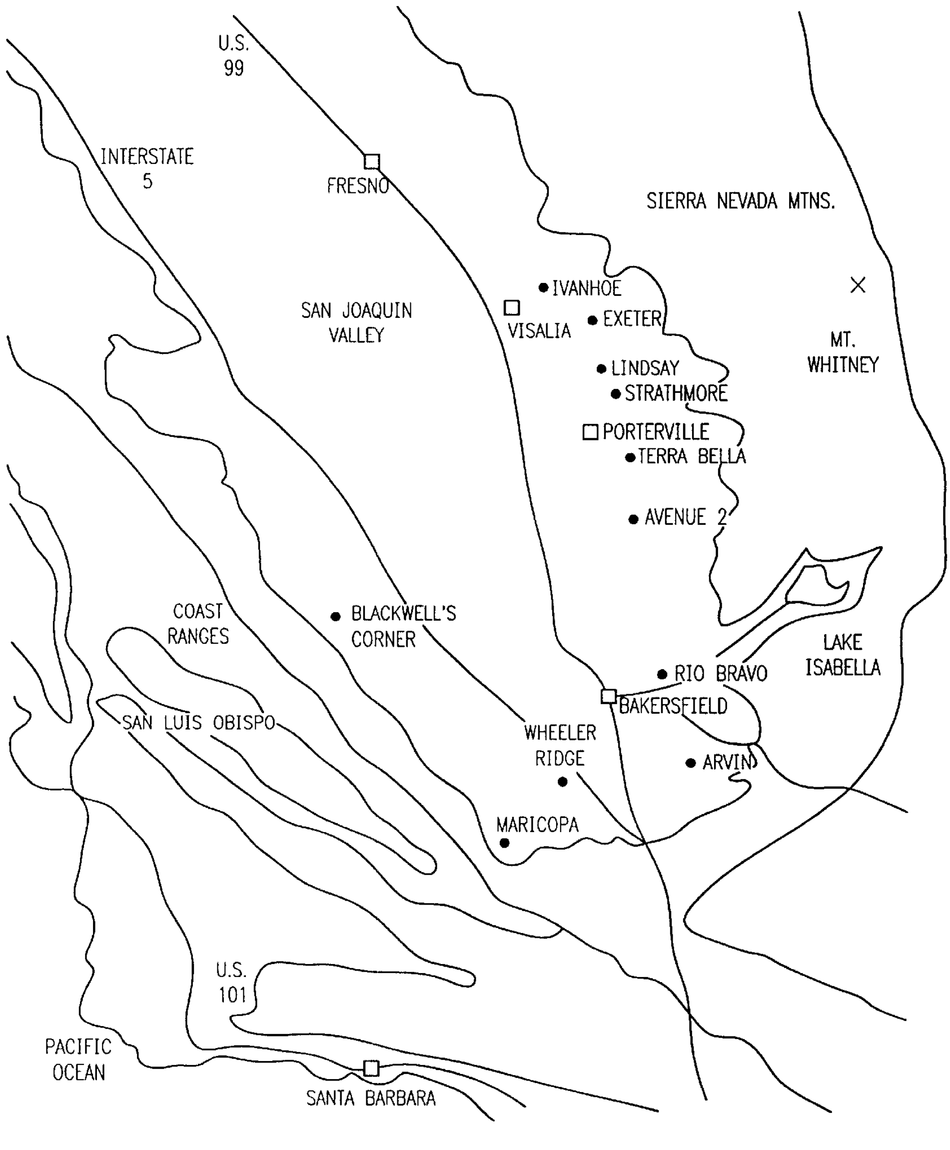


FIG. 1
PRIOR ART



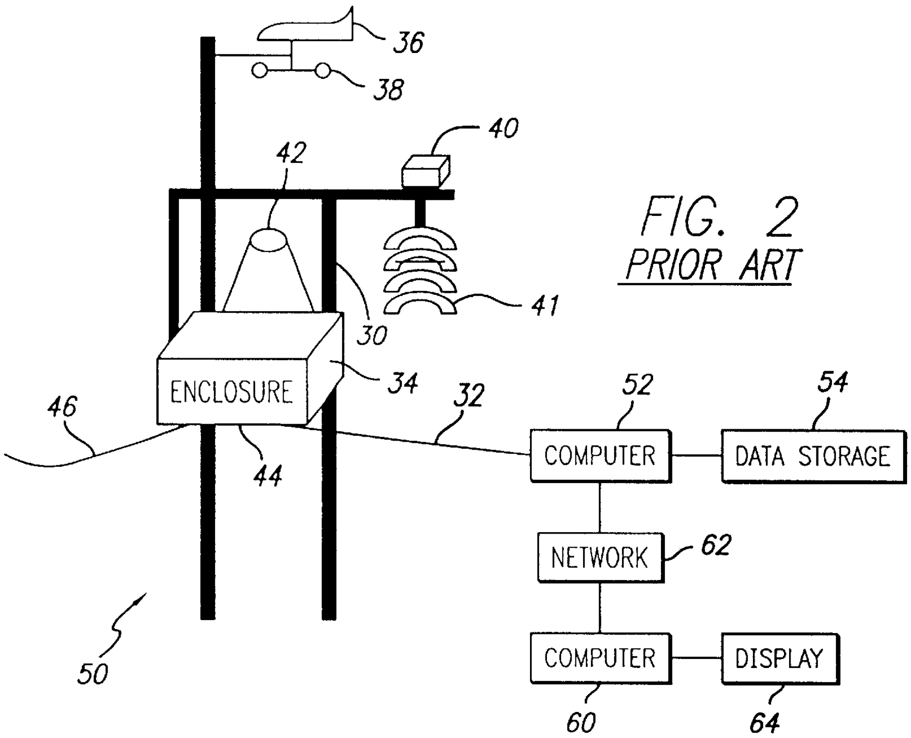


FIG. 2
PRIOR ART

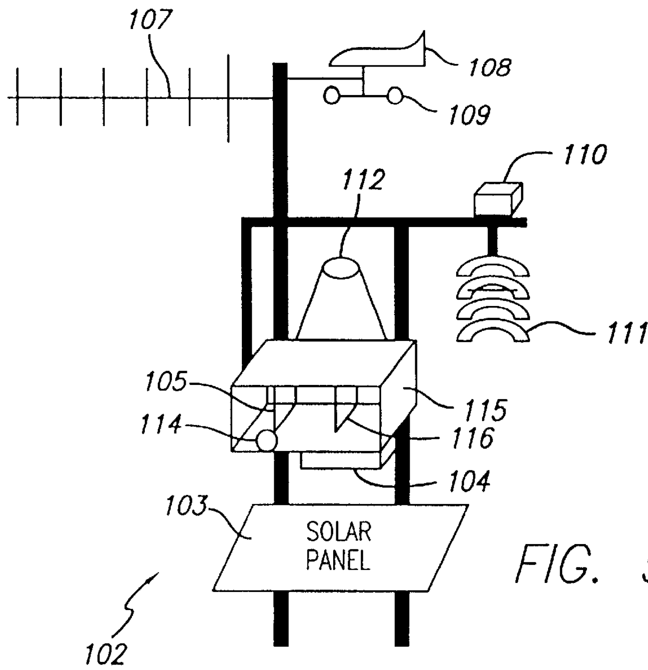


FIG. 5

DAILY WEATHER SUMMARY

ARVIN

DATE	ET	T.MAX	T.MIN	T.AVG	W.AVG	W.GUST	W.DIR	SOLAR	HUMAVG	RAIN
7/29/99	0.28	95	59	75	3.0	9	210	790	70	0
7/30/99	0.31	90	58	74	1.8	7	265	976	70	0
7/31/99	0.28	92	56	74	2.5	8	0	775	68	0
8/1/99	0.27	92	55	74	3.0	10	260	637	68	0
8/2/99	0.28	93	58	75	2.8	8	219	697	71	0
8/3/99	0.28	94	61	75	4.3	12	286	713	72	0.01
8/4/99	0.28	97	61	77	2.4	7	15	693	70	0
TOTALS	2	97	55	74.85	2	9			69	0.01

FIG. 3
PRIOR ART

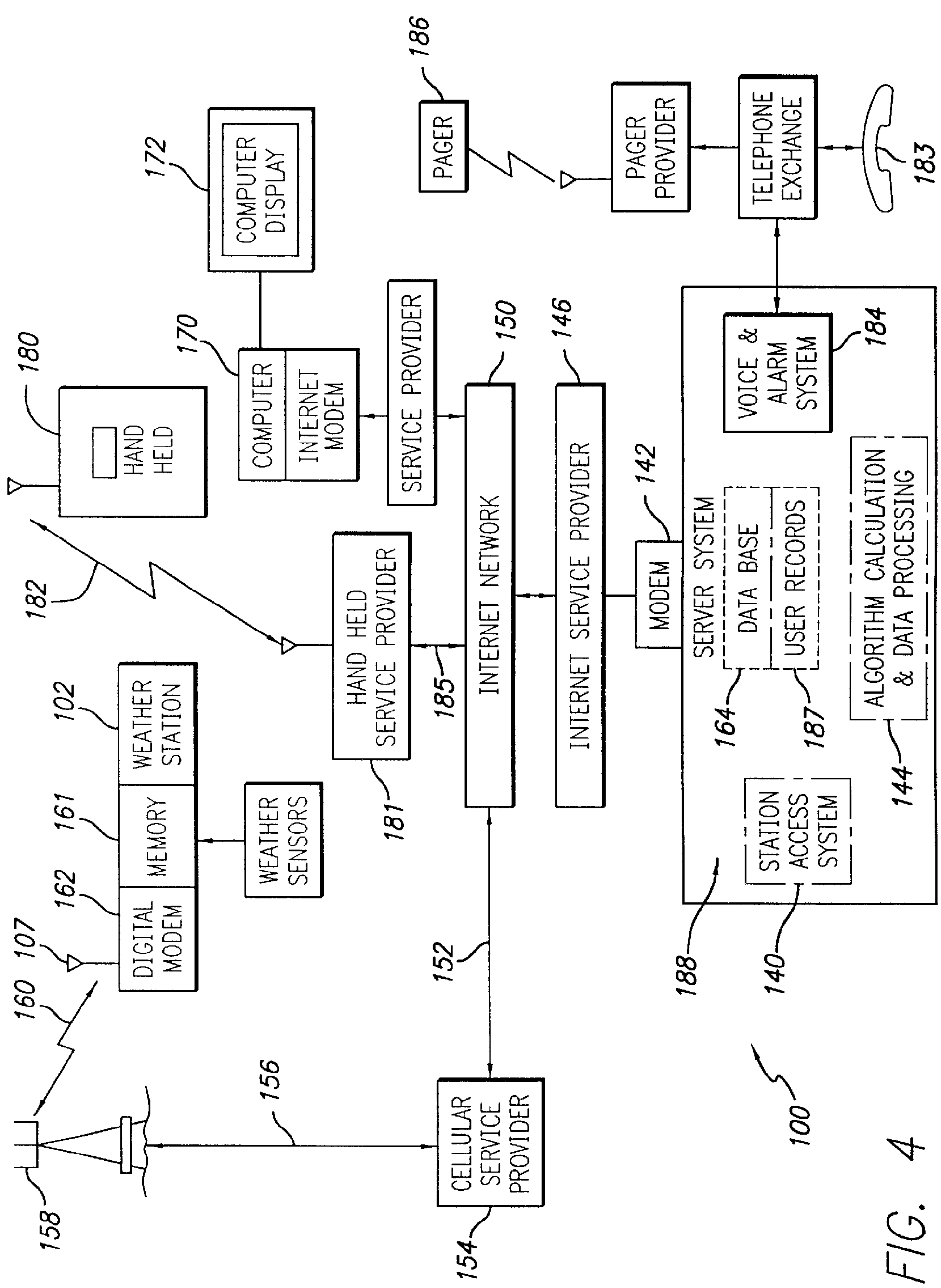

COMPUTER DISPLAY
172
PAGER
186
PAGER PROVIDER
TELEPHONE EXCHANGE
183
180
HAND HELD
170
COMPUTER
INTERNET MODEM
SERVICE PROVIDER
150
INTERNET NETWORK
146
INTERNET SERVICE PROVIDER
142
MODEM
VOICE & ALARM SYSTEM
184
SERVER SYSTEM
DATA BASE
USER RECORDS
ALGORITHM CALCULATION & DATA PROCESSING
182
HAND HELD SERVICE PROVIDER
185
181
102
WEATHER STATION
161
MEMORY
162
DIGITAL MODEM
107
160
WEATHER SENSORS
164
187
144
STATION ACCESS SYSTEM
188
140
152
156
158
CELLULAR SERVICE PROVIDER
154
100

FIG. 4

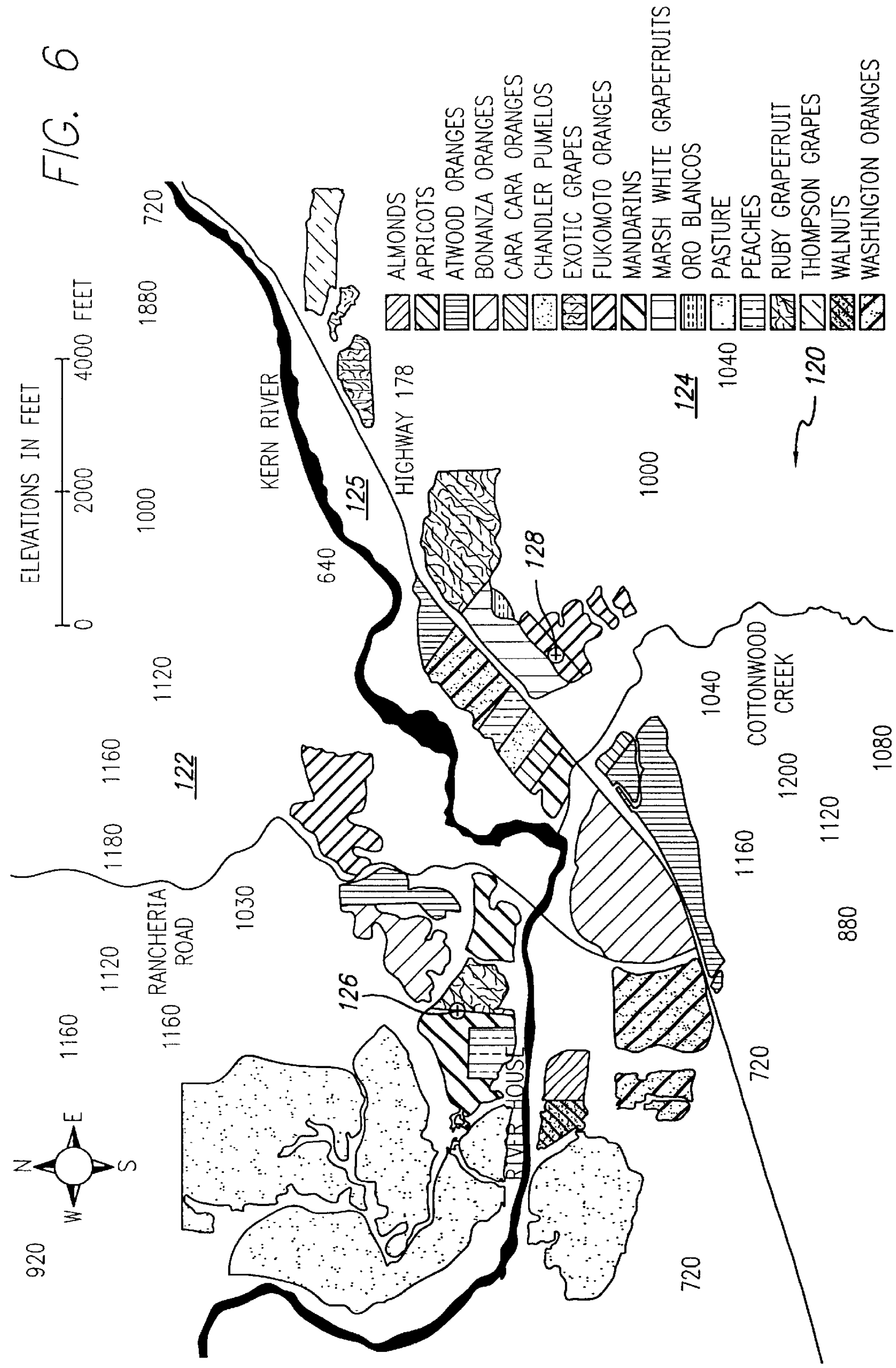

ELEVATIONS IN FEET
0 2000 4000 FEET
N E S W
KERN RIVER
HIGHWAY 178
RANCHERIA ROAD
RIVER HOUSE
COTTONWOOD CREEK
122
124
125
126
128
120
920
1160
1120
1160
1180
1160
1120
1000
1880
720
1030
640
1000
1040
1040
1160
1200
1120
1080
880
720
720
ALMONDS
APRICOTS
ATWOOD ORANGES
BONANZA ORANGES
CARA CARA ORANGES
CHANDLER PUMELOS
EXOTIC GRAPES
FUKOMOTO ORANGES
MANDARINS
MARSH WHITE GRAPEFRUITS
ORO BLANCOS
PASTURE
PEACHES
RUBY GRAPEFRUIT
THOMPSON GRAPES
WALNUTS
WASHINGTON ORANGES

FIG. 6

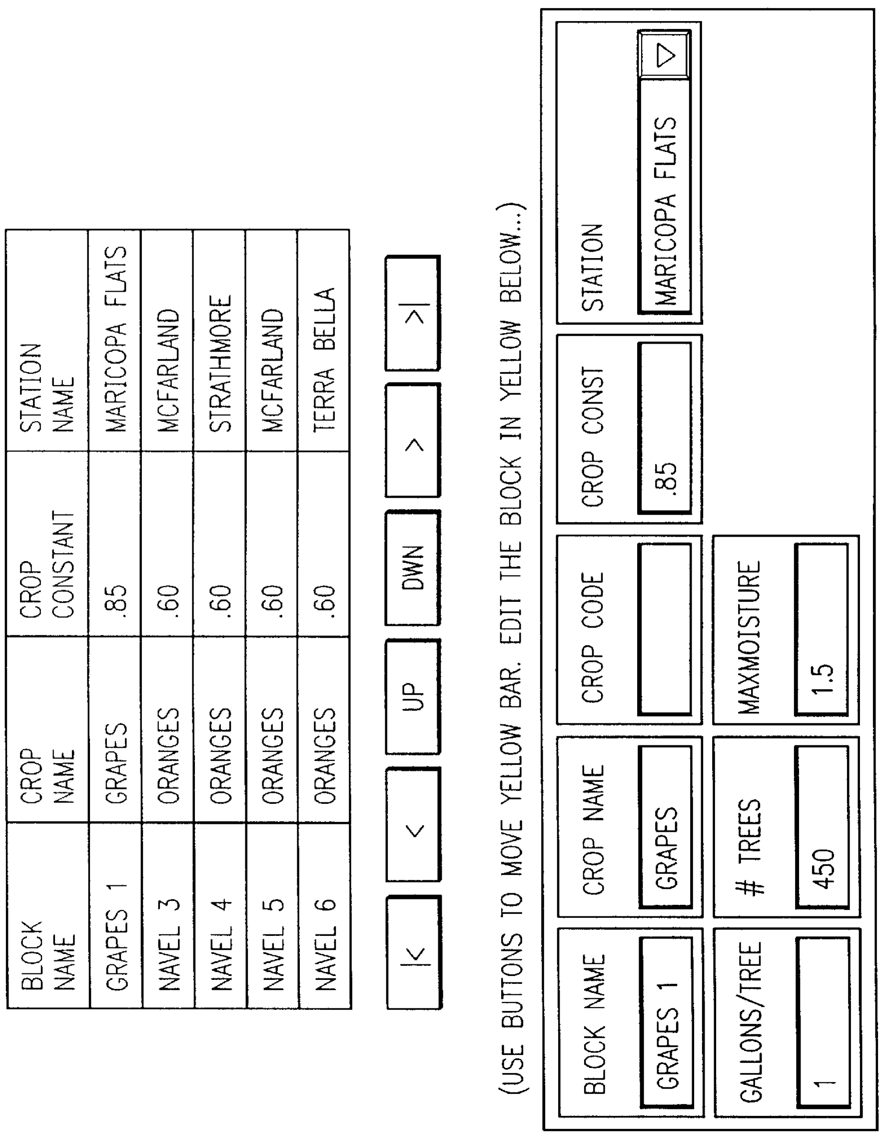

BLOCK NAME
CROP NAME
CROP CONSTANT
STATION NAME
GRAPES 1
GRAPES
.85
MARICOPA FLATS
NAVEL 3
ORANGES
.60
MCFARLAND
NAVEL 4
ORANGES
.60
STRATHMORE
NAVEL 5
ORANGES
.60
MCFARLAND
NAVEL 6
ORANGES
.60
TERRA BELLA
|<
<
UP
DWN
>
>|
(USE BUTTONS TO MOVE YELLOW BAR. EDIT THE BLOCK IN YELLOW BELOW...)
BLOCK NAME
GRAPES 1
CROP NAME
GRAPES
CROP CODE
CROP CONST
.85
STATION
MARICOPA FLATS
GALLONS/TREE
1
TREES
450
MAXMOISTURE
1.5

FIG. 7

REQUIRED WATER/EFFECTIVE RAIN

MCFARLAND

DATE	TEMP	WIND	SOLAR	HUMIDITY	ET	RAIN	NAVEL 3	NAVEL 5	NAVELS 6
7/14/99	88	0.0	737	54	0.32	0	0.19/0	0.19/0	0.27/0
7/15/99	82	0.3	765	53	0.31	0	0.18/0	0.18/0	0.26/0
7/16/99	76	0.3	761	59	0.28	0	0.16/0	0.16/0	0.23/0
7/17/99	74	0.3	778	63	0.28	0	0.16/0	0.16/0	0.23/0
7/18/99	75	0.0	777	56	0.28	0	0.16/0	0.16/0	0.23/0
7/19/99	73	0.8	764	51	0.28	0	0.16/0	0.16/0	0.23/0
7/20/99	70	0.0	785	64	0.26	0	0.15/0	0.15/0	0.22/0
TOTALS FOR PERIOD					2	0	1.2/0	1.2/0	1.7/0
REQ. HOURS FOR PERIOD							89	59	102

FIG. 8

FIG. 9

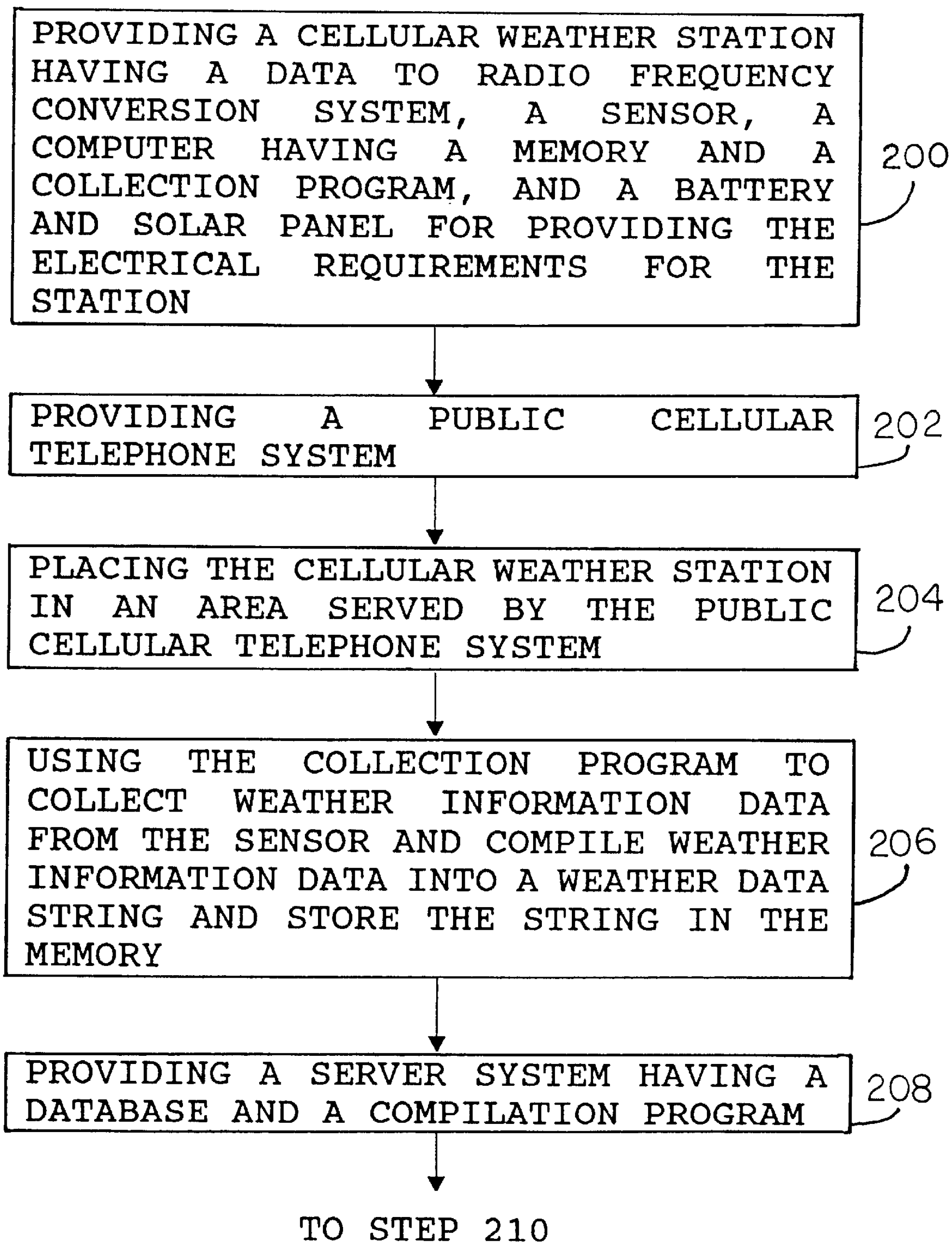

PROVIDING A CELLULAR WEATHER STATION HAVING A DATA TO RADIO FREQUENCY CONVERSION SYSTEM, A SENSOR, A COMPUTER HAVING A MEMORY AND A COLLECTION PROGRAM, AND A BATTERY AND SOLAR PANEL FOR PROVIDING THE ELECTRICAL REQUIREMENTS FOR THE STATION
200
PROVIDING A PUBLIC CELLULAR TELEPHONE SYSTEM
202
PLACING THE CELLULAR WEATHER STATION IN AN AREA SERVED BY THE PUBLIC CELLULAR TELEPHONE SYSTEM
204
USING THE COLLECTION PROGRAM TO COLLECT WEATHER INFORMATION DATA FROM THE SENSOR AND COMPILE WEATHER INFORMATION DATA INTO A WEATHER DATA STRING AND STORE THE STRING IN THE MEMORY
206
PROVIDING A SERVER SYSTEM HAVING A DATABASE AND A COMPILATION PROGRAM
208
TO STEP 210

FIG. 9A

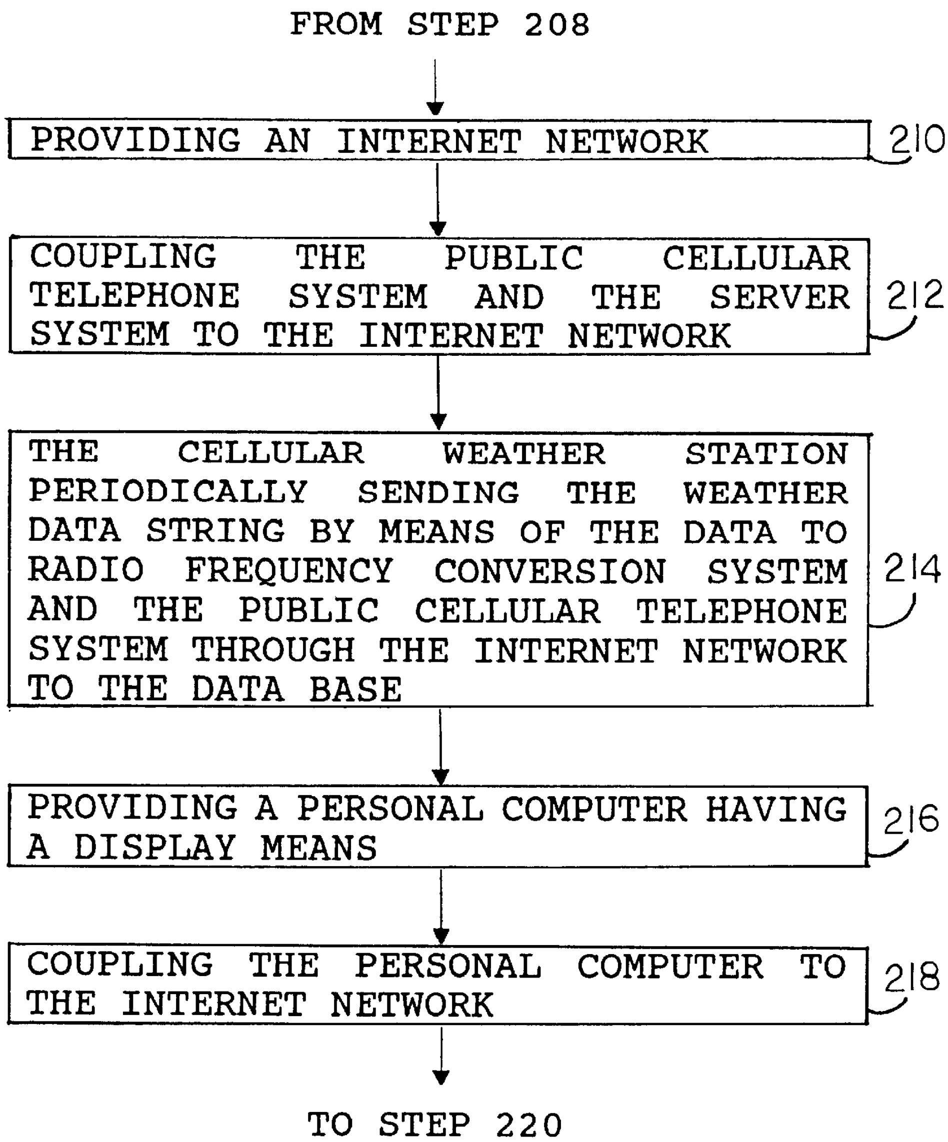

FROM STEP 208
PROVIDING AN INTERNET NETWORK
210
COUPLING THE PUBLIC CELLULAR TELEPHONE SYSTEM AND THE SERVER SYSTEM TO THE INTERNET NETWORK
212
THE CELLULAR WEATHER STATION PERIODICALLY SENDING THE WEATHER DATA STRING BY MEANS OF THE DATA TO RADIO FREQUENCY CONVERSION SYSTEM AND THE PUBLIC CELLULAR TELEPHONE SYSTEM THROUGH THE INTERNET NETWORK TO THE DATA BASE
214
PROVIDING A PERSONAL COMPUTER HAVING A DISPLAY MEANS
216
COUPLING THE PERSONAL COMPUTER TO THE INTERNET NETWORK
218
TO STEP 220

FIG. 9B

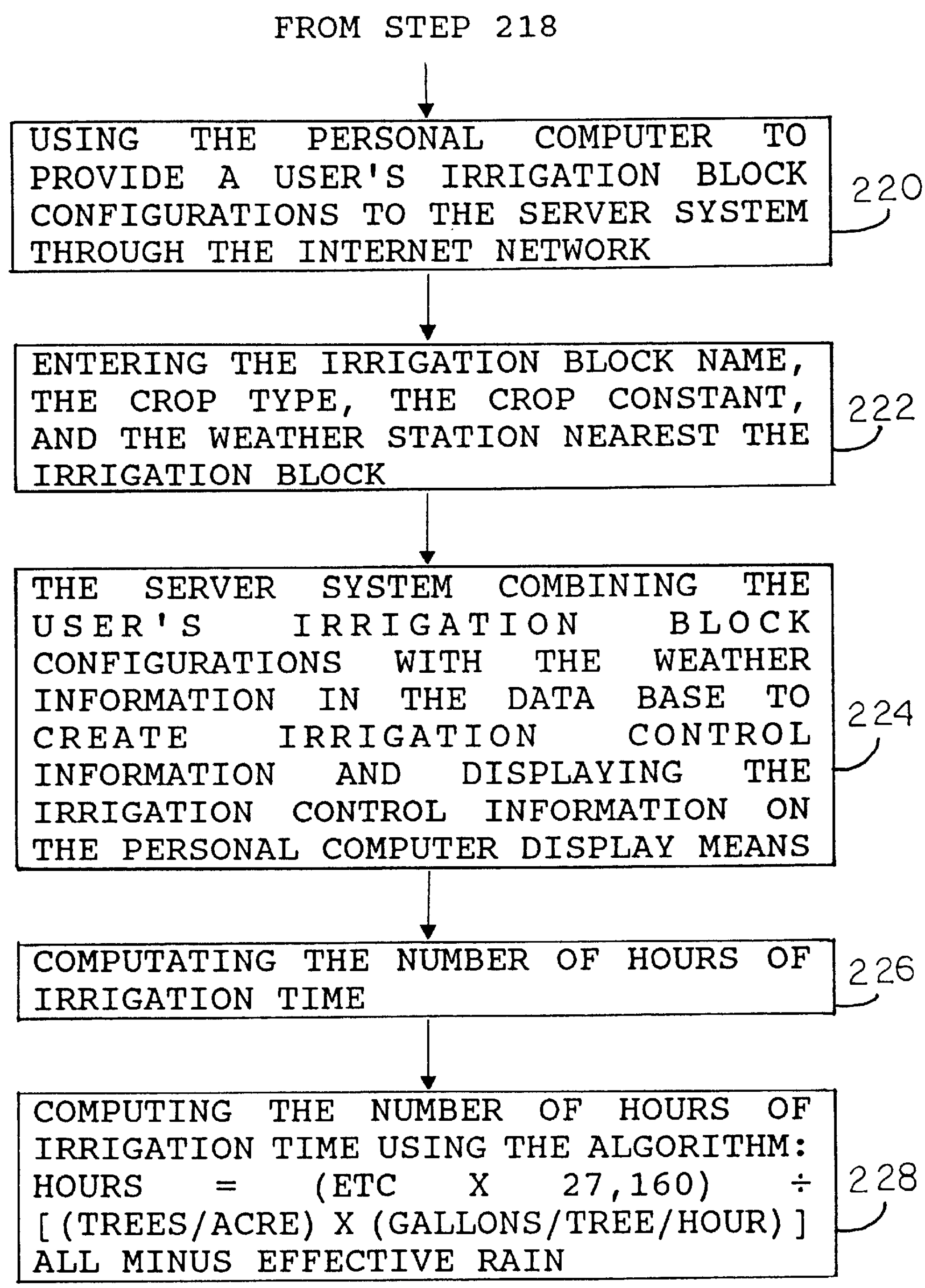

FROM STEP 218
USING THE PERSONAL COMPUTER TO PROVIDE A USER'S IRRIGATION BLOCK CONFIGURATIONS TO THE SERVER SYSTEM THROUGH THE INTERNET NETWORK
220
ENTERING THE IRRIGATION BLOCK NAME, THE CROP TYPE, THE CROP CONSTANT, AND THE WEATHER STATION NEAREST THE IRRIGATION BLOCK
222
THE SERVER SYSTEM COMBINING THE USER'S IRRIGATION BLOCK CONFIGURATIONS WITH THE WEATHER INFORMATION IN THE DATA BASE TO CREATE IRRIGATION CONTROL INFORMATION AND DISPLAYING THE IRRIGATION CONTROL INFORMATION ON THE PERSONAL COMPUTER DISPLAY MEANS
224
COMPUTATING THE NUMBER OF HOURS OF IRRIGATION TIME
226
COMPUTING THE NUMBER OF HOURS OF IRRIGATION TIME USING THE ALGORITHM: HOURS = (ETC X 27,160) ÷ [(TREES/ACRE) X (GALLONS/TREE/HOUR)] ALL MINUS EFFECTIVE RAIN
228

FIG. 10

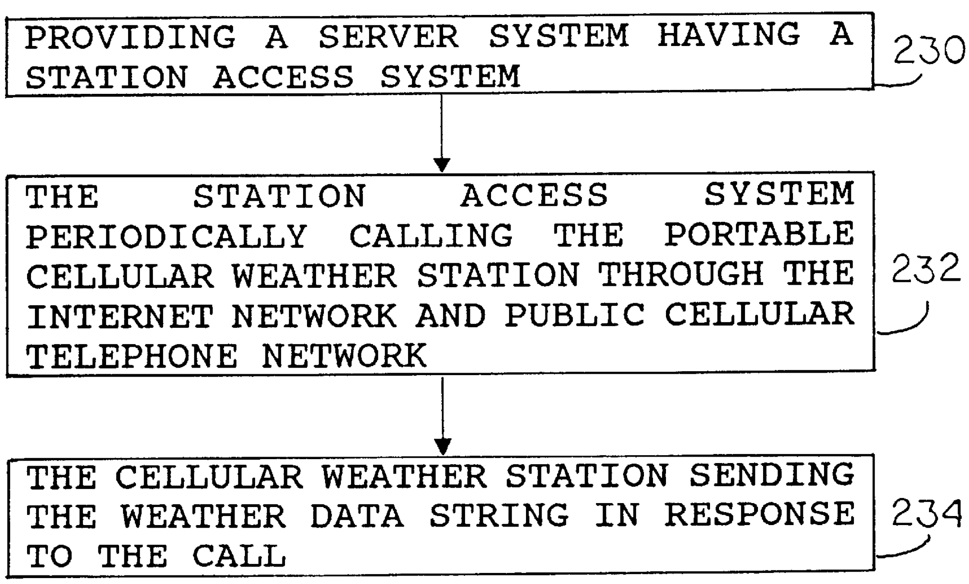

PROVIDING A SERVER SYSTEM HAVING A STATION ACCESS SYSTEM
230
THE STATION ACCESS SYSTEM PERIODICALLY CALLING THE PORTABLE CELLULAR WEATHER STATION THROUGH THE INTERNET NETWORK AND PUBLIC CELLULAR TELEPHONE NETWORK
232
THE CELLULAR WEATHER STATION SENDING THE WEATHER DATA STRING IN RESPONSE TO THE CALL
234

FIG. 11

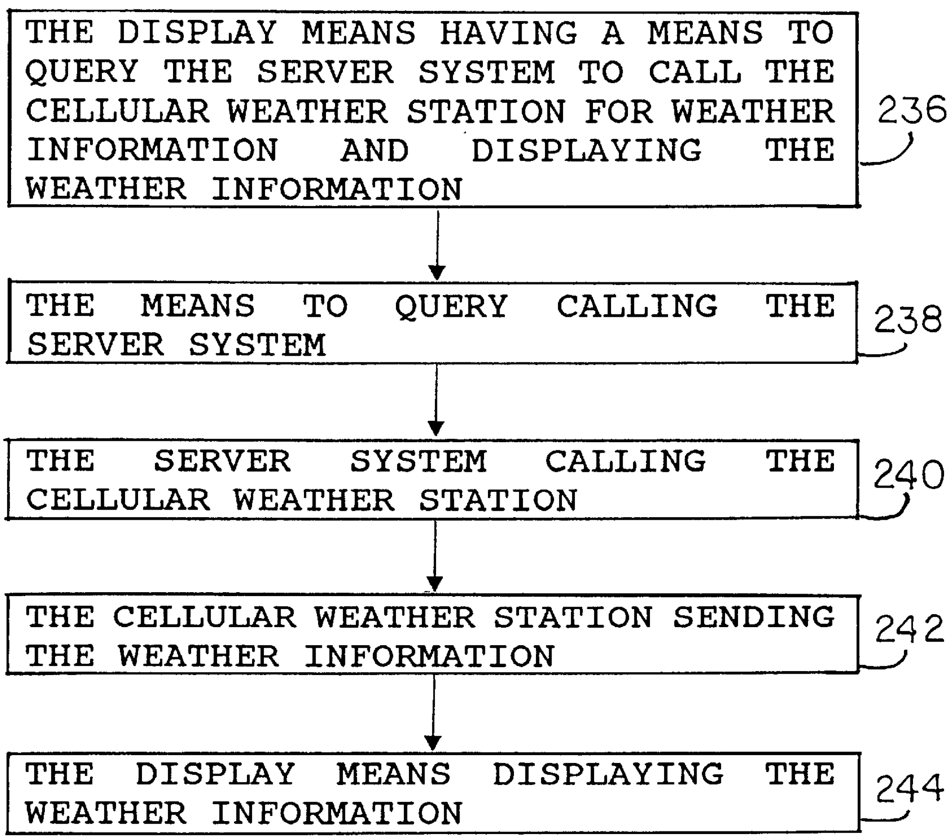

THE DISPLAY MEANS HAVING A MEANS TO QUERY THE SERVER SYSTEM TO CALL THE CELLULAR WEATHER STATION FOR WEATHER INFORMATION AND DISPLAYING THE WEATHER INFORMATION
236
THE MEANS TO QUERY CALLING THE SERVER SYSTEM
238
THE SERVER SYSTEM CALLING THE CELLULAR WEATHER STATION
240
THE CELLULAR WEATHER STATION SENDING THE WEATHER INFORMATION
242
THE DISPLAY MEANS DISPLAYING THE WEATHER INFORMATION
244

FIG. 12

HOURS = (ETc X 27,160) ÷

[(trees/acres) X (gallons/tree/hour)]

all minus effective rain

METHOD AND SYSTEM FOR PROVIDING WEATHER INFORMATION OVER THE INTERNET USING DATA SUPPLIED THROUGH THE INTERNET AND A WIRELESS CELLULAR DATA SYSTEM

TECHNICAL FIELD

The present invention relates generally to the field of transmitting information over the Internet, and more particularly to a method and system for providing weather information over the Internet using data supplied through the Internet and a wireless cellular digital packet data service.

BACKGROUND ART

Weather information has long been compiled from data from weather stations around the world. These weather stations are often located at major airports and universities where the equipment can be monitored. The raw data is brought together over telephone lines to a central location where it is processed into useful information. Maps are typically created summarizing the information for continents, nations, states, and portions of states. This general weather information is of use to most people who are planning their days and weather influenced companies such as airlines, shipping lines, and trucking companies which are planning their departures and routes over vast distances. General weather information is also of interest to farmers who operate in flat areas including the plains and prairies where they grow commodity crops such as wheat, corn, soybeans, and forage crops that are only minimally influence by the weather on any given day.

Farmers who operate in hilly regions, grow specialized crops, and/or depend upon irrigation can also use the macroclimate weather information to plan their general activities. But they can significantly improve their results if they have more specific weather information regarding their particular fields or microclimates. One well known use of specialized weather information is the reporting of freezing conditions which is used to determine the use of wind machines and smudge pots in citrus groves where a one degree difference can ruin a crop. Running the machines and pots every cold night would be too costly. Another situation where specialized weather information is useful is regarding crops that are entirely dependent upon irrigation. Too little irrigation over too long a period can destroy a crop or limit production. More than just enough irrigation to achieve the results desired is wasteful and expensive. Knowledge of exact weather conditions in the fields can help optimize the use of irrigation. In other situations, politicians have mandated that less water be used to irrigate crops. For example, in Ventura County, California, an ordinance was passed requiring a 20% decrease in water use by agricultural interests in certain water districts. The decreased amount of water is sufficient to grow the desired crops but it has to be husbanded carefully.

FIG. **1** is a map of an area in the San Joaquin Valley of central California between Bakersfield and Fresno having a multiplicity of microclimates and need for irrigation. Precise monitoring of these microclimates requires the placement of weather stations in the microclimates and transmission of data to a central location for processing into useful information. The bottom of the valley is flat and has an elevation ranging from 300 to 400 feet. To the west are the Coast Ranges which average 2000 to 3000 feet in height and to the east are the Sierra Nevada Mountains which average 8000 to 9000 in height. These elevation changes cause dramatic differences in microclimates depending upon exact location. Weather stations for monitoring some of these climates have been placed at Ivanhoe, Exeter, Lindsay, Strathmore, Terra Bella, Avenue 2, Blackwell's Corner, Rio Bravo, Arvin, Wheeler Ridge, and Maricopa. The locations of the weather stations are determined by where they are economically justified. Because the bottom of the valley is flat, weather conditions are substantially uniform allowing only two stations at Blackwell's Corner and Wheeler Ridge to suffice. Also, the bottom of the valley is planted in cotton and forage crops which do not require precise weather information. The weather information is therefore used primarily for the optimization of irrigation. Along the east side of the valley, the weather is chopped up into microclimates due to the variable terrain of the foothills of the Sierra Nevada Mountains. A variety of crops are also planted including grapes and fruit, nut, and citrus trees which have different temperature and irrigation requirements. The citrus trees are particularly susceptible to freezing with the possibility of an entire crop being destroyed in one night of cold temperatures. Several weather stations are therefore located along the foothills.

Each weather station indicated on FIG. **1** has a telephone line connected to the local telephone company. The requirement for a telephone line makes installation of a weather station expensive, limits a location to one near a telephone line, makes movement of a weather station difficult, and is expensive because each telephone call to a station is a long distance call. Because of the expense of calling, each station is typically called only three times a week. A computer in each station continuously records the weather information at the station. When the station is subsequently called, all data developed during the period after the previous call is downloaded in a few seconds. While this frequency of calling may be adequate for irrigation purposes, it is much less than is desirable for freeze warning purposes. During periods when freezes may be possible, the stations need to be called frequently. Additional stations would also be helpful because freezing conditions often tend to be highly localized. However, the number of stations must be limited because of the cost.

FIG. **2** shows a prior art hard wired weather information system **50** for reporting on microclimates. The system includes at least one weather station **30**. A telephone line **32** runs either underground or on poles to an I/O (input/output) board inside a rainproof enclosure **34**. Attached to the I/O board are a number of weather sensors including a wind direction indicator **36**, wind speed anemometer **38**, solar radiation sensor **40**, sun shielded temperature sensor **41**, tilting bucket rain gauge **42**, and humidity sensor **44**. A computer inside the enclosure processes the data from the input sensors into data that is stored in a data logger until the station is called and a download signal is given. Power is provided to the weather station from the local power grid through a wire **46**.

An access computer **52** is programmed to request a dial tone, dial a telephone number, identify an answer by the weather station **30**, and create a carrier detect signal that is sent over the telephone line **32** to the weather station **30**. In response to the carrier detect signal, the computer in the weather station accesses its memory and downloads the data over the telephone line to the data storage section **54** of the access computer **52**. After retrieving the data from one weather station, the access computer **52** continues down its list of other weather stations such as the ones in FIG. **1** collecting data from them one at a time in the same manner.

A system user can use his personal computer **60** to query the access computer **52** through a computer network **62** such as the Internet for any desired information. For example, he could ask for the most recent information from a particular weather station, a list of information for the past week, a list of information for the same week in the previous year, or any other form of useful information. The information is then presented on a display screen **64**.

FIG. **3** is a sample of the daily weather information provided by the central computer from the weather station in Arvin as it would be displayed on the display screen **64** of the user's computer **60** including maximum, minimum, and average temperature in Fahrenheit degrees; average wind speed and wind gusts in miles per hour; wind direction in degrees with north at 0°; solar radiation in langleys (watts per square centimeter); average humidity in percent; and rain in inches.

The second column labeled ET is for the evapotranspiration rate in inches of water per day at the station. Evapotranspiration is the loss of water from the soil both by evaporation from the surface and by transpiration from plants growing on the soil. The plant used to compute standard ET is grass two inches tall. For example, on Aug. 3, 1999, grass two inches tall required 0.28 inches of water to maintain normal growth because of the temperature, humidity, and solar radiation at that exact location on that day. Each crop has a different water requirement for normal growth defined as a crop constant which is stated as a percentage of the standard ET. Empirical studies have determined the following crop constants: almonds 100%, grapefruit 75%, grapes 85%, and oranges 67%. For example, if grass requires 0.30 inches of water on a day, oranges will require 67%×0.30=0.20 inches of water on the same day. This moisture can come either from irrigation or rain. If rain has occurred in the past twenty-four hours, the amount of rain is determined by the rain gauge **42** and the farmer subtracts it from the total required. For example, if 0.20 inches of water are required and 0.02 inches of effective rain have fallen in the past twenty-four hours, the farmer would irrigate his crop with 0.18 inches of water that day. The access computer **52** computes the ET values shown in FIG. **3** from the other weather data using a proprietary algorithm.

While current hard wired systems are able to provide a farmer with information on microclimates which he can use to control irrigation and control other production functions, communication between the access computer and the weather stations is expensive. Therefore, the farmer is less likely to install new stations or receive weather data as often as he would like, especially for frost protection purposes. Furthermore, the farmer usually either develops or buys software programs or uses manual calculations to apply weather station data to his specific irrigation and crop field configurations. This requires data processing or calculation expertise which he may not have. Consequently, a need exist for improvements in methods and systems for providing information from microclimate weather stations.

DISCLOSURE OF INVENTION

The present invention is directed to a system and method for accessing and displaying weather information. A weather station collects weather information data from sensors using a collection program and assembles the data as a data string in its memory or separate data logger. An access computer system periodically calls the weather station through the Internet and a wireless cellular digital packet data system. The weather station transmits the weather data string to a data base. A user contacts the data base through the Internet using the user's personal computer to ask for the weather information. The information is compiled from the data base and transmitted to the user's display over the Internet.

In accordance with another preferred embodiment of the invention, the user causes an access computer function to call the weather station at intervals between the normal periodic calls made by the access computer system by transmitting this request through the Internet from the user's personal computer.

In accordance with another preferred embodiment of the invention, the user sends the user's crop and field configurations to the data base through the Internet. The server system combines the crop and field configurations with the weather information and returns customized crop production and control information through the Internet to the user.

In accordance with another preferred embodiment of the invention, a wireless digital cellular hand held computer having a display is used and the information is displayed on the display.

In accordance with another preferred embodiment of the invention, the access computer has a computer generated voice. The user dials the access computer with a standard telephone. The keys of the telephone are used to enter codes into the access computer to request specific weather information and the access computer replies by way of the computer generated voice over the telephone.

In accordance with an important feature of the invention, the user enters a request for notification of a desired condition into the access computer. The access computer sends a page to a pager when the preexisting condition is reached which notifies the user of the condition such as a freezing temperature.

Other features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a map of an area in the San Joaquin Valley of central California having many microclimates;

FIG. **2** shows a prior art hard wired weather information system for reporting on microclimates;

FIG. **3** is a sample display of the daily weather information provided by the access computer from a weather station;

FIG. **4** illustrates a system for providing weather information over the Internet using data supplied through the Internet and a wireless cellular digital packet data service;

FIG. **5** illustrates a weather station having a wireless cellular digital packet data service connection;

FIG. **6** shows two weather stations installed on a single farm;

FIG. **7** is a sample display of a particular farmer's crop and field configurations as sent to the weather information system;

FIG. **8** is a sample display of customized crop production and control information provided in return by the weather information system to the farmer for use in controlling his specific crops.

FIG. **9** is a flow chart illustrating the steps in a method of using a cellular weather station and computer system using the public cellular data telephone system and Internet for controlling irrigation;

FIG. **10** is a flow chart illustrating the steps in another method for obtaining weather data from the cellular weather station;

FIG. **11** is a flow chart illustrating the steps in yet another method for obtaining weather data from the cellular weather station; and,

FIG. **12** is an algorithm used in the system and method.

MODES FOR CARRYING OUT THE INVENTION

Referring initially to FIG. **4**, there is illustrated a system for providing weather information over the Internet using data supplied through the Internet and a common carrier wireless cellular data service such the wireless cellular digital packet data service provided by General Telephone in accordance with the present invention, generally designated as **100**.

FIG. **5** shows a weather station **102** configured to operate within the weather information system **100**. The weather station **102** is similar to the prior art weather station **30** of FIG. **2** to which are added a solar panel **103**, a battery **104**, a data to radio frequency conversion system such as cellular digital packet modem **105**, and a cellular telephone antenna **107**. These additions make the weather station **102** entirely portable. Since weather information is most valuable if it is at the exact location of interest, a farmer can move the station **102** as needed to provide optimal benefit. For example, one year a field may be left fallow and the farmer will move the station to a field that is in use. Or a field may have a crop in a portion of a growing cycle requiring immediate information such as freezing conditions in a citrus grove. The farmer can then move a station into the grove. After the citrus crop is harvested, the farmer can move the station to another crop which is of more interest.

Data from a wind direction indicator **108**, wind speed anemometer **109**, solar radiation sensor **110**, shielded temperature sensor **111**, tilting bucket rain gauge **112**, and humidity sensor **114** are compiled and recorded as weather data strings in the memory of a micro processor computer **116** or separate data logger inside a rainproof enclosure **115** of the weather station **102** using a collection program. Other sensors may be added to monitor the specific conditions in the particular field and/or adjacent fields. For example, soil moisture sensors of the gypsum type can measure soil moisture at various root depths, a series of flow meters can be added to the irrigation pipes to measure the timing and quantity of water delivered to the crops, leaf wetness sensors can measure the moisture on leaves, chemical sensors can measure fertilizer levels, and pH meters can measure pH levels in the soil. These additional sensors can supply the weather station **102** with data for entry into the memory either through hard wires or short range radios. One advantage of radios is that they allow the sensors to be readily moved about as conditions change during the growing season.

FIG. **6** illustrates weather stations **102** installed on a single farm **120** located in the foothills with a ridge **122** to the north having elevations greater than 1000 feet and another ridge **124** to the southeast also with elevations greater than 1000 feet. The bottom **125** of the river valley through the farm ranges from 600 to 700 feet. A first weather station **126** is located at 600 feet in the center of the farm. Another weather station **128** is located at 700 feet adjacent the southeast ridge **124**. The purchase and positioning of weather stations is entirely dependent upon economics. Generally, the less expensive the stations become, the more stations the farmer will decide to purchase or have installed. In the present situation, the farmer has determined that a second weather station is warranted even though the first weather station is

located within 6000 feet of the first station. The reason is that the microclimate surrounding the second station is sufficiently different from the climate around the first station that the information provided by the first station has only limited value in the area of the second station. Whether or not a second station is actually installed is determined by the added value of the crops produced in the second area as a result of the information provided by the second weather station. Generally, the data from the first station is sufficient for most of the farm. The second station provides information on the microclimate backed up against the southeast ridge and also corroborates the data from the first station.

Even in the limited area shown in FIG. **6**, the farmer will find it more convenient to use a weather information system **100** of the present invention rather than install a hard wired system because he can readily move the weather stations around as desired and he can let someone else take care of the system. Also he can still access information from other weather stations further away from his farm if needed. But generally, he will ask for information only from weather stations **126** and **128** because they are most relevant to his situation. In contrast, a farmer in a more open area of the valley such as shown in FIG. **1**, can use a more remote preexisting station by contracting with the weather information system **100** without having to have stations installed on his property.

As shown in FIG. **4**, communication between a server system **188** and the weather station **102** has six links: 1. a modem **142** or other network connects to an Internet service provider **146**; 2. the service provider uses a hard wire connection to the Internet network **150**; 3. the call is routed through the Internet **150**; 4. a second hard wire or fiber optic cable **152** carries the call to a common carrier wireless cellular digital packet data service (CDPD) **154** such as provided by General Telephone; 5. the CDPD service transfers the call by a third hard wire or fiber optic cable **156** to its antenna **158**; and, 6. the CDPD service sends the call by a radio signal **160** to the antenna **107** of the weather station's digital modem **162**. Upon receiving an access signal from the station access system **140**, the weather station computer **116** identifies the access signal and downloads a string of data from its memory **161** through a digital packet modem **162** in the reverse direction where it is recorded in a data base **164**. A digital packet modem such as the Air Link Raven Model 9700 modem made by Air Link Communications of San Jose, Calif., can be used.

When a farmer wants to use this information and the information from the other relevant weather stations, he uses a user display means such as his personal computer **170** to call the server system **188** over the Internet **150**. The server system uses a compilation program to compile the information requested by the farmer from the data base **164**. This information is presented on the display **172** of the farmer at his personal computer **170**. The farmer can also request new information from the weather station **102** at any time through the weather information system **100**. For example, during unusual situations such as possible freezing temperatures, the farmer can ask the system to report temperatures every few minutes. The farmer can cause the station access system to update the data from the weather station of interest by sending the request for this real time information from his personal computer **170** to the station access system **140** through the Internet **150** and the server system **188**.

Farmers need to spend time in the field inspecting irrigation systems, crop disease conditions, and soil conditions. They are reluctant to spend much of their time at a computer keyboard. Therefore in another embodiment, the system does the calculation and computer data processing required allowing the farmer to spend his time in the field and other farming operations. Before such data processing can be accomplished, however, the farmer's crop and field configurations must be available to the server. This is accomplished by the farmer sending his field and sprinkler configurations to the user's records systems **187** by using his computer **170**, the Internet communication system, and the server system **188**, as described above. For example, the farmer sends the data on his irrigation block including the crop type and the sprinkler gallons per hour per tree or vine to his private table on the user records system **187** within the server system **188**.

FIG. **7** illustrates a sample display of the type of data sent regarding the crop and field configurations for a particular farmer and is shown as actually seen by the farmer on his computer display **172** (FIG. **4**). The first column of the upper table shows the block name; the second the crop type; the third the crop constant; and the fourth the weather station nearest the block for which data is requested. The bottom table allows the farmer to modify the configurations at his discretion. For example, the bottom table is shown as accessing the information regarding the top crop line of the upper table with the entries being identical. Additional information is entered on the bottom line of the bottom table. Each vine ("tree") requires 1 gallon per day. There are 450 vines ("trees") per acre. The maximum moisture entry is used in conjunction with rainfall. In the current example, all rainfall which exceeds 150% of the average required water merely runs off and is lost. It therefore is not effective and is not included in the calculations. This algorithm is done by the server system and results in the proper amount to be subtracted from the crop ET to provide the proper amount of water the block used per acre for that crop.

It is not necessary to apply an ideal amount of moisture each day. The soil acts as a sponge retaining moisture from day to day. Typically, a farmer decides on Monday how much moisture he wants to apply to a field for the whole week. He then divides the number of total hours by the number of days he wants to run the system. He can also vary the number of hours on any particular day. For example, he may decide to run the system one day, every other day, every day, or some other combination of days. He can also decide to water the same number of hours each watering day or more hours on one watering day and less on another watering day. What is important is that over the week or other period of watering, the plants receive just enough water to achieve optimal growth without too much extra.

FIG. **8** is a sample display of the customized crop production and control information provided in return to the farmer over the Internet from the server system for use in controlling his specific crops. After the configuration data of FIG. **7** is downloaded to the user records system **187**, the algorithm calculation and data processing system within the server system calculates the hours of irrigation needed to replace the water used by the crop during the previous period. The farmer in the sample is using a one week period. He decides exactly how he wants to irrigate his crops based on what happened the previous week. The most important numbers are shown in the bottom two lines. For example, his block of Navel 3 orange trees received 1.2 inches of irrigation water over the previous week and no rain. In order to apply the same amount of water over the week to come, he will have to operate his irrigation system in the Navel 3 block for a total of 89 hours. He can divide up this 89 hours over the seven days in any manner that is convenient for him. For example, he could apply the same amount of water each day by dividing by 7 for an average of about 13 hours a day.

In contrast, the number of hours required for the block Navel 5 is 59 hours total and the number of hours for the block Navel 6 is 102 hours. The differences are cause by the configurations of the irrigation systems in the different blocks. Some apply more water per hour and some apply less. How much water a given irrigation system applies in a particular block is entered into the calculation in another data table for the block that is not shown.

All of the other information on FIG. **8** is helpful to the farmer in allowing him to understand exactly what is happening but is not essential. The date of each line is given in the left column. The four components of ET are shown in the next four columns with ET shown in the sixth column. Generally, the weather was cooling off during the week with a corresponding decrease in the amount of irrigation water required. The seventh column shows that there was not any rain. The last three columns show how much water should have been applied to each of the crop blocks for each day with the irrigation component given on the left and the rain component given on the right. There has been no rain so all of the rain components are "0." Therefore, looking down the Navel 3 column only, on July 14, 0.19 inches of irrigation water were required by this particular crop on this day to replace the water used by the crop. On July 15, 0.18 inches of irrigation water were required. For the whole week, 1.2 inches of irrigation water were required (ETc, i.e., ET for the particular crop). These numbers do not represent the amounts of water the farmer actually applied on those days. They are the ideal amounts he should have applied given the weather conditions. The hours needed, i.e. 89 hours, to actually achieve this level of irrigation is given at the bottom and is calculated by the algorithm: hours=(ETc×27,160)÷[(trees/acre)×(gallons/tree/hour)] all minus the effective rain.

This all means that a farmer can determine how many hours to irrigate each week (or other period) in order to replace the water used by each block without having to make any complicated calculations. He only has to compare the amount of water applied each week with what was used by the crop to determine if he is behind or ahead of what is needed. Thus the farmer has an interactive relationship with the server system which accesses data from the relevant weather stations, creates a data base containing current and historical weather data, records the farmer's irrigation blocks and crop configurations, combines these two sets of data, calculates the irrigation times and other crop production parameters, and makes the results available to the farmer through the Internet.

Alternatively, the farmer can connect to the server system **188** using a hand held computer **180** (FIG. **4**) as a user display means having a digital radio frequency communication capability such as a Palm VII computer sold by Palm Computing, Inc. of Santa Clara, Calif. A cellular digital signal **182** from the hand held computer **180** travels to the hand held provider **181** and then through the Internet **150** to the server **188** and data base **140**. The Palm VII displays the resulting data in a limited format specifically directed to a particular field, crop, or condition.

The farmer can also call a special number through the local telephone provider using either a telephone **183** or cellular telephone which connects to the voice and alarm systems **184**. The keys on the telephone are then used to dial code numbers which cause the voice system to compile the desired information using the data base **164** and download the information to the caller in audio format over the telephone as an alternative user display means. A suitable synthesized computer voice module is sold by Dial Logic of

Parsippany, N.J. The connection to the audio output of the voice system **184** is particularly helpful for monitoring freezing conditions and controlling other crop production operations when the farmer is out in the field. For example, the access computer can keep track of the current weather conditions and the amount of irrigation water applied up to the query time and then tell the caller how much time remains for the valves to stay open to complete the irrigation needed.

When information on only a particular event is required, a pager **186** can be used as another alternate user display means. Prior to going out into the field, the farmer can use his computer **170** or telephone **183** to tell the access computer to send a signal to his pager **186** when a particular event occurs. For example, the access computer could be directed to send a signal to a pager only when a freezing temperature has been reached. Or real time temperatures can be continuously displayed on the display screen of the pager identifying the value of the variable as well as previous values.

FIG. **9** is a flow chart illustrating the steps in a method of using a cellular weather station and computer system using the public cellular data telephone system and Internet for controlling irrigation. A cellular weather station is provided in step **200** having a data to radio frequency conversion system, a sensor, a computer having a memory and a collection program, and a battery and solar panel for providing the electrical power requirements for the cellular weather station. A public cellular telephone system is provided in step **202** and the cellular weather station is placed in step **204** in an area served by the public cellular telephone system. The collection program is used to collect in step **206** weather information data from the sensor and compile it into a weather data string and store the string in the memory. A server system is provided in step **208** having a data base and a compilation program. An Internet network is provided in step **210** and the public cellular telephone system and the server system are coupled in step **212** to it. The cellular weather station periodically sends in step **214** and the weather data string by means of the data to radio frequency conversion system and the public cellular telephone system through the Internet network to the data base. A personal computer is provided in step **216** having a display. The personal computer is coupled in step **218** to the Internet network. The personal computer is used in step **220** to provide a user's irrigation block configurations to the server system through the Internet network. The user's irrigation block configurations are entered in step **222** including the irrigation block name, the crop type, the crop constant, and the weather station nearest the irrigation block. The server system combines in step **224** the user's irrigation block configurations with the weather information in the data base to create irrigation control information and displays the irrigation control information on the personal computer display means. The step of combining the user's crop and field configurations with the weather information to create irrigation control information includes computation in step **226** of the number of hours of irrigation time. The number of hours of irrigation time is computer in step **228** using the algorithm: hours=(ETc×27,160)÷[(trees/acre)×(gallons/tree/hour)] all minus effective rain. See FIG. **12**.

FIG. **10** is a flow chart illustrating the steps in another method for obtaining weather data from the cellular weather station. The server system is provided in step **230** with a station access system. The station access system periodically calls in step **232** that portable cellular weather station through the Internet network and public cellular telephone network. The cellular weather station sends in step **234** the weather data string in response to the cell.

FIG. **11** is a flow chart illustrating the steps in yet another mtehod for obtaining weather data from the cellular weather station. The display means of the personal computer is provided with a means to query in step **236**. The means to query calls in step **238** the server system. The server system calls in step **240** the cellular weather station. The cellular weather station sends in step **242** the weather information to the display means. And the display means displays in step **244** the weather information.

The preferred embodiments of the invention described herein are exemplary and numerous modifications, dimensional variations, and rearrangements can be readily envisioned to achieve an equivalent result, all of which are intended to be embraced within the scope of the appended claims.

We claim:

1. A method for controlling irrigation, comprising:

providing at least one cellular weather station having:
 a data to radio frequency conversion system;
 at least one sensor; and,
 a computer having a memory and a collection program;

providing a public cellular telephone system;

placing said at least one cellular weather station in an area served by said public cellular telephone system;

using said collection program to collect weather information data from said at least one sensor and compiling said weather information data into at least one weather data string and storing said at least one weather data string in said memory;

providing a server system having a data base and a compilation program;

providing an Internet network;

coupling said public cellular telephone system and said server system to said Internet network;

said at least one cellular weather station periodically sending said at least one weather data string by means of said data to radio frequency conversion system and said public cellular telephone system through said Internet network to said data base;

providing a personal computer having a display means;

coupling said personal computer to said Internet network;

using said personal computer to provide a user's irrigation block configurations to said server system through said Internet network; and,

said server system combining said user's irrigation block configurations with said weather information in said data base to create irrigation control information and displaying said irrigation control information on said personal computer display means.

2. The method of claim **1**, wherein said step of providing said user's irrigation block configurations includes the steps of entering the irrigation block name, the crop type, the crop constant, and the weather station nearest the irrigation block.

3. The method of claim **2**, wherein said step of combining said user's irrigation block configurations with said weather information to create irrigation control information includes computation of the number of hours of irrigation time.

4. The method of claim 3, wherein said number of hours of irrigation time is substantially computed using the algorithm:

hours=(ETc×27,160)÷[(trees/acre)×(gallons/tree/hour)] all minus effective rain.

5. A cellular weather station and computer system using the public cellular telephone system and the Internet network for controlling irrigation, comprising;

at least one cellular weather station having:

a data to radio frequency conversion system;

at least one sensor; and,

a computer having a memory and a collection program for collecting weather information data from said at least one sensor and compiling said weather information data into at least one weather data string and storing said at least one weather data string in said memory;

a public cellular telephone system;

a server system having a data base and a compilation program;

an Internet network coupled to said server system and said public cellular telephone system;

said at least one cellular weather station for periodically sending said at least one weather data string by means of said data to radio frequency conversion system and said public cellar telephone system through said Internet network to said data base;

a personal computer having a display means and coupled to said Internet network for entering a user's irrigation block configurations in said server system through said Internet network; and,

said server system for combining said user's irrigation block configurations with said weather information in said data base to create irrigation control information and displaying said irrigation control information on said personal computer display means.

6. The system of claim 5, wherein said display means for entering a user's irrigation block configurations includes a means for entering the irrigation block name, the crop type, the crop constant, and the weather station nearest the irrigation block.

7. The system of claim 6, wherein said combining said user's irrigation block configurations with said weather information to create irrigation control information includes computation of the number of hours of irrigation time.

8. The system of claim 7, wherein said irrigation time is substantially the number of hours computed using the algorithm:

hours=(ETc×27,160)÷[(trees/acre)×(gallons/tree/hour)] all minus effective rain.

9. The system of claim 5, wherein said personal computer display means has a means to query said server system to call said at least one cellular weather station for weather information and displaying the weather information.

10. The system of claim 5, said at least one cellular weather system further including a battery and solar panel for providing the electrical power requirements for said at least one cellular weather station.

11. The system of claim 5, further including said server system having a station access system for periodically calling said portable cellular weather station through said Internet network and public cellular telephone network and said at least one cellular weather station sending said at least one weather data string in response to said call.

12. The method of claim 1, wherein said step of providing a personal computer having a display means includes said display means having a means to query said server system to call said at least one cellular weather station for weather information and displaying the weather information, further including:

said means to query calling said server system;

said server system calling said at least one cellular weather station; and,

said at least one cellular weather station sending said weather information; and,

said display means displaying said weather information.

13. The method of claim 1, said step of providing at least one cellular weather station further including a battery and solar panel for providing the electrical power requirements for said at least one cellular weather station.

14. The method of claim 1, further including:

said step of providing a server system having a station access system;

said station access system periodically calling said portable cellular weather station through said Internet network and public cellular telephone network; and,

said at least one cellular weather station sending said at least one weather data string in response to said call.

* * * * *

US006437692B1

(12) **United States Patent**
Petite et al.

(10) **Patent No.: US 6,437,692 B1**
(45) **Date of Patent: Aug. 20, 2002**

(54) **SYSTEM AND METHOD FOR MONITORING AND CONTROLLING REMOTE DEVICES**

(75) Inventors: **Thomas D. Petite**, Douglasville; **Richard M. Huff**, Conyers, both of GA (US)

(73) Assignee: **StatSignal Systems, Inc.**, Atlanta, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/439,059**

(22) Filed: **Nov. 12, 1999**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/271,517, filed on Mar. 18, 1999, which is a continuation-in-part of application No. 09/102,178, filed on Jun. 22, 1998, which is a continuation-in-part of application No. 09/172,554, filed on Oct. 14, 1998, now Pat. No. 6,028,522, which is a continuation-in-part of application No. 09/412,895, filed on Oct. 5, 1999, now Pat. No. 6,218,953

(60) Provisional application No. 60/146,817, filed on Aug. 2, 1999.

(51) **Int. Cl.**[7] **G08B 21/00**

(52) **U.S. Cl.** **340/540**; 340/531; 340/539; 340/3.1; 340/426; 340/521; 340/870.01; 340/870.03; 340/870.07; 340/870.08; 340/870.16; 340/870.17; 700/108; 702/56

(58) **Field of Search** .... 340/531, 539, 340/3.1, 426, 540, 521, 870.01, 870.03, 870.07, 870.08, 870.16, 870.17, 988; 700/108; 343/711, 700 R, 720; 702/56

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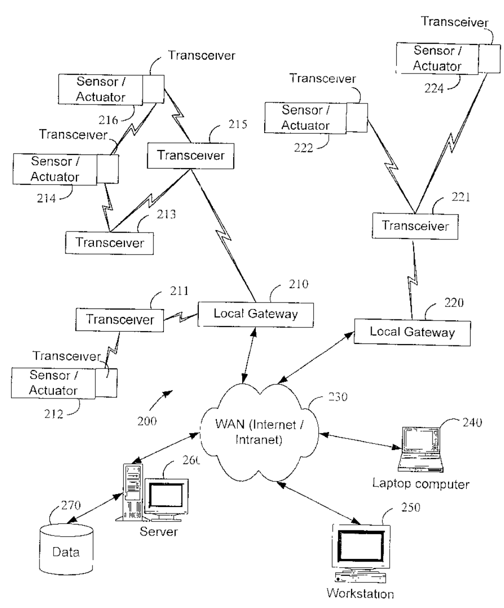
Primary Examiner—Benjamin C. Lee
(74) *Attorney, Agent, or Firm*—Thomas, Kayden, Horstemeyer & Risley

(57) **ABSTRACT**

The present invention is generally directed to a system for monitoring a variety of environmental and/or other conditions within a defined remotely located region. In accordance with one aspect of the invention, a system is configured to monitor utility meters in a defined area. The system is implemented by using a plurality of wireless transmitters, wherein each wireless transmitter is integrated into a sensor adapted to monitor a particular data input. The system also includes a plurality of transceivers that are dispersed throughout the region at defined locations. The system uses a local gateway to translate and transfer information from the transmitters to a dedicated computer on a network. The dedicated computer, collects, compiles, and stores the data for retrieval upon client demand across the network. The computer further includes means for evaluating the received information and identifying an appropriate control signal, the system further including means for applying the control signal at a designated actuator.

64 Claims, 18 Drawing Sheets



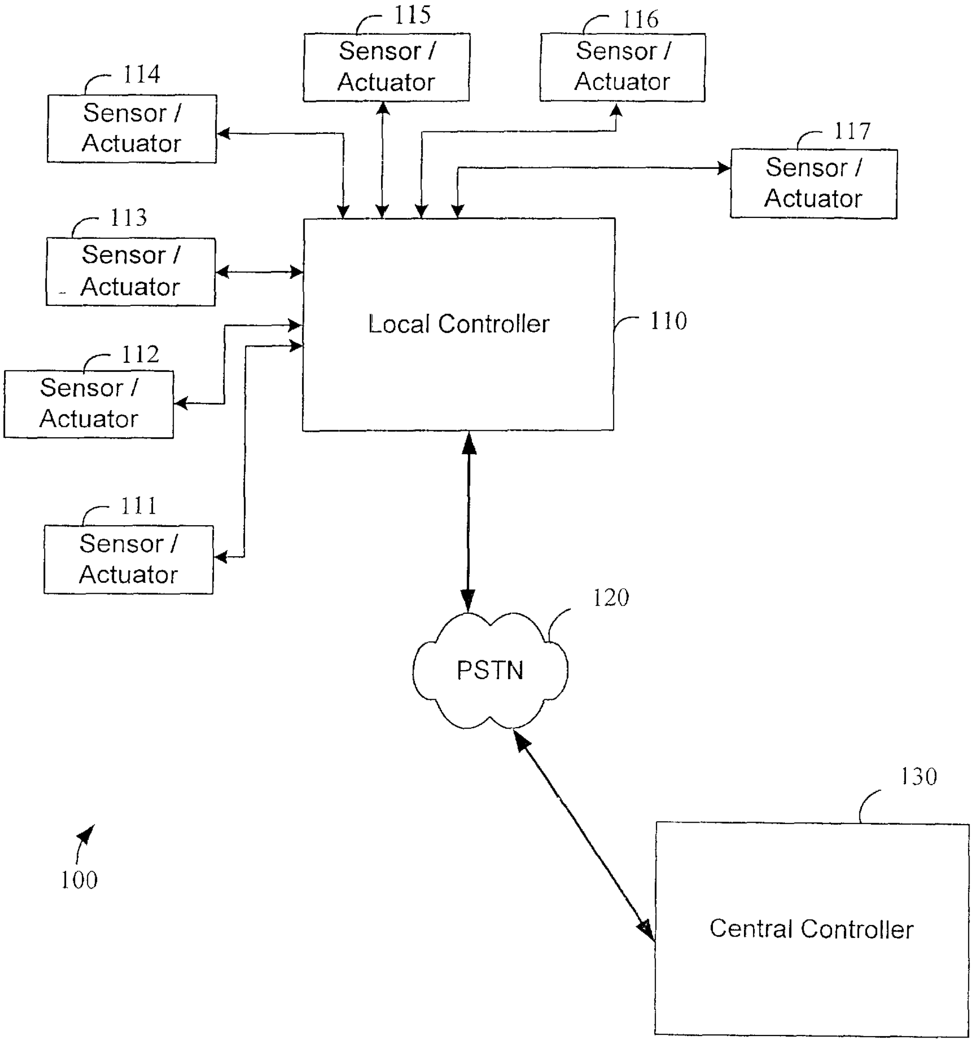


FIG. 1
(PRIOR ART)

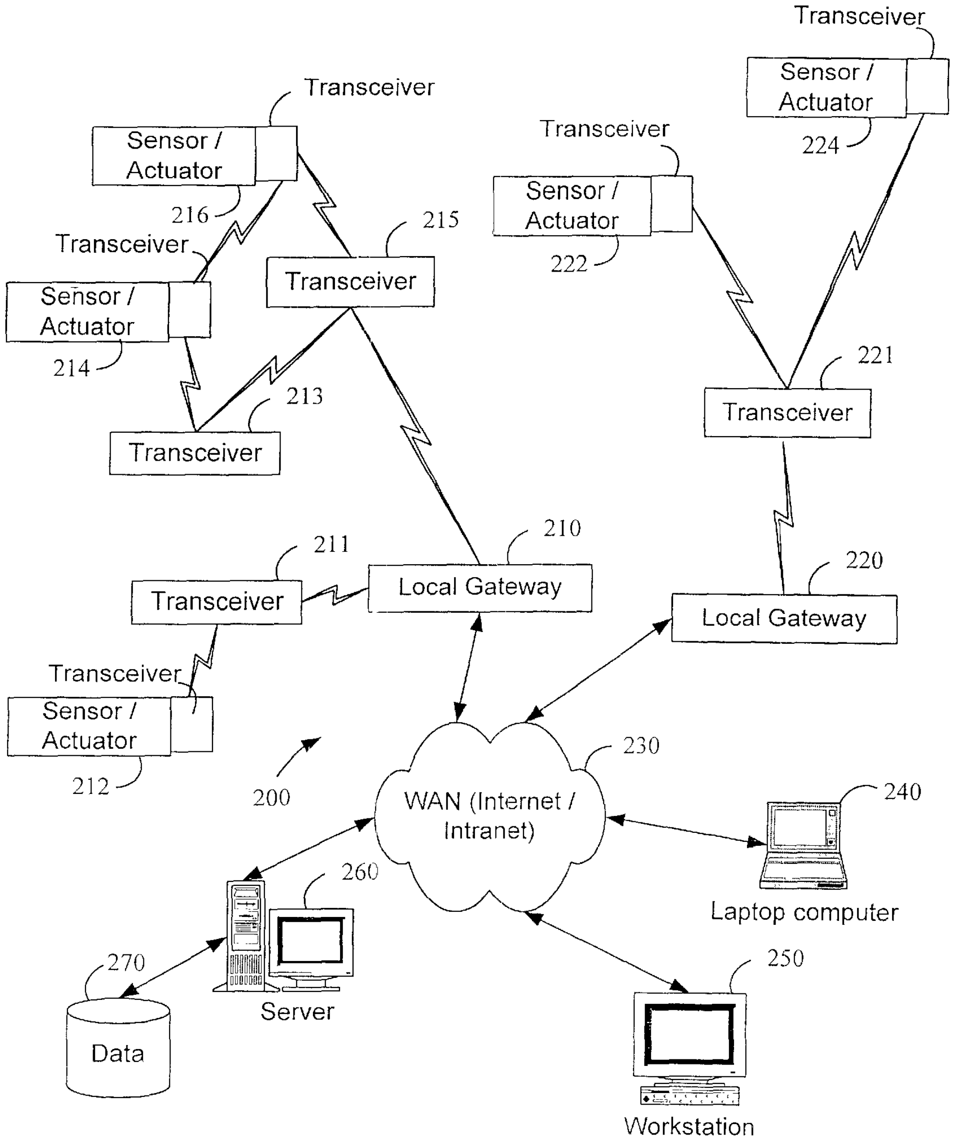

Transceiver
Sensor / Actuator
224
Transceiver
Sensor / Actuator
216
Transceiver
Sensor / Actuator
222
215
Transceiver
Transceiver
Sensor / Actuator
214
221
213
Transceiver
Transceiver
210
211
220
Transceiver
Local Gateway
Local Gateway
Transceiver
Sensor / Actuator
212
200
230
WAN (Internet / Intranet)
240
260
Laptop computer
270
250
Server
Data
Workstation

FIG. 2

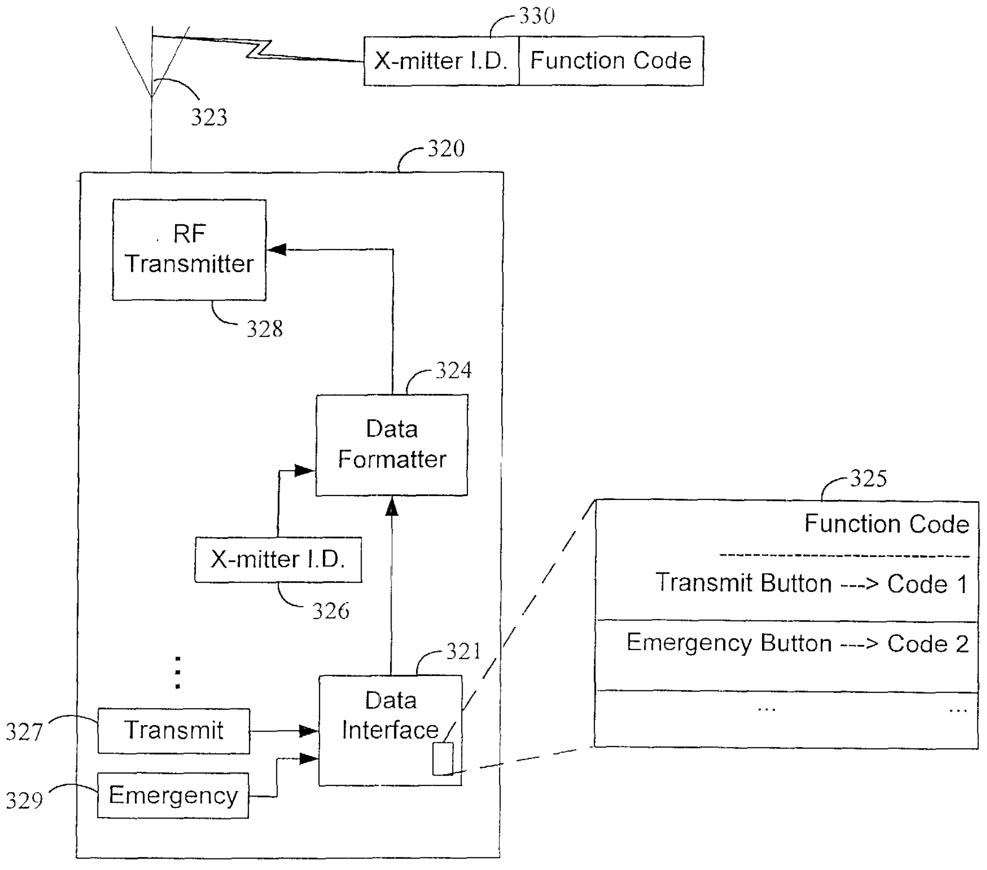

330
X-mitter I.D.
Function Code
323
320
RF Transmitter
328
324
Data Formatter
325
Function Code
Transmit Button ---> Code 1
Emergency Button ---> Code 2
X-mitter I.D.
326
321
Data Interface
327
Transmit
329
Emergency

FIG. 3A

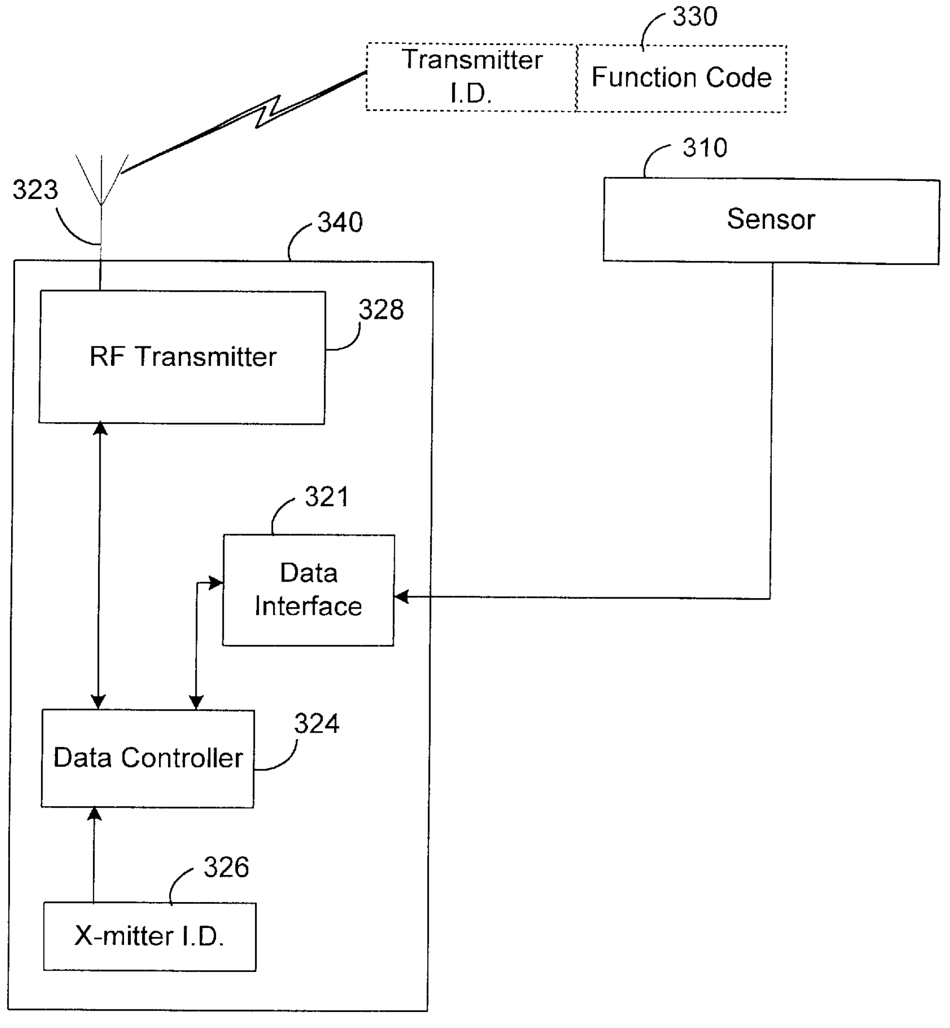

330
Transmitter I.D.
Function Code
310
Sensor
323
340
RF Transmitter
328
321
Data Interface
Data Controller
324
326
X-mitter I.D.

FIG. 3B

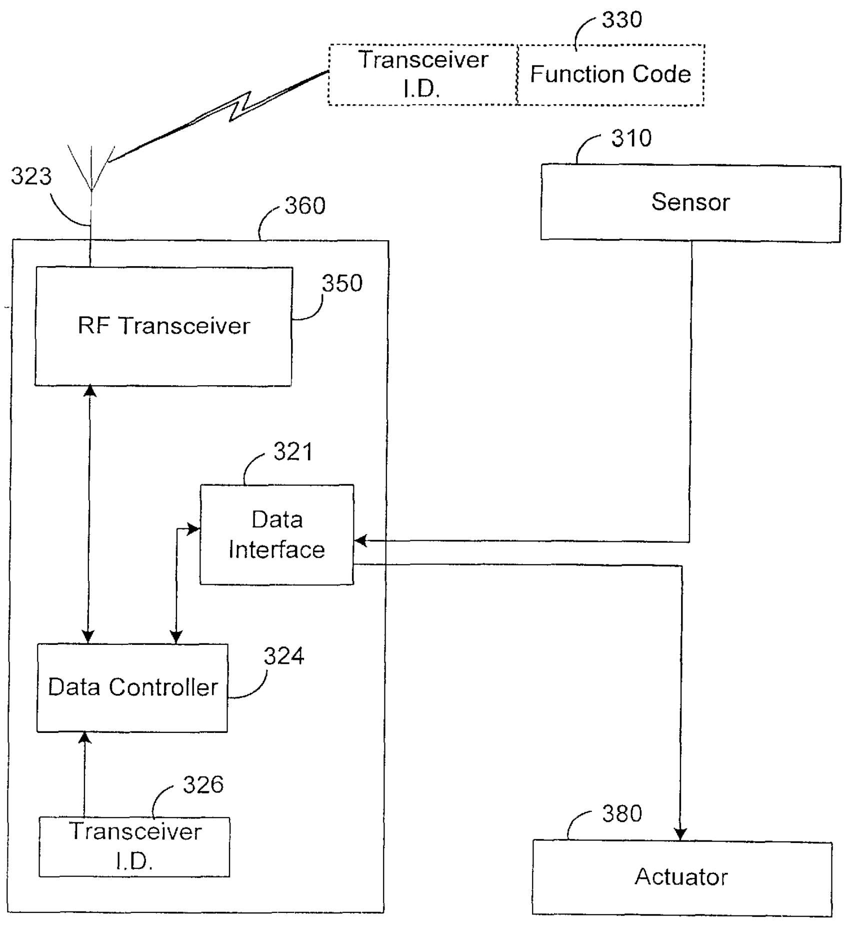

330
Transceiver I.D.
Function Code
310
Sensor
323
360
RF Transceiver
350
321
Data Interface
Data Controller
324
326
Transceiver I.D.
380
Actuator

FIG. 3C

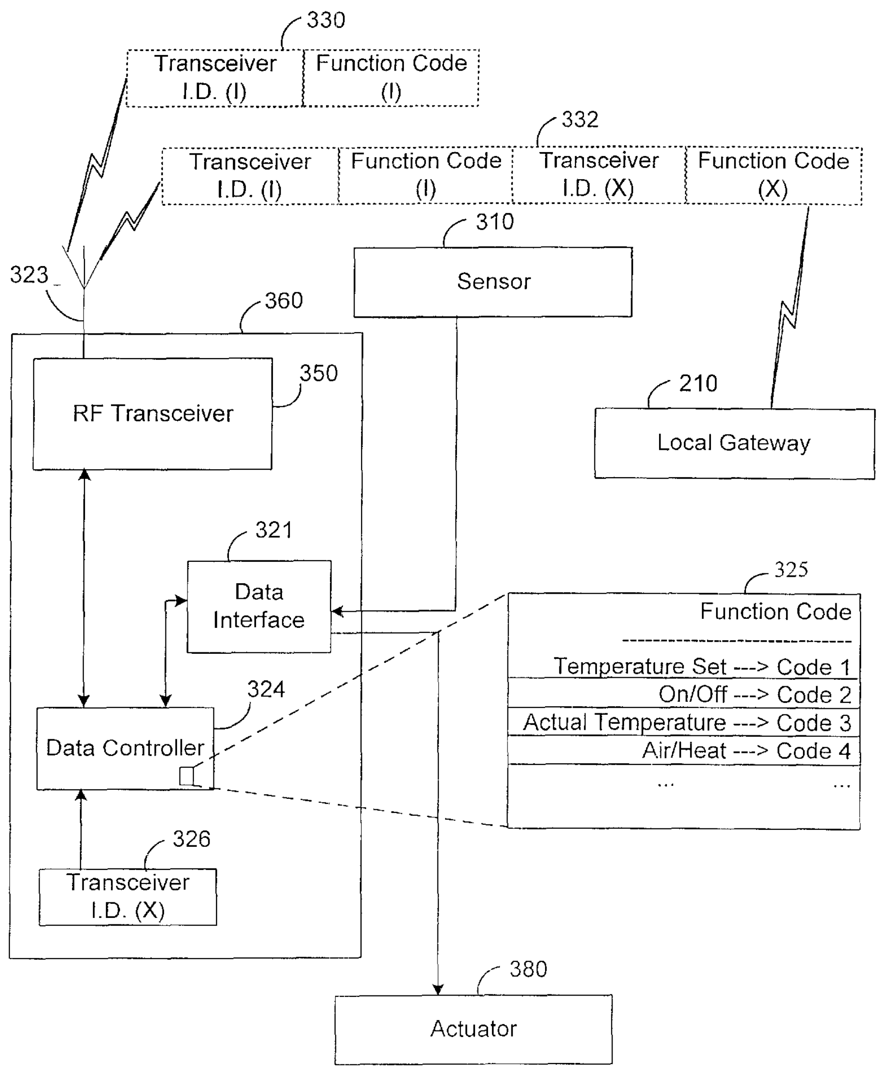

330
Transceiver I.D. (I)
Function Code (I)
332
Transceiver I.D. (I)
Function Code (I)
Transceiver I.D. (X)
Function Code (X)
310
Sensor
323
360
350
RF Transceiver
210
Local Gateway
321
Data Interface
325
Function Code
Temperature Set ---> Code 1
On/Off ---> Code 2
Actual Temperature ---> Code 3
Air/Heat ---> Code 4
... ...
324
Data Controller
326
Transceiver I.D. (X)
380
Actuator

FIG. 3D

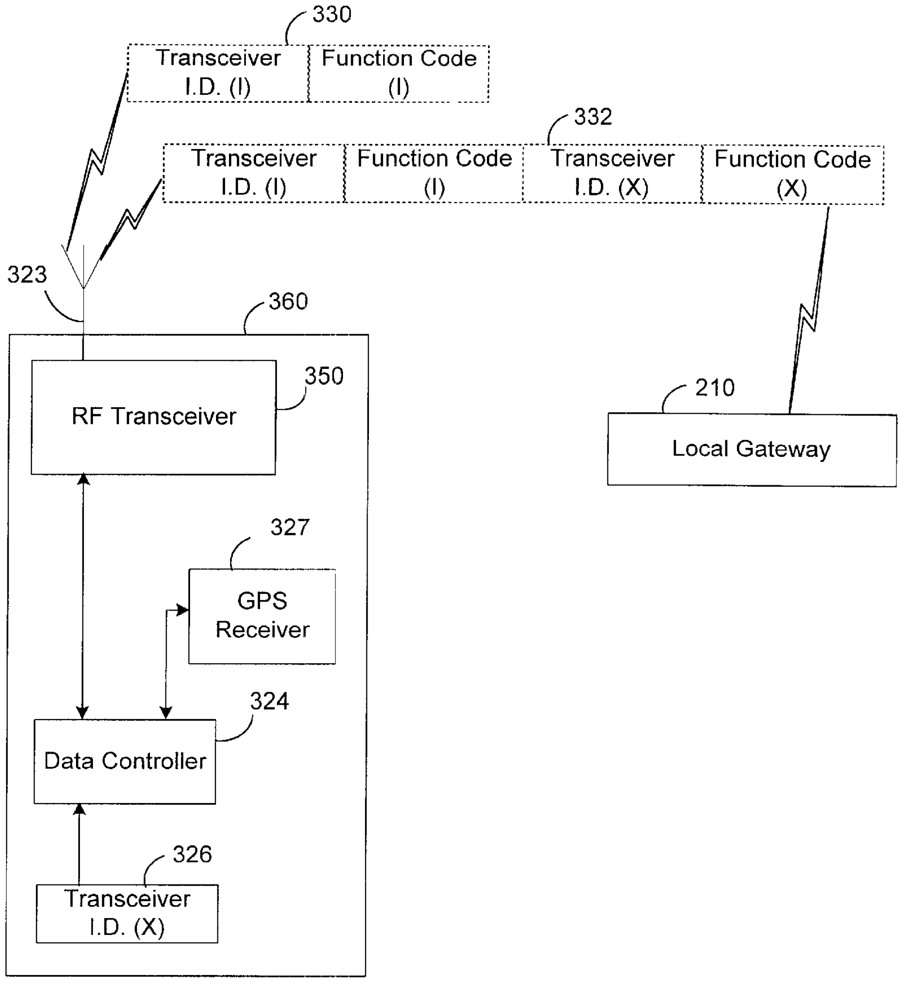

330
Transceiver I.D. (I)
Function Code (I)
332
Transceiver I.D. (I)
Function Code (I)
Transceiver I.D. (X)
Function Code (X)
323
360
350
RF Transceiver
210
Local Gateway
327
GPS Receiver
324
Data Controller
326
Transceiver I.D. (X)

FIG. 3E

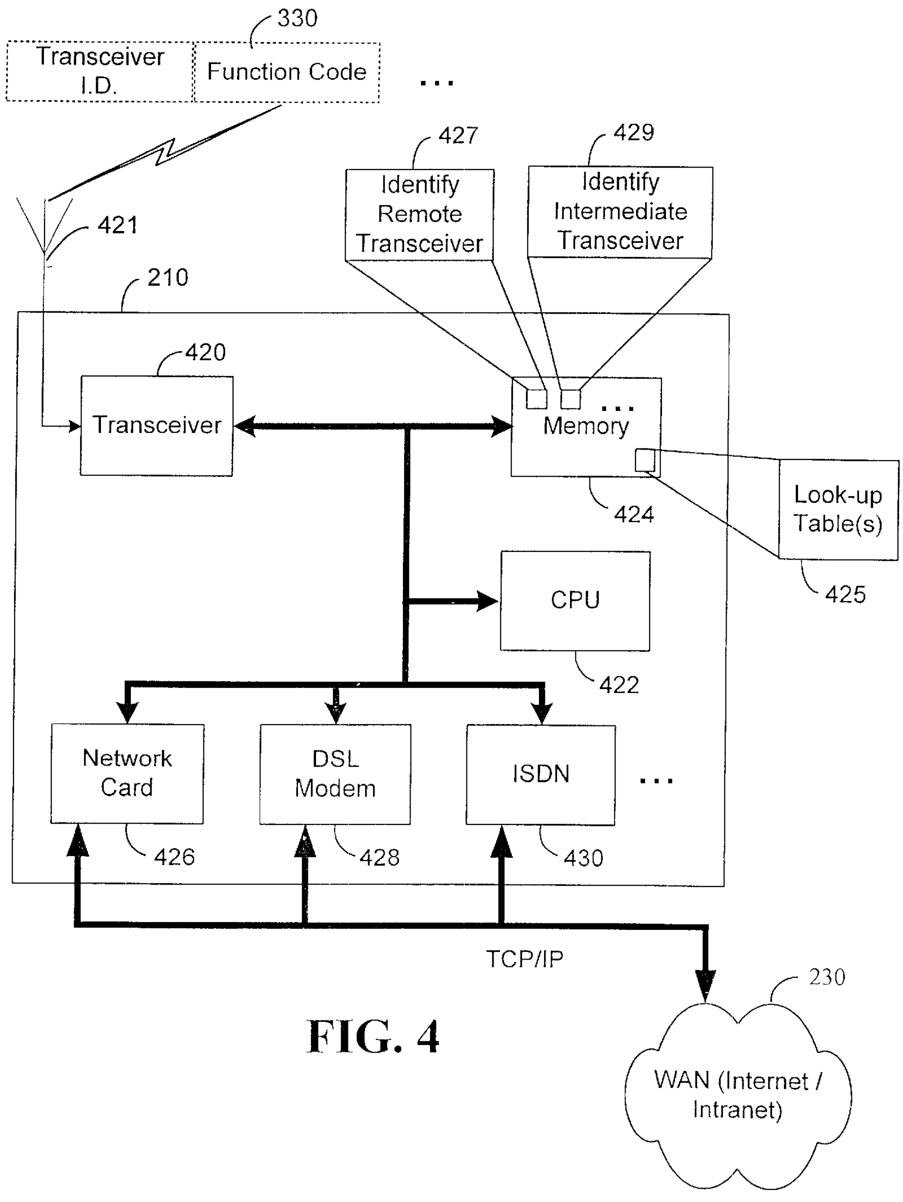

330
Transceiver I.D.
Function Code
...
427
Identify Remote Transceiver
429
Identify Intermediate Transceiver
421
210
420
Transceiver
...
Memory
424
Look-up Table(s)
425
CPU
422
Network Card
DSL Modem
ISDN
...
426
428
430
TCP/IP
230
WAN (Internet / Intranet)

FIG. 4

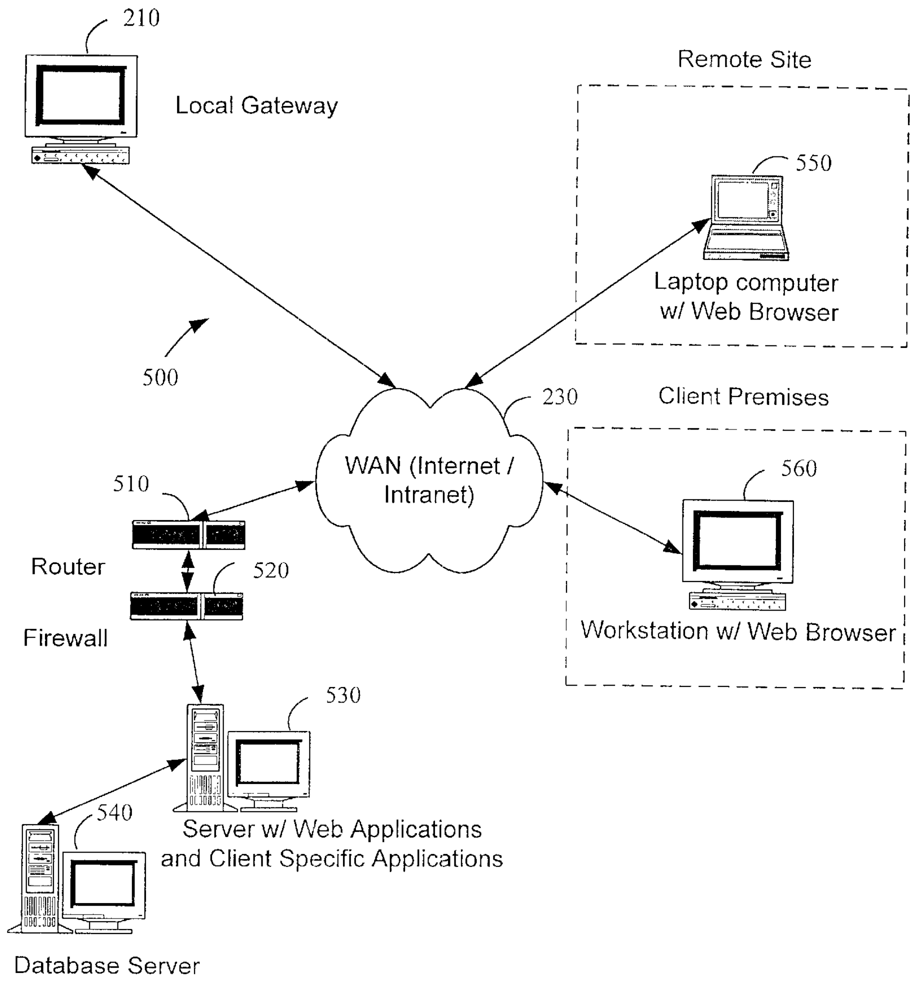
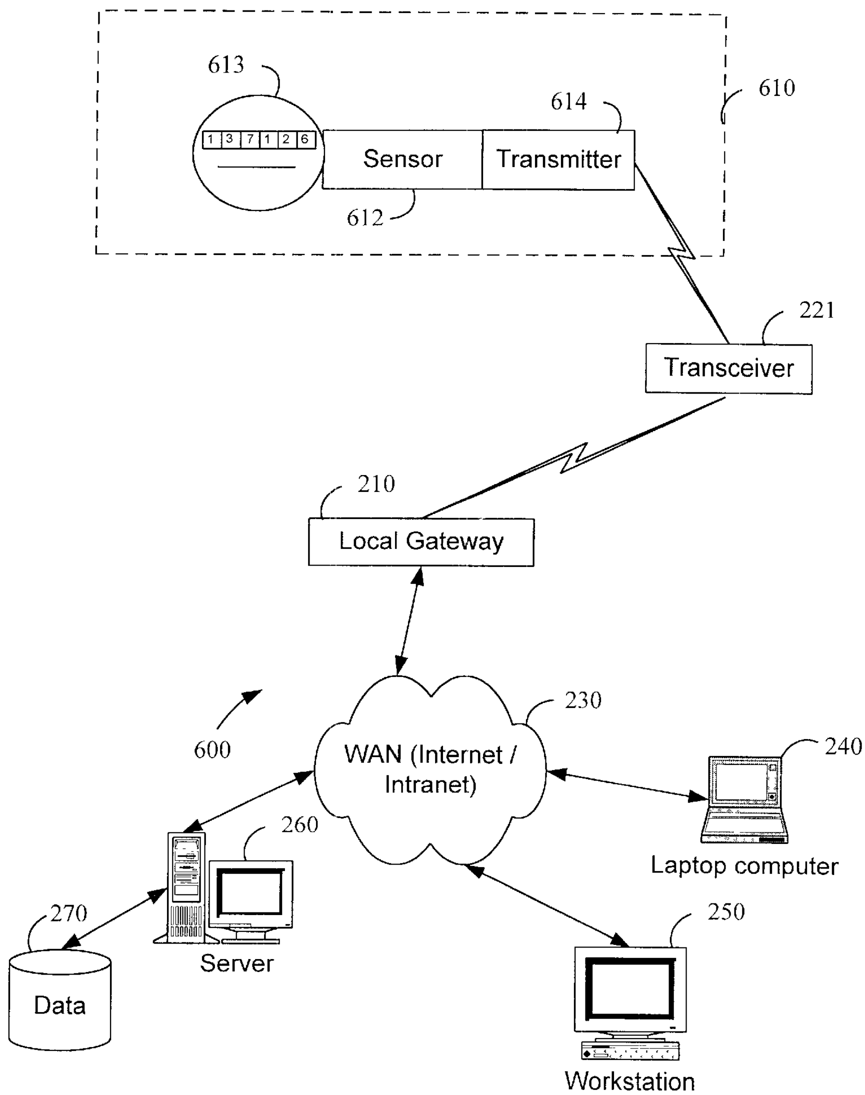
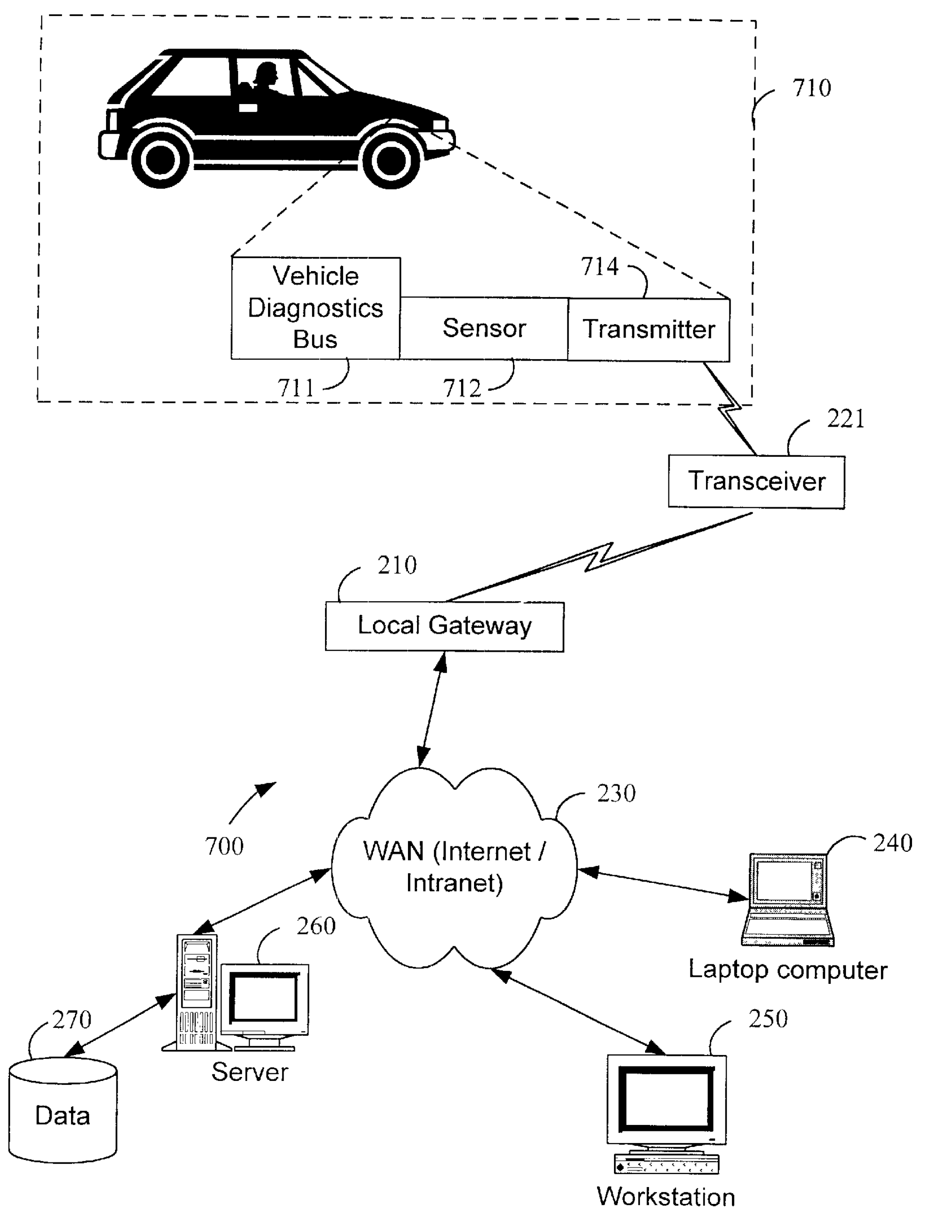

210
Local Gateway
Remote Site
550
Laptop computer
w/ Web Browser
500
230
Client Premises
WAN (Internet /
Intranet)
510
560
Router
520
Firewall
Workstation w/ Web Browser
530
540
Server w/ Web Applications
and Client Specific Applications
Database Server

FIG. 5



613
614
610
1 3 7 1 2 6
Sensor
Transmitter
612
221
Transceiver
210
Local Gateway
230
600
WAN (Internet / Intranet)
240
260
Laptop computer
270
250
Server
Data
Workstation

FIG. 6



710
Vehicle Diagnostics Bus
Sensor
Transmitter
714
711
712
221
Transceiver
210
Local Gateway
230
WAN (Internet / Intranet)
700
240
Laptop computer
260
Server
270
Data
250
Workstation

FIG. 7

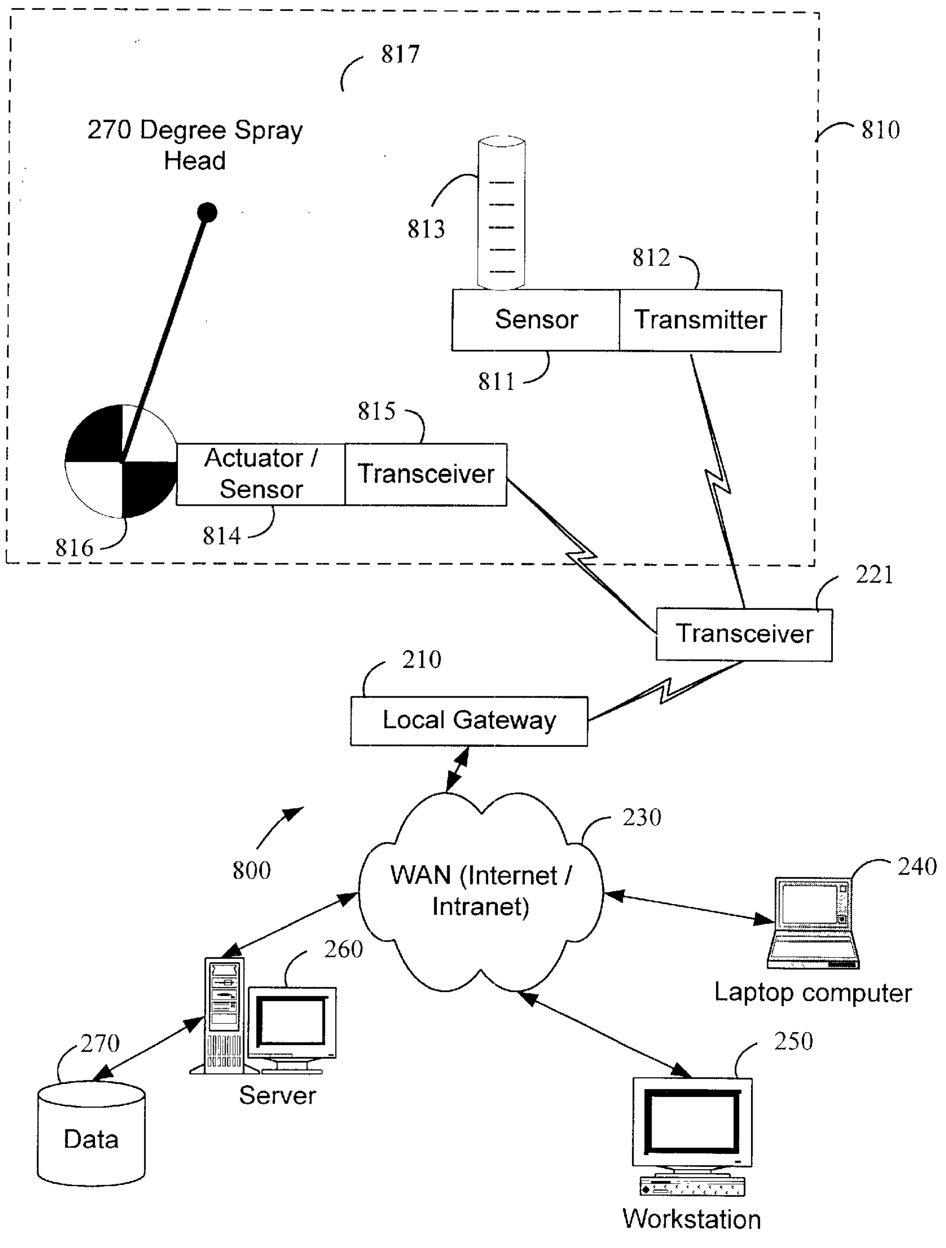

817
810
270 Degree Spray Head
813
812
Sensor
Transmitter
811
815
Actuator / Sensor
Transceiver
816
814
221
Transceiver
210
Local Gateway
230
800
WAN (Internet / Intranet)
240
Laptop computer
260
270
Server
250
Data
Workstation

FIG. 8

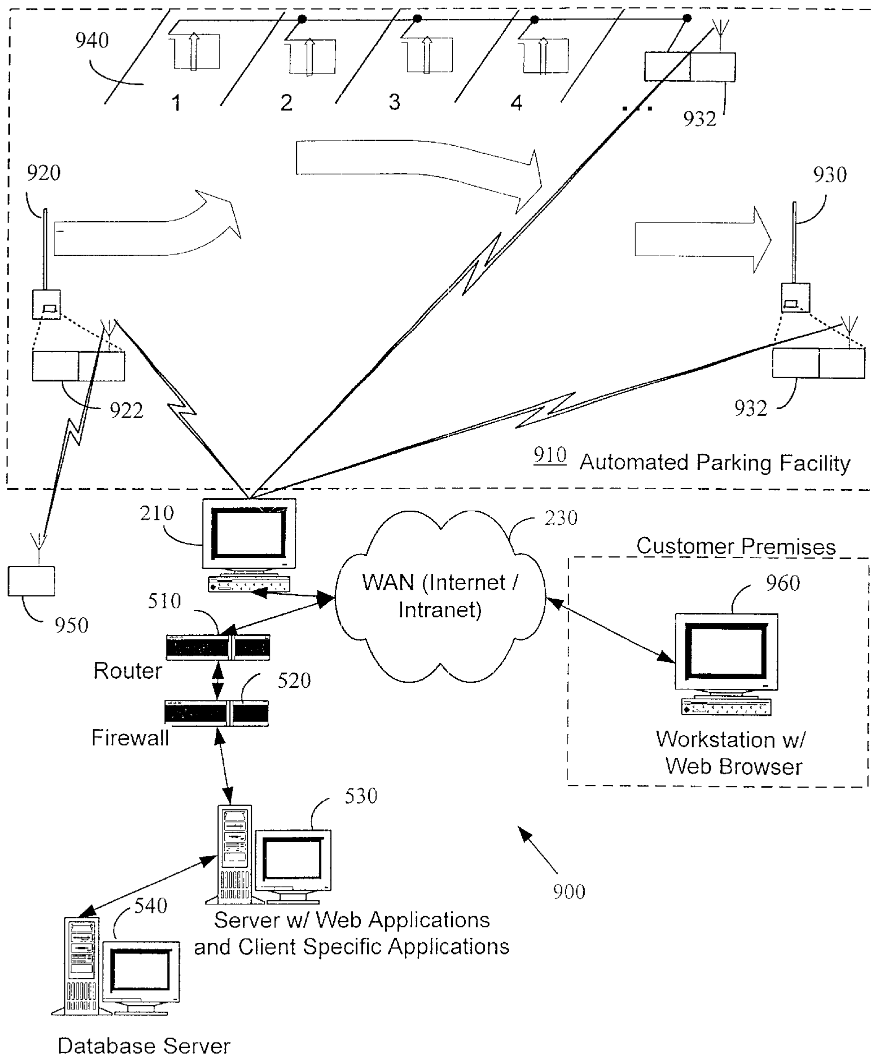

940
1
2
3
4
932
920
930
922
932
910 Automated Parking Facility
210
230
WAN (Internet / Intranet)
Customer Premises
960
950
510
Router
520
Firewall
Workstation w/ Web Browser
530
900
540
Server w/ Web Applications and Client Specific Applications
Database Server

FIG. 9

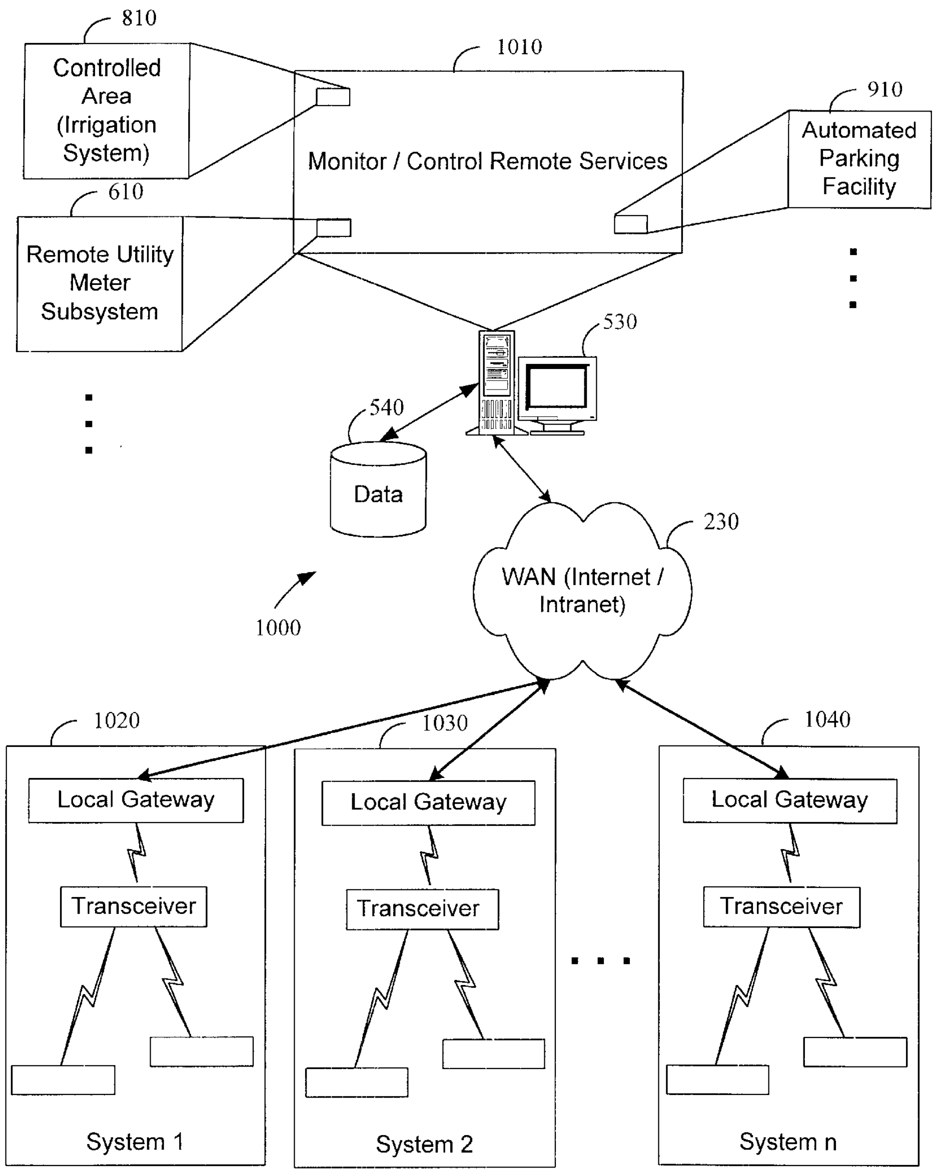

810
Controlled Area (Irrigation System)
1010
Monitor / Control Remote Services
910
Automated Parking Facility
610
Remote Utility Meter Subsystem
530
540
Data
230
WAN (Internet / Intranet)
1000
1020
1030
1040
Local Gateway
Transceiver
System 1
Local Gateway
Transceiver
System 2
Local Gateway
Transceiver
System n

FIG. 10

FIG. 11 Message Structure

To Addr. (1-6)	From Addr. (6)	Pkt. No. (1)	Pkt. Max. (1)	Pkt. Lngth. (1)	Cmd. (1)	Data (0-238)	CkH (1)	CkL (1)

The order of appearance remains fixed although byte position number in each packet may vary due to one or more of the following reasons:

1. Scalability of the "TO ADDRESS" (1 to 6 Bytes).
2. The CMD Byte.
3. Scalability of the Data portion of the message (0 to 238 Bytes).

"To Address" Byte Assignment:

MSB - Byte 1 Device Type	FF-F0 (16) - Broadcast All Devices (1 Byte Address) EF-1F (224) - Device Type Base (2 to 6 Byte Address) 0F-00 (16) - Personal Transceiver Identification (6 Byte Address)
Byte 2 Mfg./Owner ID	FF-F0 (16) - Broadcast all Devices (Byte 1 Type) (2 Byte Broadcast Address) EF-00 (240) - Mfg./Owner Code Identification Number
Byte 3 Mfg./Owner Extension ID	FF-F0 (16) - Broadcast all Devices (Byte 1 & Byte 2 Type) (3 Byte Broadcast Address) EF-00 (240) - Device Type/Mfg./Owner Code ID Number
Byte 4	FF-F0 (16) - Broadcast all Devices (Byte 1 & Byte 2 Type) (4 Byte Broadcast Address) EF-00 (240) - ID Number
Byte 5	(FF-00) 256 - Identification Number
Byte 6	(FF-00) 256 - Identification Number

"From Address" Byte Assignment:

From Address	(FF-00) Full "ID" of Originating Device (up to 6 Bytes)
Packet Number	(FF-00) Packet Number of Msg. longer than 256 Bytes
Packet Max.	(FF-00) Number of Packets in Message over 256 Bytes
Packet Length	(FF-00) Length (in Bytes) of Packet/Message Transmission*
Command	(FF-00) Command Byte
Data	(FF-00) Data as required by specific command
ChkH	(FF-00) Packet Checksum, High Byte
ChkL	(FF-00) Packet Checksum, Low Byte

* Packet Length - 13 Bytes (Min.) / 256 Bytes (Max.)

Sample Messages

Central Server to Personal Transceiver - Broadcast Message - FF (Emergency)

Byte Count = 12

To Addr.	From Addr.	Pkt. No.	Pkt. Max.	Pkt. Lngth.	Cmd.	CkH	CkL
(FF)	(12345678)	(00)	(00)	(0C)	(FF)	(02)	(9E)

First Transceiver to Repeater (Transceiver)
Broadcast Message - FF (Emergency)

Byte Count = 17

To Addr.	From Addr.	Pkt. No.	Pkt. Max.	Pkt. Lngth.	Cmd.		CkH	CkL
(F0)	(12345678)	(00)	(00)	(11)	(FF)		(03)	(A0)

Data
(A000123456)

Note: Additional Transceiver Re-Broadcasts do not change the message.
The messages are simply received and re-broadcast.

Message to Device "A0" From Device "E1" Command - "08" (Respond to PING)
Response will reverse "To" and "From" Addresses

Byte Count = 17

To Addr.	From Addr.	P #	P Max.	P Lngth.	Cmd.	Data	CkH	CkL
(A012345678)	(E112345678)	(00)	(00)	(11)	(08)	(A5)	(04)	(67)

FIG. 12

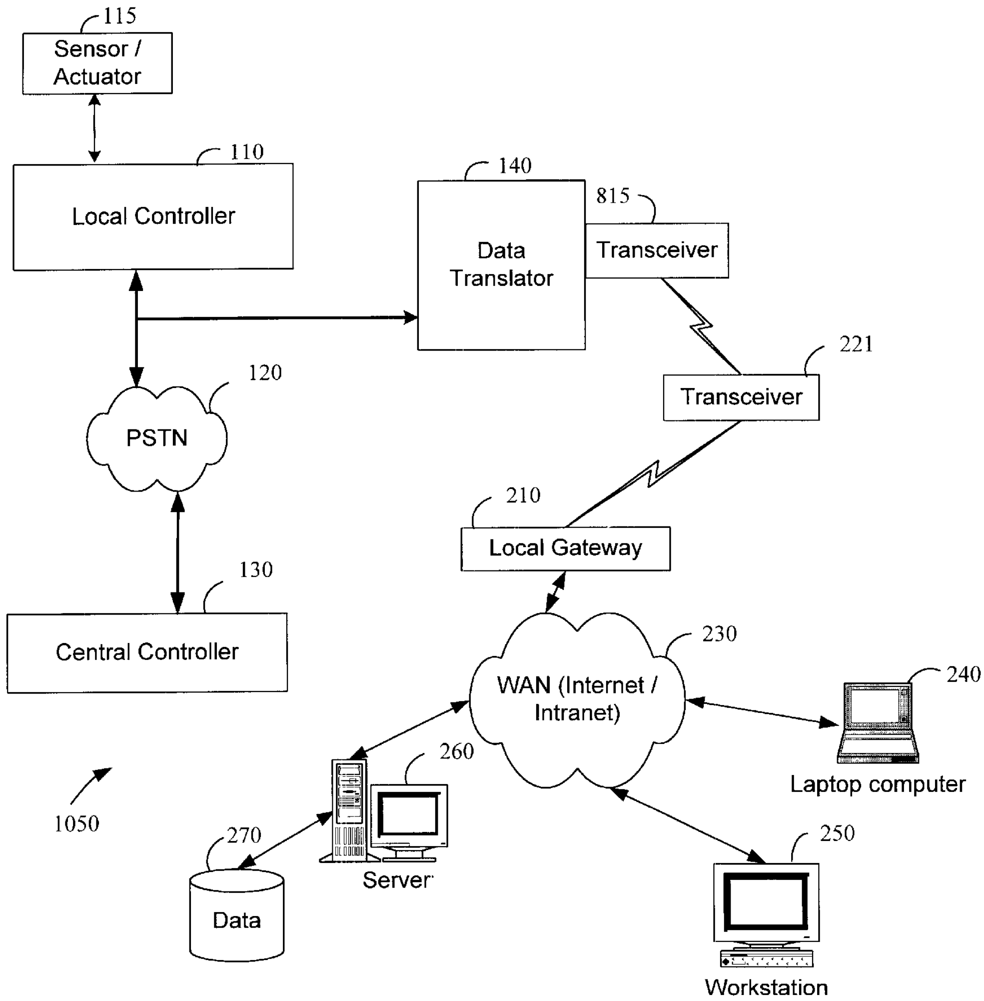

115
Sensor / Actuator
110
Local Controller
140
Data Translator
815
Transceiver
221
Transceiver
120
PSTN
210
Local Gateway
130
Central Controller
230
WAN (Internet / Intranet)
240
Laptop computer
260
Server
1050
270
Data
250
Workstation

FIG. 13

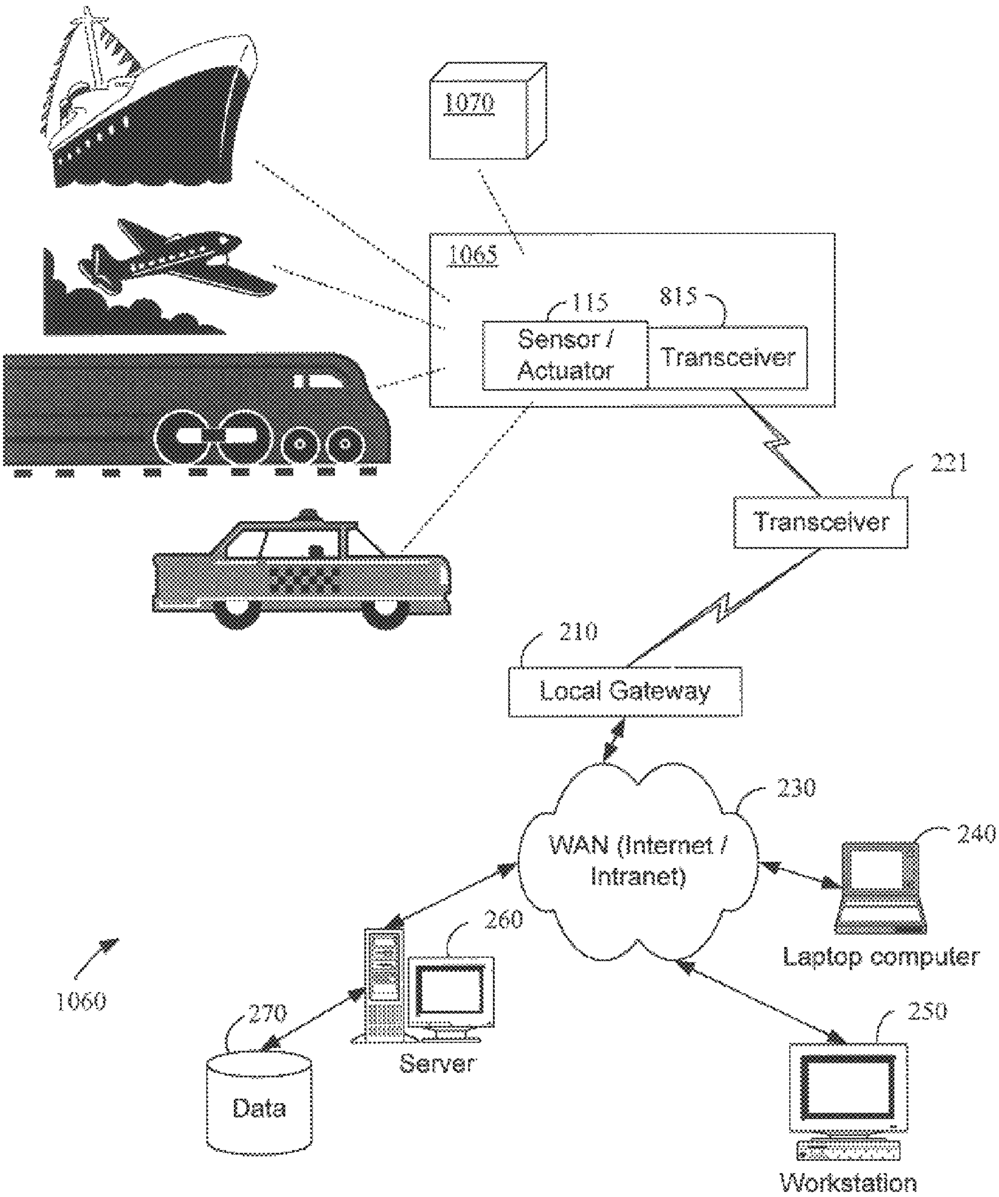

1070
1065
115
815
Sensor / Actuator
Transceiver
221
Transceiver
210
Local Gateway
230
WAN (Internet / Intranet)
240
Laptop computer
260
Server
270
Data
250
Workstation
1060

FIG. 14

SYSTEM AND METHOD FOR MONITORING AND CONTROLLING REMOTE DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent applications Ser. No. 09/271,517; filed Mar. 18, 1999, and entitled, "System For Monitoring Conditions in a Residential Living Community;" Ser. No. 09/102,178; filed Jun. 22, 1998, entitled, "Multi-Function General Purpose Transceiver;" Ser. No. 09/172,554; filed Oct. 14, 1998, entitled, "System for Monitoring the Light Level Around an ATM," now Pat. No. 6,028,522; Ser. No. 09/412,895; filed Oct. 5, 1999, entitled, "System and Method for Monitoring the Light Level Around an ATM now U.S. Pat. No. 6,218,953; and further claims the benefit of provisional patent application Serial No. 60/146,817; filed Aug. 2, 1999 entitled, "System and Method for Monitoring and Controlling Residential Devices." Each of the above identified disclosures are incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to remotely operated systems, and more particularly to a computerized system for monitoring, reporting on, and controlling remote systems by transferring information signals through a wide area network (WAN) and using software applications hosted on a connected server to appropriately process the information.

2. Discussion of the Related Art

As is known, there are a variety of systems for monitoring and controlling manufacturing processes, inventory systems, emergency control systems, and the like. Most automatic systems use remote sensors and controllers to monitor and automatically respond to system parameters to reach desired results. A number of control systems utilize computers to process system inputs, model system responses, and control actuators to implement process corrections within the system. Both the electric power generation and metallurgical processing industries have had success controlling production processes by implementing computer controlled control systems in individual plants.

One way to classify control systems is by the timing involved between subsequent monitoring occurrences. Monitoring processes can be classified as aperiodic or random, periodic, and real-time. A number of remotely distributed service industries implement the monitoring and controlling process steps through manual inspection and intervention.

Aperiodic monitoring systems (those that do not operate on a predetermined cycle) are inherently inefficient as they require a service technician to physically traverse an area to record data, repair out of order equipment, add inventory to a vending machine, and the like. Such service trips are carried out in a number of industries with the associated costs being transferred to the consumers of the service.

Conversely, utility meter monitoring, recording, and client billing are representative of a periodic monitoring system. In the past, utility providers sent a technician from meter to meter on a periodic basis to verify meter operation and to record utility use. One method of cutting operating expenses in the utility industry involved increasing the period at which manual monitoring and meter data recording was performed. While this method decreased the monitoring

and recording expense associated with more frequent meter observation and was convenient for consumers who favor the consistent billed amounts associated with "budget billing," the utility provider retained the costs associated with less frequent meter readings and the processing costs associated with reconciling consumer accounts.

Lastly, a number of environmental and safety systems require constant or real-time monitoring. Heating, ventilation, and air-conditioning systems, fire reporting and damage control systems, alarm systems, and access control systems are representative systems that utilize real-time monitoring and often require immediate feedback and control. These real-time systems have been the target of control systems theory and application thereof for some time.

A problem with expanding the use of control systems technology to distributed systems are the costs associated with the sensor-actuator infrastructure required to monitor and control functions within such systems. The typical approach to implementing control system technology is to install a local network of hard-wired sensors and actuators along with a local controller. Not only is there expense associated with developing and installing appropriate sensors and actuators but the added expense of connecting functional sensors and controllers with the local controller. Another prohibitive cost associated with applying control systems technology to distributed systems is the installation and operational expense associated with the local controller.

Accordingly, an alternative solution to applying monitoring and control system solutions to distributed systems that overcomes the shortcomings of the prior art is desired.

SUMMARY OF THE INVENTION

Certain objects, advantages and novel features of the invention will be set forth in part in the description that follows and in part will become apparent to those skilled in the art upon examination of the following or may be learned with the practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

To achieve the advantages and novel features, the present invention is generally directed to a cost effective method of monitoring and controlling remote devices. More specifically, the present invention is directed to a computerized system for monitoring, reporting, and controlling remote systems and system information transfer by transmitting information signals to a WAN gateway interface and using applications on a connected server to process the information. Because the applications server is integrated on a WAN, Web browsers can be used by anyone with Internet access (and the appropriate access permissions) to view and download the recorded data.

In accordance with a broad aspect of the invention, a system is provided having one or more sensors to be read and/or actuators to be controlled remotely, ultimately through a computer on the Internet. The sensors and/or actuators are interfaced with wireless transceivers that transmit and/or receive data to and from the Internet. In this regard, additional wireless transceivers may relay information between the transceivers disposed in connection with the sensors and actuators and a gateway to the Internet. It should be appreciated that, a portion of the information communicated includes data that uniquely identifies the sensors and/or actuators.

In accordance with one aspect of the invention, a system is configured to monitor and report system parameters. The system is implemented by using a plurality of wireless transceivers. At least one wireless transceiver is interfaced with a sensor, transducer, actuator or some other device associated with the application parameter of interest. In this regard, the term "parameter" is broadly construed and may include, but is not limited to, a system alarm condition, a system process variable, an operational condition, etc. The system also includes a plurality of transceivers that act as signal repeaters that are dispersed throughout the nearby geographic region at defined locations. By defined locations, it is meant only that the location of each transceiver is known to a central computer. The central computer may be informed of transceiver physical locations after permanent installation, as the installation location of the transceivers is not limited. Each transceiver that serves to repeat a previously generated data signal may be further integrated with its own unique sensor or a sensor actuator combination as required. Additional transceivers may be configured as stand-alone devices that serve to simply receive, format, and further transmit system data signals. Further, the system includes a local data formatter that is configured to receive information communicated from the transceivers, format the data, and forward the data via the gateway to one or more servers interconnected with the WAN. The server further includes means for evaluating the received information and identifying the system parameter and the originating location of the parameter. The server also includes means for updating a database or further processing the reported parameters.

Consistent with the broader concepts of the invention, the "means" for evaluating the received information and the "means" for reporting system parameters are not limited to a particular embodiment or configuration. Preferably, these "means" will be implemented in software that is executed by a processor within a server integrated with the Internet. However, dedicated WANs or Intranets are suitable backbones for implementing defined system data transfer functions consistent with the invention.

In one embodiment, a client retrieves configured system data by accessing an Internet Web site. In such an embodiment, a system consistent with the present invention acts as a data collector and formatter with data being delivered upon client request, with availability twenty-four hours a day, seven days a week.

In more robust embodiments, a system can be configured to collect, format, and deliver client application specific information on a periodic basis to predetermined client nodes on the WAN. In these embodiments, client intervention would serve to close the feedback loop in the control system.

In yet another embodiment, a system can be configured to collect, format, and control client application specific processes by replacing a local control computer with a WAN interfaced server and integrating system specific actuators with the aforementioned system transceivers.

It should be further appreciated that the information transmitted and received by the wireless transceivers may be further integrated with other data transmission protocols for transmission across telecommunications and computer networks other than the Internet. In addition, it should be further appreciated that telecommunications and computer networks other than the Internet can function as a transmission path between the networked wireless transceivers, the local gateways, and the central server.

In yet a further embodiment, a system can be configured using the present invention to translate and transmit control signals from an existing local controller via the networked wireless transceivers. In this regard, the system of the present invention would require a data translator to tap into the data stream of an existing control system. Distinct control system signals may be mapped to function codes used by the present invention in order to provide customer access to control system data. In this way, the system of the present invention can be integrated with present data collection and system controllers inexpensively, as customers will only have to add a data translator and a wireless transmitter or transceiver as the application demands. By integrating the present invention with the data stream generated by present monitoring and control systems, potential customers enjoy the benefits of the present invention without the difficulties associated with integrating sensors and actuators to monitor individual system parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings incorporated in and forming a part of the specification, illustrate several aspects of the present invention, and together with the description serve to explain the principles of the invention. In the drawings:

FIG. **1** is a block diagram of a prior art control system;

FIG. **2** is a block diagram illustrating a monitoring/control system of the present invention;

FIG. **3** A is a functional block diagram that illustrates a transmitter in accordance with the present invention integrated in a portable device with user operable buttons that trigger data transmissions as desired;

FIG. **3**B is a functional block diagram that illustrates the integration of a sensor with a transmitter in accordance with the invention;

FIG. **3**C is a block diagram illustrating a transceiver in accordance with the present invention integrated with a sensor and an actuator;

FIG. **3**D is a functional block diagram further illustrating the transceiver of FIG. **3**C as applied to a heating, ventilation, and air conditioning system controller;

FIG. **3**E is a functional block diagram illustrating the combination of the transceiver of FIG. **3**D with a global positioning system (GPS) receiver;

FIG. **4** is a functional block diagram that illustrates the functional components of a local WAN gateway constructed in accordance with the invention;

FIG. **5** is a diagram illustrating WAN connectivity in a system constructed in accordance with the invention;

FIG. **6** is a block diagram illustrating a client specific application in accordance with the invention (simple data collection or monitoring);

FIG. **7** is a block diagram illustrating another data monitoring and reporting application consistent with the present invention;

FIG. **8** is a block diagram illustrating a third client specific application in accordance with the invention (monitoring and controlling a process);

FIG. **9** is a block diagram illustrating the present invention as deployed in a particular business application;

FIG. **10** is a block diagram further illustrating the present invention as deployed in a plurality of business applications;

FIG. **11** is a table illustrating the message protocol of the present invention;

FIG. **12** illustrates three sample messages using the message protocol of the present invention;

FIG. **13** is a block diagram illustrating the system of the present invention integrated with the local controller of FIG. **1**; and

FIG. **14** is a block diagram illustrating the system of the present invention integrated with a mobile inventory unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Having summarized the invention above, reference is now made in detail to the description of the invention as illustrated in the drawings. While the invention will be described in connection with these drawings, there is no intent to limit it to the embodiment or embodiments disclosed therein. On the contrary, the intent is to cover all alternatives, modifications and equivalents included within the spirit and scope of the invention as defined by the appended claims.

Referring now to the drawings, reference is made to FIG. **1**, which is a block diagram illustrating certain fundamental components of a prior art control system **100**. More particularly, a prior art control system **100** includes a plurality of sensor actuators **111**, **112**, **113**, **114**, **115**, **116**, and **117** electrically coupled to a local controller **110**. In a manner well known in the art of control systems, local controller **110** provides power, formats and applies data signals from each of the sensors to predetermined process control functions, and returns control signals as appropriate to the system actuators. Often, prior art control systems are further integrated via the public switched telephone network (PSTN) **120** to a central controller **130**. Central controller **130** can be further configured to serve as a technician monitoring station or to forward alarm conditions via PSTN **120** to appropriate public safety officers.

Prior art control systems consistent with the design of FIG. **1** require the development and installation of an application-specific local system controller, as well as, the routing of electrical conductors to each sensor and actuator as the application requires. Such prior art control systems are typically augmented with a central controller **130** that may be networked to the local controller **110** via PSTN **120**. As a result, prior art control systems often consist of a relatively heavy design and are subject to a single point of failure should local controller **110** go out of service. In addition, these systems require electrical coupling between the local controller and system sensors and actuators. As a result, appropriately wiring an existing industrial plant can be a dangerous and expensive proposition.

Having described a prior art control system and delineated some of its shortcomings, reference is now made to FIG. **2**, which is a block diagram that illustrates a control system in accordance with the present invention. Control system **200** consists of one or more sensor/actuators **212**, **214**, **216**, **222**, and **224** each integrated with a transceiver. The transceivers are preferably RF (Radio Frequency) transceivers, that are relatively small in size and transmit a relatively low power RF signal. As a result, in some applications, the transmission range of a given transceiver may be relatively limited. As will be appreciated from the description that follows, this relatively limited transmission range of the transceivers is an advantageous and desirable characteristic of control system **200**. Although the transceivers are depicted without a user interface such as a keypad, in certain embodiments of the invention the transceivers may be configured with user selectable buttons or an alphanumeric keypad. Often, the transceivers will be electrically interfaced with a sensor or actuator, such as a smoke detector, a thermostat, a security system, etc., where external buttons are not needed.

Control system **200** also includes a plurality of stand-alone transceivers **211**, **213**, **215**, and **221**. Each stand-alone transceiver **211**, **213**, **215**, and **221** and each of the integrated transceivers **212**, **214**, **216**, **222**, and **224** may be configured to receive an incoming RF transmission (transmitted by a remote transceiver) and to transmit an outgoing signal. This outgoing signal may be another low power RF transmission signal, a higher power RF transmission signal, or alternatively may be transmitted over a conductive wire, fiber optic cable, or other transmission media. The internal architecture of a transceiver integrated with a sensor/actuator **212** and a stand-alone transceiver **211** will be discussed in more detail in connection with FIGS. **3A** through **3C**. It will be appreciated by those skilled in the art that integrated transceivers **212**, **214**, **216**, **222**, and **224** can be replaced by RF transmitters (not shown) for client specific applications that require data collection only.

Local gateways **210** and **220** are configured and disposed to receive remote data transmissions from the various stand-alone transceivers **211**, **213**, **215**, and **221** or integrated transceivers **212**, **214**, **216**, **222**, and **224** having an RF signal output level sufficient to adequately transmit a formatted data signal to the gateways. Local gateways **210** and **220** analyze the transmissions received, convert the transmissions into TCP/IP format and further communicate the remote data signal transmissions via WAN **230**. In this regard, and as will be further described below, local gateways **210** and **220** may communicate information, service requests, control signals, etc. to remote sensor/actuator transceiver combinations **212**, **214**, **216**, **222**, and **224** from server **260**, laptop computer **240**, and workstation **250** across WAN **230**. Server **260** can be further networked with database server **270** to record client specific data.

It will be appreciated by those skilled in the art that if an integrated transceiver (either of **212**, **214**, **216**, **222**, and **224**) is located sufficiently close to local gateways **210** or **220** such that its RF output signal can be received by a gateway, the RF data signal need not be processed and repeated through stand-alone transceivers **211**, **213**, **215**, or **221**.

It will be further appreciated that a monitoring system constructed in accordance with the teachings of the present invention may be used in a variety of environments. In accordance with a preferred embodiment, a monitoring system such as that illustrated in FIG. **2** may be employed to monitor and record utility usage by residential and industrial customers as illustrated in FIG. **6**. Another preferred monitoring system is illustrated in FIG. **7**. FIG. **7** depicts the transfer of vehicle diagnostics from an automobile via a RF transceiver integrated with the vehicle diagnostics bus to a local transceiver that farther transmits the vehicle information through a local gateway onto a WAN.

It will be further appreciated that a monitoring and control system consistent with the present invention may be used in a variety of environments. In accordance with a preferred embodiment, a control system such as that illustrated in FIG. **2** may be employed to monitor and control an irrigation system as illustrated in FIG. **8**. Another preferred control system is illustrated in FIG. **9**. FIG. **9** depicts a business application of a control system wherein the operation of a parking facility may be automated.

As will be further appreciated from the discussion herein, transceivers **212**, **214**, **216**, **222**, and **224** may have substantially identical construction (particularly with regard to their internal electronics), which provides a cost effective implementation at the system level. Furthermore, a plurality of stand-alone transceivers **211**, **213**, **215**, and **221**, which may be identical, are disposed in such a way that adequate coverage in an industrial plant or community is provided. Preferably, stand-alone transceivers **211**, **213**, **215**, and **221** may be dispersed sufficient that only one stand-alone transceiver will pick up a transmission from a given integrated transceiver **212**, **214**, **216**, **222**, and **224** (due in part to the low power transmission nature of each transmitter). However, in certain instances two, or even more, stand-alone transceivers may pick up a single transmission. Thus, the local gateways **210** and **220** may receive multiple versions of the same data transmission signal from an integrated transceiver, but from different stand-alone transceivers. The local gateways **210** and **220** may utilize this information to triangulate, or otherwise more particularly assess the location from which the transmission is originating. Due to the transmitting device identification that is incorporated into the transmitted signal, duplicative transmissions (e.g., transmissions duplicated to more than one gateway, or to the same gateway, more than once) may be ignored or otherwise appropriately handled.

In accordance with the preferred embodiment shown in FIG. **2**, integrated transceivers **212**, **214**, **216**, **222**, and **224** may be disposed within automobiles (see FIG. **7**), a rainfall gauge (see FIG. **8**), or a parking lot access gate (see FIG. **9**) to monitor vehicle diagnostics, total rainfall and sprinkler supplied water, and access gate position, respectively. The advantage of integrating a transceiver, as opposed to a one-way transmitter, into a monitoring device relates to the ability of the transceiver to receive incoming control signals, as opposed to merely transmitting data signals. Significantly, local gateways **210** and **220** may communicate with all system transceivers. Since local gateways **210** and **220** are permanently integrated with WAN **230**, server **260** can host application specific software which was typically hosted in an application specific local controller as shown in FIG. **1**. Of further significance, the data monitoring and control devices of the present invention need not be disposed in a permanent location as long as they remain within signal range of a system compatible transceiver that subsequently is within signal range of a local gateway interconnected through one or more networks to server **260**. In this regard, small application specific transmitters compatible with control system **200** can be worn or carried about one's person as will be further described below.

In one embodiment, server **260** collects, formats, and stores client specific data from each of the integrated transceivers **212**, **214**, **216**, **222**, and **224** for later retrieval or access from workstation **250** or laptop **240**. In this regard, workstation **250** or laptop **240** can be used to access the stored information through a Web browser in a manner that is well known in the art. In another embodiment, server **260** may perform the additional functions of hosting application specific control system functions and replacing the local controller by generating required control signals for appropriate distribution via WAN **230** and local gateways **210** and **211** to the system actuators. In a third embodiment, clients may elect for proprietary reasons to host control applications on their own WAN connected workstation. In this regard, database **270** and server **260** may act solely as a data collection and reporting device with client workstation **250** generating control signals for the system.

It will be appreciated by those skilled in the art that the information transmitted and received by the wireless transceivers of the present invention may be further integrated with other data transmission protocols for transmission across telecommunications and computer networks other than the Internet. In addition, it should be further appreciated that telecommunications and computer networks other than the Internet can function as a transmission path between the networked wireless transceivers, the local gateways, and the central server.

Reference is now made to FIG. **3**A, which is a block diagram that illustrates the functional components of a RF transmitter **320**, of a type worn or carried by a person, in more detail. Blocks **327** and **329** represent physical buttons, which a user may actuate to cause the RF transmitter **320** to initiate different signal transmissions. In the illustrated embodiment, these include a "transmit" button **327** and a panic or "emergency" button **329**. Of course, additional, fewer, or different buttons may be provided on a given transmitter, depending upon the system or implementation desired. Each of these buttons may be electrically wired to a data interface **321** which is configured to receive electrical signals from buttons **327** and **329**, and ultimately convey that information to a data formatter **324**. In one embodiment, data interface **321** may simply comprise an addressable port that may be read by the data formatter **324**.

For example, each of the signal lines extending between the buttons and the data interface **321** may be pulled up by individual pull up resistors (not shown). Depressing any of the individual buttons may ground the electrical signal line interconnecting the respective button and the data interface **321**. Data formatter **324** may constantly read from the port defined by data interface **321**, and all bit positions should remain high at any given time, if no buttons are depressed. If, however, the data formatter **324** reads a zero in one or more of the bit positions, it then recognizes that one or more of the buttons **327** and **329** have been depressed.

Each transmitter unit may be configured to have a unique identification code (e.g., transmitter identification number) **326**, that uniquely identifies the transmitter to the functional blocks of control system **200** (see FIG. **2**). This transmitter identification number may be electrically programmable, and implemented in the form of, for example, an EPROM. Alternatively, the transmitter identification number may be set/configured through a series of DIP switches. Additional implementations of the transmitter identification number, whereby the number may be set/configured, may be implemented consistent with the broad concepts of the present invention.

Finally, an additional functional block of the transmitter **320** is a RF transmitter **328**. This circuit is used to convert information from digital electronic form into a format, frequency, and voltage level suitable for transmission from antenna **323** via an RF transmission medium.

The data formatter **324** operates to format concise data packets **330** that may be transmitted via RF to a nearby transceiver. From a substantive basis, the information conveyed includes a function code, as well as, a transmitter identification number. As previously mentioned, the transmitter identification number is set for a given transmitter **320**. When received by server **260** (see FIG. **2**), the transmitter identification number may be used to access a look up table that identifies, for example, the person assigned to carry that particular transmitter. Additional information about the person may also be provided within the lookup table, such as, a physical description, and/or any other information that may be deemed appropriate or useful under the circumstances or implementation of the particular system.

In addition, a function code is communicated from RF transmitter **320** to the nearby transceiver. FIG. **3**A illustrates a lookup table **325** that may be provided in connection with data formatter **324**. Lookup table **325** may be provided to assign a given and unique function code for each button pressed. For example, transmit button **327** may be assigned a first code to identify the party depressing the button. The emergency button **329** may be assigned a second code. Furthermore, additional codes may be provided as necessary to accommodate additional functions or features of a given transmitter **320**. Thus, in operation, a user may depress the emergency button **329**, which is detected by the data formatter **324**. The data formatter **324** may then use the information pertaining to the emergency button **329** to access a look up table **325** to retrieve a code that is uniquely assigned to emergency button **329**. The data formatter **324** may also retrieve the preconfigured transmitter identification number **326** in configuring a data packet **330** for communication via RF signals to a nearby transceiver.

Reference is now made briefly to FIG. **3**B, which is a block diagram illustrating certain functional blocks of a similar transmitter **340** that may be integrated with sensor **310**. For example, sensor **310** in its simplest form could be a two-state device such as a smoke alarm. Alternatively, the sensor **310** may output a continuous range of values to the data interface **321**. If the signal output from the sensor **310** is an analog signal, the data interface **321** may include an analog-to-digital converter (not shown) to convert signals output to the actuator **340**. Alternatively, a digital interface (communicating digital signals) may exist between the data interface **321** and each sensor **310**.

As illustrated, many of the components of RF transmitter **340** are similar to that of RF transmitter **320** and need not be repeated herein. The principal difference between the configurations of RF transmitter **320** of FIG. **3**A and the RF transmitter **340** of FIG. **3**B lies at the input of the data interface **321**. Specifically, RF transmitter **320** included user interface buttons **327** and **329**. RF transmitter **340**, illustrates electrical integration with sensor **310**. Unique transmitter identification code **326** coupled with a function code for a smoke alarm on condition is formatted by data controller **324** for transformation into a RF signal by RF transmitter **328** and transmission via antenna **323**. In this way, data packet **330** communicated from transmitter **340** will readily distinguish from similar signals generated by other RF transmitters in the system. Of course, additional and/or alternative configurations may also be provided by a similarly configured RF transmitter. For example, a similar configuration may be provided for a transmitter that is integrated into, for example, a carbon monoxide detector, a door position sensor and the like. Alternatively, system parameters that vary across a range of values may be transmitted by RF transmitter **340** as long as data interface **321** and data controller **324** are configured to apply a specific code, consistent with the input from sensor **3 1 0**. As long as the code was understood by server **260** or workstation **250** (see FIG. **2**) the target parameter could be monitored with the present invention.

Reference is now made to FIG. **3**C, which is a block diagram similar to that illustrated in FIGS. **3**A and **3**B, but illustrating a transceiver **360** that is integrated with a sensor **310** and an actuator **380**. In this illustration, data interface **321** is shown with a single input from sensor **310**. It is easy to envision a system that may include multiple sensor inputs. By way of example, a common home heating and cooling system might be integrated with the present invention. The home heating system may include multiple data interface inputs from multiple sensors. A home thermostat control connected with the home heating system could be integrated with a sensor that reports the position of a manually adjusted temperature control (i.e., temperature set value), as well as, a sensor integrated with a thermister to report an ambient temperature. The condition of related parameters can be input to data interface **321** as well, including the condition of the system on/off switch, and the climate control mode selected (i.e., heat, fan, or AC). In addition, depending upon the specific implementation, other system parameters may be provided to data interface **321** as well.

The addition of actuator **380** to the assembly permits data interface **321** to apply control signals to the manual temperature control for the temperature set point, the climate control mode switch, and the system on/off switch. In this way, a remote workstation **250** or laptop **240** with WAN access (see FIG. **2**) could control a home heating system from a remote location.

Again, each of these various input sources are routed to data interface **321** which provides the information to a data controller **324**. The data controller may utilize a look up table to access unique function codes that are communicated in data packet **330**, along with a transceiver identification code **326** via RF, to a local gateway and further onto a WAN. In general, the operation of transceiver **360** will be similar to that described for a transmitter as previously illustrated in FIGS. **3**A and **3**B. It is significant to note that data packet **330** will include a concatenation of the individual function codes selected for each of the aforementioned input parameters. As by way of example, server **260** may provide client workstation **250** with a Web page display that models a common home thermostat. As previously described, either server **260** or workstation **250** may include application software that would permit a user with access to remotely adjust the controls on a home heating system by adjusting related finctional controls on a graphical user interface updated with feedback from the aforementioned control system.

Reference is now made to FIG. **3**D, which is a block diagram further illustrating the transceiver of FIG. **3**C in light of the home heating system described above. Specifically, transceiver **360** is shown with four specific parameters related to four specific function codes as illustrated in look up table **325**. In this regard, sensor(s) **310** (one sensor shown for simplicity) inputs a data signal to data interface **321**. Data controller receives an input from data interface **321** that it associates with a specific function code as shown in look up table **325**. Data controller **324** assembles data packet **332** by concatenating received data packet **330** with its own transceiver identification code **326** and its own specific function codes. Data packet **332** is configured by RF transceiver **350** for transmission via antenna **323** to either a stand-alone transceiver as shown in FIG. **2**, or alternatively, to local gateway **210**. It will be appreciated by persons skilled in the art that data interface **321** may be uniquely configured to interface with specialized sensor(s) **310**. This circuit, therefore, may differ from transceiver to transceiver, depending upon the remote system parameter that is monitored and the related actuator to be controlled. Implementation of data interface **321** will be understood by persons skilled in the art, and need not be described herein.

Reference is now made to FIG. **3**E, which is a block diagram further illustrating the transceiver of FIG. **3**C in combination with a GPS receiver. Specifically, GPS receiver **327** replaces data interface **321**, sensor **310**, and actuator **380** as illustrated in FIG. **3**C. In this regard, GPS receiver **327** inputs a data signal containing latitude and longitude coordinates to data controller **324**. Data controller **324** assembles data packet **332** by concatenating received data packet **330** with its own transceiver identification code **326** and the coordinates received from GPS receiver **327**. Data packet **332** is configured by RF transceiver **350** for transmission via antenna **323** to either a stand-alone transceiver as shown in FIG. **2**, or alternatively, to local gateway **210** as previously described.

Having illustrated and described the operation of the various combinations of RF transmitters and transceivers consistent with the present invention, reference is now made to FIG. **4**, which is a block diagram illustrating certain principal components and the operation of a local gateway **210** of a control system **100** (see FIG. **2**) constructed in accordance with the present invention. The primary physical components that may be provided within local gateway **210** are a transceiver **420**, a CPU **422**, a memory **424**, a network card **426**, a DSL modem **428**, an ISDN card **430**, as well as other components not illustrated in the FIG. **4** that would enable a TCP/IP connection to WAN **230**. The transceiver **420** is configured to receive incoming signals consistently formatted in the convention previously described. Local gateway **210** may be configured such that memory **424** includes look up table **425** to assist in identifying the remote and intermediate transceivers used in generating and transmitting the received data transmission. Program code within the memory **424** may also be provided and configured for controlling the operation of a CPU **422** to carry out the various functions that are orchestrated and/or controlled by local gateway **210**. For example, memory **424** may include program code for controlling the operation of the CPU **422** to evaluate an incoming data packet to determine what action needs to be taken. In this regard, look up tables **425** may also be stored within memory **424** to assist in this process. Furthermore, memory **424** may be configured with program code configured to identify a remote transceiver **427** or identify an intermediate transceiver **429**. Function codes, transmitter and or transceiver identification numbers, may all be stored with associated information within look up tables **425**.

Thus, one look up table may be provided to associate transceiver identification numbers with a particular user. Another look up table may be used to associate function codes with the interpretation thereof For example, a unique code may be associated by a look up table to identify functions such as test, temperature, smoke alarm active, security system breach, etc. In connection with the lookup tables **425**, memory **424** may also include a plurality of code segments that are executed by CPU **422**, and which largely control the operation of the computer. For example, a first data packet segment **330** may be provided to access a first lookup table to determine the identity of the transceiver which transmitted the received message. A second code segment may be provided to access a second lookup table to determine the proximate location of the message generating transceiver, by identifying the transceiver that relayed the message. A third code segment may be provided to identify the content of the message transmitted. Namely, is it a fire alarm, a security alarm, an emergency request by a person, a temperature control setting, etc. Consistent with the invention, additional, fewer, or different code segments may be provided to carryout different functional operations and data signal transfers throughout the transceiver network. The local gateway **210** may also include one or more mechanisms through which to communicate with remote systems. For example, the gateway may include a network card **426**, which would allow the gateway **210** to communicate across a local area network to a network server, which in turn may contain a backup gateway to WAN **230**. Alternatively, local gateway **210** may contain a DSL modem **428**, which may be configured to provide a direct dial link to a remote system, by way of the PSTN. Alternatively, local gateway **210** may include an ISDN card **430** configured to communicate via an ISDN connection with a remote system. Other communication gateways may be provided as well to serve as primary and or backup links to WAN **230** or to local area networks that might serve to permit local monitoring of gateway health and data packet control.

Reference is now made to FIG. **5**, which is a diagram illustrating WAN connectivity in a system constructed in accordance with the invention. In this regard, local gateway **210** is configured to transmit control signals and receive data signals using the open data packet protocol as previously described. Local gateway **210** is preferably interconnected permanently on WAN **230** and configured to translate received data signals for WAN transfer via TCP/IP. A server **530** configured with web applications and client specific applications as required is connected to WAN **230** via router **510** and further protected and buffered by firewall **520**. Consistent with the present invention, server **530** is assisted in its task of storing and making available client specific data by database server **540**. A workstation **560** configured with a Web browser is connected to WAN **230** at client premises by any suitable means known by those of skill in the art. Alternatively, clients may access WAN **230** via remote laptop **550** or other devices configured with a compatible Web browser. In this way, server **530** may provide client specific data upon demand.

Having described the control system of FIG. **2**, reference is now made to FIG. **6** which illustrates a specific monitoring embodiment consistent with application of the invention. More specifically, FIG. **6** illustrates a remote utility meter monitoring system **600**. Remote utility meter subsystem **610** consists of utility meter **613** and an appropriately integrated sensor **612** wherein the current utility meter operational status and current utility meter usage total is transmitted via functional codes along with a transceiver identification code in a manner previously described by transmitter **614** to stand-alone transceiver **221**. Stand-alone transceiver **221** further processes and transmits the encoded data to local gateway **210** which translates the data packet information into TCP/IP format for transfer across WAN **230** to server **260**. Server **260** collects and formats the utility meter information for viewing and or retrieval upon client demand in a manner previously described.

Having described a specific client application consistent with the present invention wherein the remote transmitter is permanently integrated with a stationary data input point (a utility meter), reference is now made to FIG. **7** which more fully illustrates the flexibility of the invention. More specifically, FIG. **7** illustrates a remote automotive diagnostics monitoring system **700**. Remote automotive diagnostics interface unit **710** consists of sensor **712** integrated with the vehicle diagnostics data bus **711**, and transmitter **714** wherein contents of the vehicle diagnostics can be downloaded upon a control signal to sensor **712** from a remote location serviced by local gateway **210**. In this manner, a vehicle in need of service but still capable of accessing the vehicle diagnostics codes can be remotely diagnosed by uploading the information through remote automotive diagnostics monitoring system **700** and accessing a custom report created by server **260** in a manner previously described. In this regard, server **260** could be configured to perform any of a number of levels of diagnostics and provide service manual instructions, figures, and local authorized service contact information via WAN **230** on a fee basis or per a predetermined level of service plan.

Having described a monitoring system consistent with the present invention wherein the control signal initiates the monitoring process, reference is now made to FIG. **8**. FIG. **8** illustrates a client specific control system consistent with both monitoring and control functions of the invention.

More specifically, FIG. **8** illustrates a remote irrigation control system **800**. For simplicity, controlled area **810** is represented by a single rain gauge **813** and a single related spray head **817**. It is easy to see that such a system could be modified and expanded to monitor and control any of a number of irrigation systems integrated with the present invention.

Controlled area **810** is configured with a rain gauge **813** integrated with sensor **811** wherein rainfall and applied water to the adjacent area is transmitted via functional codes by transmitter **812** along with a related transceiver identification code in a manner previously described to stand-alone transceiver **221**. Stand-alone transceiver **221** further processes and transmits the encoded data to local gateway **210** which translates the data packet information into TCP/IP format for transfer across WAN **230** to server **260**. Server **260** collects and formats the rain gauge data for viewing or retrieval upon client demand in a manner previously described. Additionally, server **260** may be configured to communicate data to operate spray head **817** by opening water supply valve **816** integrated with actuator **814** by sending a control signal to transceiver **815**, per a client directed water application control schedule. Alternatively, a customer workstation **250** could periodically download and review the rain gauge data and could initiate an automatic control signal appropriate with the customer's watering requirements. In yet another embodiment, a customer technician could initiate a control signal upon review of the rain gauge information and making the determination that more water is required.

Reference is now made to FIG. **9** which illustrates the operation of an automated parking control system **900** consistent with the present invention. Automated parking facility **910** consists of a controlled access area with ingress gate **920** and egress gate **930**. Both gates **920** and **930** are further configured with a position sensor, an actuator, and transceiver illustrated as ingress assembly **922** and egress assembly **932**, respectively. Parking spaces **940** may be configured with vehicle sensors. Sensor—transceiver assembly **932** may be configured to transmit a function code associated with the condition of parking spaces **1**, **2**, **3**, and **4**. It will be appreciated by those skilled in the art that the single row of four appropriately configured parking spaces illustrated can be expanded by adding parking spaces configured with vehicle sensors integrated with control system **900** via multiple sensor—transceiver assemblies. Automated parking control system **900** collects data signals from each sensor—transceiver assembly **932**, integrated in the system, and compiles a master schedule consisting of scheduled use for each parking space in the automated parking facility. In this manner, a customer with access to WAN **230** and server **530** may make a reservation and or check the availability of parking spaces at the automated parking facility from her home or office (or through any Internet portal). For example, a customer that will be out of town on business for **2** days next week, may access the automated parking control system server **530** by using a Web browser to view parking availability for the target travel dates. The customer may reserve the parking slot by providing a personal transmitter identification code (or other identification code) that the customer intends to use to access and exit the facility the following week. When the customer arrives at the ingress gate **920**, the customer may enter the automated parking facility **910** by depressing a button on her personal portable transmitter (see FIG. **3**A). Ingress assembly **922** receives and forwards the customer's transmitted identification code to server **530** via gateway **210** and WAN **230** in a manner previously described. Server **530** confirms the customer's reservation, alternatively checks space availability to determine if access should be granted. In addition, server **530** may be further programmed to determine if the particular customer has an established account with the facility owner or whether a credit card payment transaction is in order. Automatic parking facility control system **900** would record the actual use of the reserved parking space for storage on database server **540**. Server **530** could retrieve the stored usage information on a periodic basis from database server **540** and generate appropriate bills for each customer.

Alternatively, the customer could reserve the slot by providing billing information via WAN **230** and ingress gate **920** could be further configured with a credit card reader and an alphanumeric keypad interface. Both the credit card reader and the alphanumeric keypad interface could be interconnected to the automated parking facility control system **900** by their own appropriately configured transceiver. Either or both the credit card reader and the alphanumeric keypad interface could be used to identify customers with reservations.

The operator of parking facility control system **900**, can expand both the level of security of the parking facility and the services provided by adding networked peripherals in a manner previously described and upgrading the software applications on server **530**. For example, by adding automated ingress and egress gates configured to allow the entry and exit of parking facility customers and authorized personnel and configuring the egress gate **930** for vehicles such that only identified customers may exit with a vehicle, both customers and their vehicles are protected from thieves.

A further example of expanding the services offered by automated parking facility control system **900** might consist of offering a schedule of vehicle services that could be scheduled and performed on the vehicles of long-term parking customers. By adding the appropriate interface to server **530**, parking facility customers could be prompted when making their reservation with a list of potential vehicle services that could be scheduled and performed by vehicle service technicians during the duration of the customer's business trip. A customer interested in having her automobile's oil changed and tires rotated would authorize and schedule the desired services when arranging her parking reservation. Upon leaving the parking facility at the start of her business trip, the customer could leave her vehicle valet key in an appropriately identified lock box. After her trip is complete, the customer returns to the lot. She gains access to the lot by any of the aforementioned methods and retrieves her valet key by similarly identifying herself as the vehicle owner.

Having illustrated specific applications using the present invention in FIGS. **6** through **9**, reference is now made to FIG. **10** which illustrates a system **1000** that monitors and controls remote data points associated with a plurality of systems. In this embodiment, server **530** may be configured with monitor/control remote services **1010** application-specific software. For example, the controlled area **810** of the irrigation control system shown in FIG. **8**, the remote utility meter subsystem **610** of FIG. **6**, and the automated parking facility **910** of FIG. **9** may be monitored and remotely controlled (where required) by server **530**. In a manner previously described herein, server **530** collects and processes data information transferred and sent over WAN **230** by local gateways coupled via RF links to transceivers and transmitters associated with systems **1020**, **1030**, and **1040**. Alternatively, server **530** initiates control signals that may be sent via the gateways to the appropriate transceivers and transmitters as required. For ease of illustration and description, FIG. **10** shows each of the systems serviced by server **530** requiring its own dedicated local gateway. It will be appreciated by those skilled in the art that small-scale systems jointly located within a geographic area served by an array of transceivers and a gateway may be configured to share the transceiver and gateway infrastructure of a previously installed local system.

Having described the physical layer of a system consistent with the present invention, reference is now made to FIG. **11** which describes the data structure of messages sent and received using the invention. In this regard, the standard message consists of: to address; from address; packet number; maximum packet number, packet length; command; data; packet check sum (high byte); and packet check sum (low byte). The "to address" or message destination consists from 1 to 6 bytes. The "from address" or message source device is coded in a full 6 byte designator. Bytes **11** through **13** are used by the system to concatenate messages of packet lengths greater than 256 bytes. Bytes **14** is a command byte. Byte **14** works in conjunction with bytes **15** through **30** to communicate information as required by system specific commands. Bytes **31** and **32** are packet check sum bytes. The packet check sum bytes are used by the system to indicate when system messages are received with errors. It is significant to note that bytes **31** and **32** may be shifted in the message to replace bytes **15** and **16** for commands that require only one byte. The order of appearance of specific information within the message protocol of FIG. **11** remains fixed although the byte position number in individual message transmissions may vary due to scalability of the "to address," the command byte, and scalability of the data frame.

Having described the general message structure of a message of the present invention, reference is directed to FIG. **12** which illustrates three sample messages. The first message illustrates the broadcast of an emergency message "FF" from a central server with an address "0012345678" to a personal transceiver with an address of "FF."

The second message illustrated reveals how the first message might be sent to a transceiver that functions as a repeater. In this manner, emergency message "FF" from a central server with address "0012345678" is first sent to transceiver "F0." The second message, further contains additional command data "A000123456" that may be used by the system to identify further transceivers to send the signal through on the way to the destination device.

The third message illustrated on FIG. **12** reveals how the message protocol of the present invention may be used to "ping" a remote transceiver in order to determine transceiver health. In this manner, source unit "E112345678" originates a ping request by sending command "08" to a transceiver identified as "A012345678." The response to the ping request can be as simple as reversing the "to address" and the "from address" of the command, such that, a healthy transceiver will send a ping message back to the originating device. The system of the present invention may be configured to expect a return ping within a specific time period. Operators of the present invention could use the delay between the ping request and the ping response to model system loads and to determine if specific system parameters might be adequately monitored and controlled with the expected feedback transmission delay of the system.

Having described the message structure of a message of the present invention, reference is directed to FIG. **13** which illustrates the integration of the system of the present invention with the control system of FIG. **1**. Having previously illustrated several variations consistent with the principles of the present invention, it will be appreciated by those skilled in the art that multiple variations of the present invention may be integrated with existing control systems. In this regard, an existing control system with local controller **110** and a plurality of sensor actuators **115** (one shown for simplicity of illustration) are in communication with central controller **130** via PSTN **120** as previously described. In a manner well known in the art of control systems, local controller **110** transmits appropriate status information via PSTN **120** to central controller **130**.

Control systems consistent with the design of FIG. **1**, as further illustrated in FIG. **13**, require the routing of electrical conductors to each sensor and actuator as the application requires. It will be appreciated by those skilled in the art that the system of the present invention can take advantage of the infrastructure of an existing system by inserting data translator **140** such that system data is sent to both the central controller **130** in the old configuration, as well as, the data translator **140**. Data translator **140** serves to convert system data to function codes as previously described. Once data translator **140** successfully converts the system data stream to the message protocol of the present invention, transceiver **815** further converts the system data stream to a RF signal.

As previously described in connection with FIG. **2**, stand-alone transceiver **221** receives and repeats the RF data transmission received from transceiver **815**. Local gateway **210** receives the RF data transmission repeated by stand-alone transceiver **221** and converts the RF data transmission into TCP/IP for further transmission across WAN **230** to server **260**. In this regard, server **260** may further manage the data for internal storage or alternatively storage in database **270**. Customers with WAN **230** access may access the system data from workstation **250** or laptop computer **240**.

Having described integration of the system of the present invention with the control system of FIG. **1** in FIG. **13**, reference is now directed to FIG. **14** which illustrates integration of the system of the present invention with mobile inventory units. In this regard, system **1060** consists of the system of the present invention as previously illustrated and described in FIGS. **1** and **13**. Having previously illustrated several variations consistent with the principles of the present invention, it will be appreciated by those skilled in the art that multiple variations of the present invention may be integrated with mobile inventory units **1070**. In this regard, sensor/actuator **115** integrated with transceiver **815** in sensor-transceiver assembly **1065** is further integrated with any of a number of mobile inventory units **1070** (one sensor-transceiver unit **1065** shown for simplicity of illustration). It will be appreciated by those skilled in the art that as long as a mobile inventory unit **1070**, herein represented by a package, ship, airplane, train, and a taxi are within the radio-frequency transmission and receiving range of stand-alone transceiver **221**, the system of the present invention may be used to monitor, store and report information of and relating to mobile inventory unit **1070**.

It will be further appreciated by those skilled in the art that the system of the present invention may be used to transfer information to adequately equipped mobile inventory units **1070**. In this regard, shipping companies may use the present invention to update a database containing location and status information for each mobile inventory unit **1070** in the company fleet. Shipping companies may also transfer informative messages or other information using the system of the present invention.

In one embodiment, the present invention may be used to store, retrieve, and update maintenance information related to individual mobile inventory units. For example, federally registered airplanes must keep a maintenance log with the craft detailing all inspections, maintenance, and repairs. The system of the present invention could be used by fixed base operators (FBOs) who perform inspections and maintenance on aircraft to retrieve and update the aircraft maintenance log. In this way, FBOs located throughout the world will be able to retrieve and update an electronic version of the maintenance history of an aircraft. In addition, a properly configured system could also contain maintenance directives and other service bulletins related to the particular aircraft.

In yet another embodiment, a properly integrated sensor/actuator **115** with transceiver **815** may be used to monitor mobile inventory unit system parameters. For example, an airplane could be configured to monitor and report engine run time, time elapsed since the last recorded inspection of a particular type, and related system information. It will be appreciated by those skilled in the art that the system of the present invention may be integrated with remote units other than those shown. The ship, package, airplane, train, and taxi shown in FIG. **14** are for example only and not meant to limit the scope of the present invention.

It will be appreciated that the foregoing description has illustrated certain fundamental concepts of the invention, but that other additions and/or modifications may be made consistent with the inventive concepts. For example, the one-way transmitters illustrated in FIG. **3**A and implemented in a control system as illustrated in FIG. **6** may be adapted to monitor the current status of water, gas, and other utility meters. One-way transmitters might further be used to monitor and report actual operational hours on rental equipment or any other apparatus that must be serviced or monitored on an actual runtime schedule.

The two-way transceivers of the current invention, may be adapted to monitor and apply control signals in an unlimited number of applications. By way of example only, two-way transceivers of the current invention can be adapted for use with pay type publicly located telephones, cable television set converter boxes, as well as, for use with a host of residential appliances and devices to enable a remote controllable home automation and security system.

In a geographic area appropriately networked with permanently located transceivers consistent with the invention, personal transmitters consistent with the invention can be used to monitor and control personnel access and egress from specific rooms or portions thereof within a controlled facility. Personal transmitters can further be configured to transfer personal information to public emergency response personnel, personal billing information to vending machines, or to monitor individuals within an assisted living community.

Two-way transceivers consistent with the present invention can be integrated to monitor and control a host of industrial and business applications as well. By way of example only, building automation systems, fire control systems, alarm systems, industrial trash compactors, and building elevators can be monitored and controlled with devices consistent with the present invention. In addition, courier drop boxes, time clock systems, automated teller machines, self-service copy machines, and other self-service devices can be monitored and controlled as appropriate. By way of further example, a number of environment variables that require monitoring can be integrated with the system of the present invention to permit remote monitoring and control. For instance, light levels in the area adjacent to automated teller machines must meet minimum federal standards, the water volume transferred by water treatment plant pumps, smokestack emissions from a coal burning power plant or a coke fueled steel plant oven may also be remotely monitored.

The two-way transceivers of the present invention may be further integrated with a voice-band transmitter and receiver. As a result, when a person presses, for example, the emergency button on his/her transmitter, medical personnel, staff members, or others may respond by communicating via two-way radio with the party in distress. In this regard, each transmitter may be equipped with a microphone and a speaker that would allow the person to communication information such as their present emergency situation, their specific location, etc.

The foregoing description has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obvious modifications or variations are possible in light of the above teachings. For example, it should be appreciated that, in some implementations, the transceiver identification number is not necessary to identify the location of the transmitter. Indeed, in implementations where the transmitter is permanently integrated into an alarm sensor other stationary device within a system, then the control system server and or local gateway could be configured to identify the transmitter location by the transmitter identification number alone. In will be appreciated that, in embodiments that do not utilize repeating transceivers, the transmitters will be configured to transmit at a higher RF power level, in order to effectively communicate with the control system local gateway.

The embodiment or embodiments discussed were chosen and described illustrate the principles of the invention and its practical application to enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly and legally entitled.

What is claimed is:

1. A system for remote data collection, assembly, and storage comprising:

a computer configured to execute at least one computer program that formats and stores select information for retrieval upon demand from a remotely located device, said computer integrated with a wide area network (WAN);

at least one wireless transmitter configured to transmit select information and transmitter identification information;

a plurality of relatively low-power radio-frequency (RF) transceivers dispersed geographically at defined locations configured to receive select information transmitted from at least one nearby wireless transmitter and further configured to transmit the select information, the transmitter identification information and transceiver identification information; and

at least one gateway connected to the wide area network configured to receive and translate the select information, the transmitter identification information, and transceiver identification information, said gateway further configured to farther transmit the translated information to the computer over the WAN.

2. The system defined in claim **1**, the computer program further comprising:

a first segment for evaluating received information to identify an originating transmitter;

a second segment for evaluating the received information and identifying transceivers that relayed the select information from the originating transmitter to the gateway;

a third segment for evaluating the select information transmitted from the originating transmitter embedded within the received information; and

a fourth segment responsive to the first, second, and third segments for determining an action to be taken based upon the select information, the identified originating transmitter, and the identified transceivers.

3. The system as defined in claim **1**, wherein each wireless transmitter is configured to transmit a relatively low-power radio-frequency (RF) signal.

4. The system as defined in claim **1**, wherein each wireless transmitter is integrated with a sensor.

5. The system as defined in claim **1**, wherein the RF signal transmitted by the transceiver contains a concatenation of information comprising select information and transmitter identification information from the originating transmitter and transceiver identification information for each transceiver that receives and repeats the RF signal.

6. The system as defined in claim **5**, wherein the at least one transmitter is replaced by a transceiver, the transceiver further integrated with an actuator.

7. The system as defined in claim **6**, wherein the transceivers are configured to communicate with the gateway via a RF signal.

8. The system as defined in claim **7**, wherein the computer is further configured to respond to received select information by communicating a control signal to at least one transceiver, wherein the actuator integrated with the transceiver is responsive to the control signal.

9. The system as defined in claim **8**, wherein select transceivers further include a microphone, a speaker, and means for communicating two-way voice information to the WAN via the transceivers.

10. The system as defined in claim **1**, wherein the gateway is permanently connected to the WAN.

11. The system as defined in claim **1**, wherein the gateway includes one selected from the group consisting of: a modem for establishing a dial-up connection with a remote computer; a network card for communicating across a local area network; a network card for communicating across the WAN; a DSL modem; and an ISDN card to permit backup access to the computer.

12. The system as defined in claim **1**, wherein the gateway translates the select information, the transmitter identification, and the transceiver identification information into TCP/IP for communication over the WAN.

13. The system as defined in claim **1**, wherein the WAN is the Internet.

14. The system as defined in claim **1**, wherein the WAN is a dedicated Intranet.

15. The system as defined in claim **2**, further including a first lookup table that is utilized by the first segment, wherein the first lookup table is configured to associate a plurality of unique transmitter identification numbers with a plurality of unique transmitter identifiers, wherein each transmitter identification number is uniquely associated with a unique transmitter identifier.

16. The system as defined in claim **15**, further including a second lookup table that is utilized by the second segment, wherein the second lookup table is configured to associate a plurality of unique transceiver identification numbers with a plurality of unique geographic locations, wherein each transceiver identification number is uniquely associated with a unique geographic location.

17. The system as defined in claim **16**, further including a third lookup table that is utilized by the third segment, wherein the first lookup table is configured to associate a plurality of unique transmitter codes with a plurality of unique information fields associated with the transmitter codes, wherein each transmitter code is uniquely associated with a unique information field.

18. A method for collecting information and providing data services comprising:

adaptively configuring at least one transmitter with a sensor wherein the transmitter generates an information signal consisting of a transmitter identification code and an information field;

placing a plurality of relatively low-power radio-frequency (RF) transceivers dispersed geographically wherein the information signal is received and repeated as required to communicate the information signal to a gateway, the gateway providing access to a WAN;

translating the information signal within the gateway into a WAN compatible data transfer protocol;

transferring the information signal via the WAN to a computer wherein the computer is configured to manipulate and store data provided in the information signal; and granting client access to the computer.

19. The method of claim **18**, wherein the WAN is the Internet.

20. The method of claim **18**, wherein the WAN is an Intranet.

21. The method of claim **18**, wherein the computer is configured to provide the information in hypertext mark-up language (HTML).

22. The method of claim **18**, wherein clients access the information using a web browser.

23. The method of claim **18**, wherein the step of adaptively configuring at least one transmitter is modified to replace the sensor with a global positioning system receiver.

24. A method for controlling a system comprising:

remotely collecting data from at least one sensor;

processing the data into a radio-frequency (RF) signal;

transmitting the RF signal, via a relatively low-power RF transceiver, to a gateway;

translating the data in the RF signal into a network transfer protocol;

sending the translated data to a computer, wherein the computer is configured to appropriately respond to the data generated by the at least one sensor by generating an appropriate control signal;

sending the control signal via the network to the gateway;

translating the control signal from a network transfer protocol into a RF control signal;

transmitting the RF control signal;

receiving the RF control signal;

translating the received RF control signal into an analog signal; and

applying the analog signal to an actuator to effect the desired system response.

25. The method of claim **24**, wherein the RF signal contains a concatenation of information comprising encoded data information and transmitter identification information from an originating transmitter.

26. The method of claim 25, wherein the step of transmitting the RF signal is further performed by at least one transceiver, wherein the transceiver is configured to concatenate a transceiver identification code to the RF signal.

27. The method of claim 25, wherein the step of transmitting the RF control signal is further performed by at least one transceiver, wherein the transceiver is configured to receive and transmit the RF control signal.

28. The method of claim 25, wherein the steps of translating and applying the received RF control signal are performed only by an identified transceiver electrically integrated with an actuator.

29. The method of claim 25, wherein the network is the Internet.

30. The method of claim 25, wherein the network is an Intranet.

31. The method of claim 25, wherein the network transfer protocol is TCP/IP.

32. A system for monitoring remote devices comprising:

at least one sensor adapted to generate an electrical signal in response to a physical condition;

at least one wireless transmitter configured to encode the electrical signal, the wireless transmitter further configured to transmit the encoded electrical signal and transmitter identification information in a low-power radio-frequency (RF) signal;

at least one gateway connected a wide area network (WAN) configured to receive and translate the RF signal, the gateway further configured to deliver the encoded electrical signal and transmitter identification information to a computer on the WAN; and

a computer configured to execute at least one computer program that formats and stores select information responsive to the electrical signal for retrieval upon demand from a remotely located device.

33. The system defined in claim 32, the at least one computer program further comprising:

a first segment for evaluating received information to identify an originating transmitter;

a second segment for evaluating the received information and identifying transceivers that relayed the select information from the originating transmitter to the gateway;

a third segment for evaluating the select information transmitted from the originating transmitter embedded within the received information; and

a fourth segment responsive to the first, second, and third segments for determining an action to be taken based upon the select information, the identified originating transmitter, and the identified transceivers.

34. The system as defined in claim 32, wherein each wireless transmitter is configured to transmit a relatively low-power radio-frequency (RF) signal.

35. The system as defined in claim 32, wherein the at least one gateway is permanently connected to the WAN.

36. The system as defined in claim 32, wherein the gateway translates the encoded electrical signal, the transmitter identification, and the transceiver identification information into TCP/IP for communication over the WAN.

37. The system as defined in claim 32, wherein the WAN is the Internet.

38. The system as defined in claim 32, wherein the WAN is a dedicated Intranet.

39. The system as defined in claim 33, further including a first lookup table that is utilized by the first segment, wherein the first lookup table is configured to associate a plurality of unique transmitter identification numbers with a plurality of unique transmitter identifiers, wherein each transmitter identification number is uniquely associated with a unique transmitter identifier.

40. The system as defined in claim 39, further including a second lookup table that is utilized by the second segment, wherein the second lookup table is configured to associate a plurality of unique transceiver identification numbers with a plurality of unique geographic locations, wherein each transceiver identification number is uniquely associated with a unique geographic location.

41. The system as defined in claim 40, further including a third lookup table that is utilized by the third segment, wherein the first lookup table is configured to associate a plurality of unique transmitter codes with a plurality of unique information fields associated with the transmitter codes, wherein each transmitter code is uniquely associated with a unique information field.

42. A system for controlling remote devices comprising:

a computer configured to execute at least one computer program that generates at least one control signal responsive to a system input signal; said computer integrated with a wide area network (WAN);

at least one gateway connected to the WAN configured to receive and translate the at least one control signal; said gateway further configured to transmit a radio-frequency (RF) signal containing the control signal and destination information;

at least one wireless low-power RF transceiver configured to receive the RF signal from the gateway; said wireless transceiver configured to translate the RF signal to an analog output signal, the wireless transceiver electrically coupled with an actuator; and

an actuator configured to receive the analog output signal from the wireless transceiver, the actuator further configured to translate the analog output signal into a response.

43. The system defined in claim 42, the system input signal comprising:

a concatenation of information including data from a sensor, transceiver identification information from the originating transceiver, and transceiver identification information for each transceiver that receives and repeats the RF signal.

44. The system defined in claim 42, at least one computer program further comprising:

a first segment for evaluating a system input signal to identify an originating transceiver;

a second segment for evaluating the system input signal and identifying transceivers that relayed the system input from the originating transceiver to the gateway;

a third segment for evaluating the system input signal transmitted from the originating transceiver; and

a fourth segment responsive to the first, second, and third segments for determining an action to be taken based upon the data from a sensor, the identified originating transceiver, and the identified transceivers.

45. The system as defined in claim 42, wherein the at least one gateway is permanently connected to the WAN.

46. The system as defined in claim 42, wherein the gateway translates the RF signal and the RF control signal into TCP/IP for communication over the WAN.

47. The system as defined in claim 42, wherein the WAN is the Internet.

48. The system as defined in claim 42, wherein the WAN is a dedicated Intranet.

49. A system for managing an arrangement of application specific remote devices comprising:

a computer configured to execute a multiplicity of computer programs, each computer program executed to generate at least one control signal in response to at least one application system input, said computer integrated with a wide area network (WAN);

at least one gateway connected to the WAN configured as a two-way communication device to receive and translate the at least one control signal and the at least one application system input; said gateway further configured to translate and transmit a radio-frequency (RF) signal containing the control signal and destination information, said gateway further configured to receive and translate the at least one application system input and source information;

at least one wireless relatively low-power RF transceiver per computer program configured to receive the RF signal from the gateway; said wireless transceiver configured to translate the RF signal to an analog output signal, the wireless transceiver electrically coupled with an actuator and a sensor;

an actuator configured to receive the analog output signal from the wireless transceiver, the actuator further configured to translate the analog output signal into a response; and

a sensor configured to translate a physical condition into an analog version of the application system input.

50. The system as defined in claim 49, wherein the at least one gateway is permanently connected to the WAN.

51. The system as defined in claim 49, wherein the at least one gateway translates the RF signal and the RF control signal into TCP/IP for communication over the WAN.

52. The system as defined in claim 49, wherein the WAN is the Internet.

53. The system as defined in claim 49, wherein the WAN is a dedicated Intranet.

54. The system as defined in claim 49, wherein the at least one gateway is connected to the WAN by a network selected from the group consisting of a telecommunications network, private radio-frequency network, and a computer network.

55. A method for collecting information and providing data services comprising:

adaptively configuring a data translator at the output of a local controller, wherein the data translator converts the output data stream into an information signal consisting of a transmitter code and an information field;

adaptively configuring at least one transmitter with the data translator, wherein the transmitter converts the information signal into a low-power RF signal;

placing a plurality of relatively low-power radio-frequency (RF) transceivers dispersed geographically wherein the low-power RF signal is received and repeated as required to communicate the information signal to a gateway, the gateway providing access to a WAN;

translating the low-power RF signal within the gateway into a WAN compatible data transfer protocol;

transferring the translated low-power RF signal via the WAN to a computer wherein the computer is configured to manipulate and store data provided in said signal; and

granting client access to the computer.

56. The method of claim 55, wherein the WAN is the Internet.

57. The method of claim 55, wherein the WAN is an Intranet.

58. The method of claim 55, wherein the computer is configured to provide the information in hypertext mark-up language (HTML).

59. The method of claim 55, wherein clients access the information using a web browser.

60. A method for controlling an existing control system with a local controller comprising:

adaptively configuring a data translator disposed between and in communication with both a local controller and a wireless transceiver, wherein the data translator is configured to translate the local controller data stream into an information signal consisting of a transceiver identification code and a concatenation of function codes, the data translator further configured to translate control signals from the wireless transceiver into local controller recognized control signals;

remotely collecting data from at least one relatively low-power radio-frequency (RF) transceiver integrated with the data translator;

processing the data into a RF signal;

transmitting the RF signal to a gateway;

translating the data in the RF signal into a network transfer protocol;

sending the translated data to a computer, wherein the computer is configured to appropriately respond to the data generated by at least one sensor by generating an appropriate control signal;

sending the control signal via the network to the gateway;

translating the control signal from a network transfer protocol into a RF control signal;

transmitting the RF control signal;

receiving the RF control signal;

translating the received RF control signal into a local controller recognized control signal; and

applying the local controller recognized control signal via a local controller to effect the desired system response.

61. The method of claim 60, wherein the step of transmitting the RF control signal is further performed by at least one transceiver, wherein the transceiver is configured to receive and transmit the RF control signal.

62. The method of claim 60, wherein the network is the Internet.

63. The method of claim 60, wherein the network is an Intranet.

64. The method of claim 60, wherein the network transfer protocol is TCP/IP.

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(12) **United States Patent**
Lavoie

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(54) **IRRIGATION CONTROLLER**

(76) Inventor: **Nathan Lavoie**, 192 Old Westford Rd., Chelmsford, MA (US) 01824

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(52) **U.S. Cl.** **700/284**; 700/11; 700/14; 700/16; 700/19; 700/20; 700/86; 137/78.2; 137/78.3; 137/624.11; 137/624.12; 137/624.18; 239/63; 239/64; 239/69; 239/70; 239/551

(58) **Field of Search** 700/16–18, 19, 700/20, 83–86, 284, 11–14; 239/63–64, 70, 69, 542, 67, 99; 137/1–2, 78.2–78.7, 624.12, 624.13–18, 624.11, 550–551

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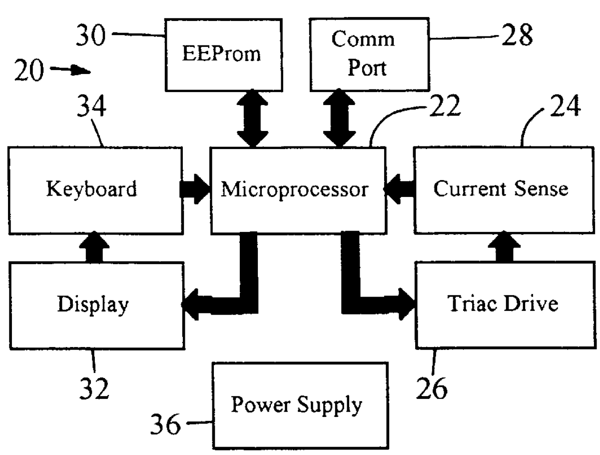
Primary Examiner—Ramesh Patel
(74) *Attorney, Agent, or Firm*—O'Connell Law Firm

(57) **ABSTRACT**

An irrigation controller in one embodiment comprising a microprocessor for controlling a plurality of watering zones of an irrigation system, a keyboard for enabling an inputting of commands relating to watering programs, a display for displaying information relating to watering programs, and an EEPROM for retaining information relating to watering programs and an on/off status variable even during extended periods without power. The irrigation controller may employ the EEPROM to retain a germinate watering program wherein everyday watering is triggered automatically and a multiplicity of watering start times can be selected. The irrigation controller may employ an analog precision rectifier for detecting how many valves are operational in a given watering zone, and the irrigation controller may also automatically adjust a maximum allowable current in response to how many valves are operational in a given watering zone. The irrigation controller may incorporate a power supply, and it may measure current draw from the power supply with an analog-to-digital converter and compare it to a maximum current capability of the power supply. A winterize mode may be provided, which allows simultaneous activation of multiple watering zones. A main controller may include a communication port comprising a four-wire interface that enables a transmittal of diagnostic information to a remote control device and enables remote operation of the valves of the irrigation system. Valve status may be indicated with a bi-color status LED.

21 Claims, 14 Drawing Sheets



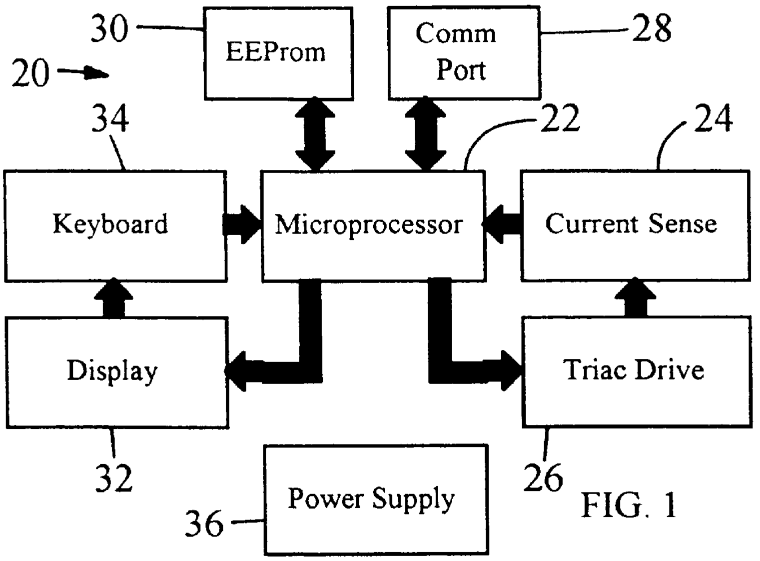

30
EEProm
Comm
Port
28
20
34
22
24
Keyboard
Microprocessor
Current Sense
Display
Triac Drive
32
26
36
Power Supply

FIG. 1

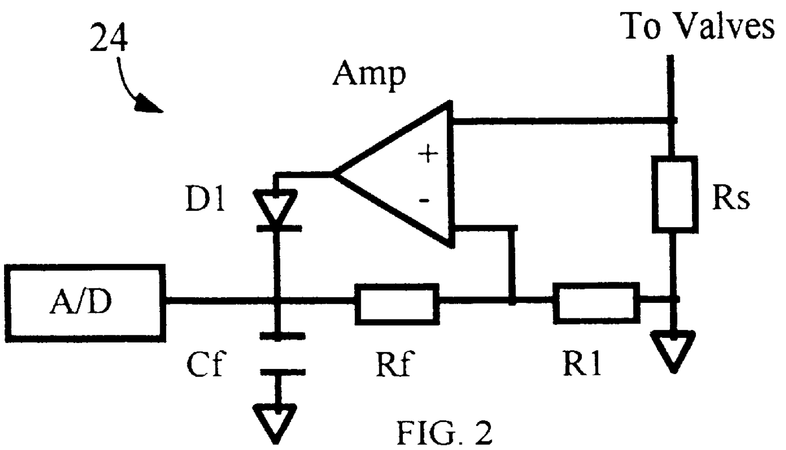

24
To Valves
Amp
+
-
D1
Rs
A/D
Cf
Rf
R1

FIG. 2

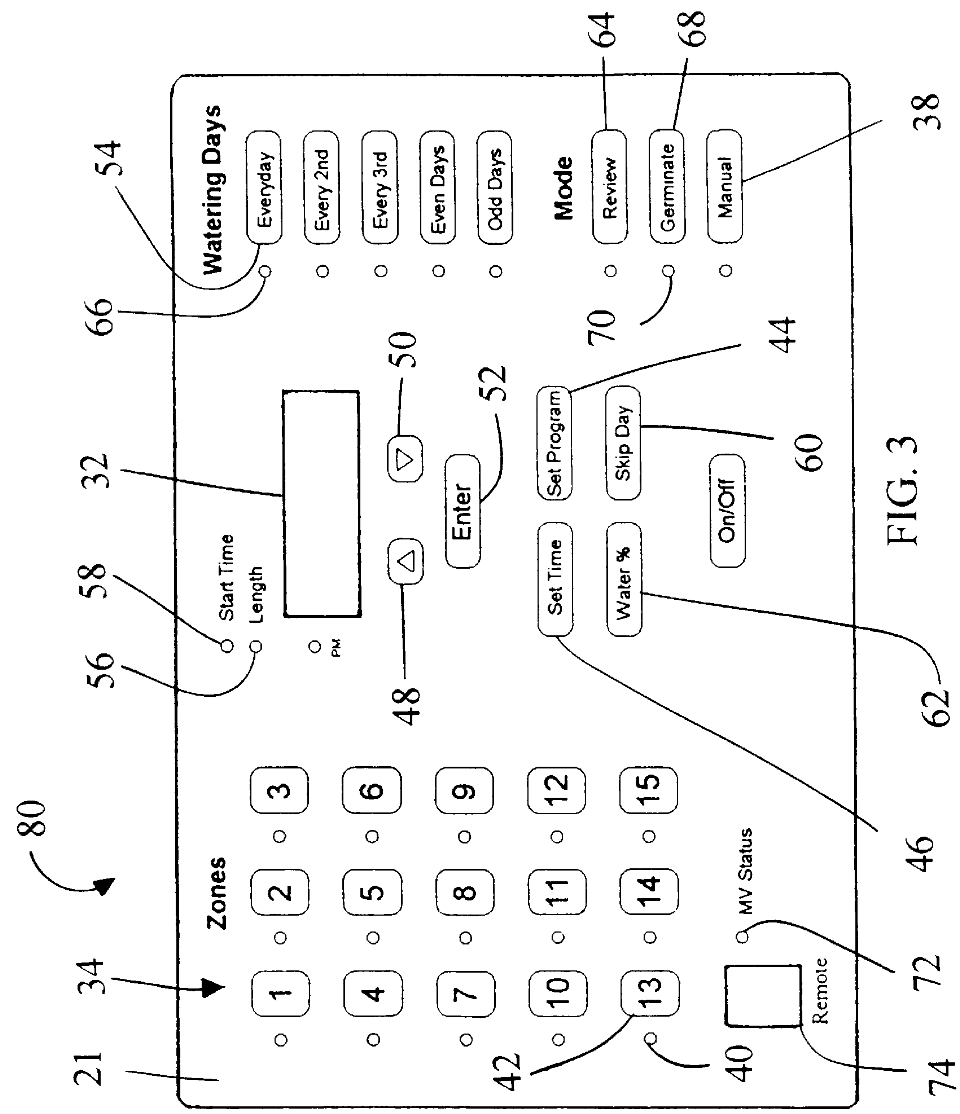

Watering Days
Everyday
Every 2nd
Every 3rd
Even Days
Odd Days
Mode
Review
Germinate
Manual
Start Time
Length
PM
Enter
Set Program
Skip Day
Set Time
Water %
On/Off
Zones
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
MV Status
Remote
21
32
34
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
80

FIG. 3

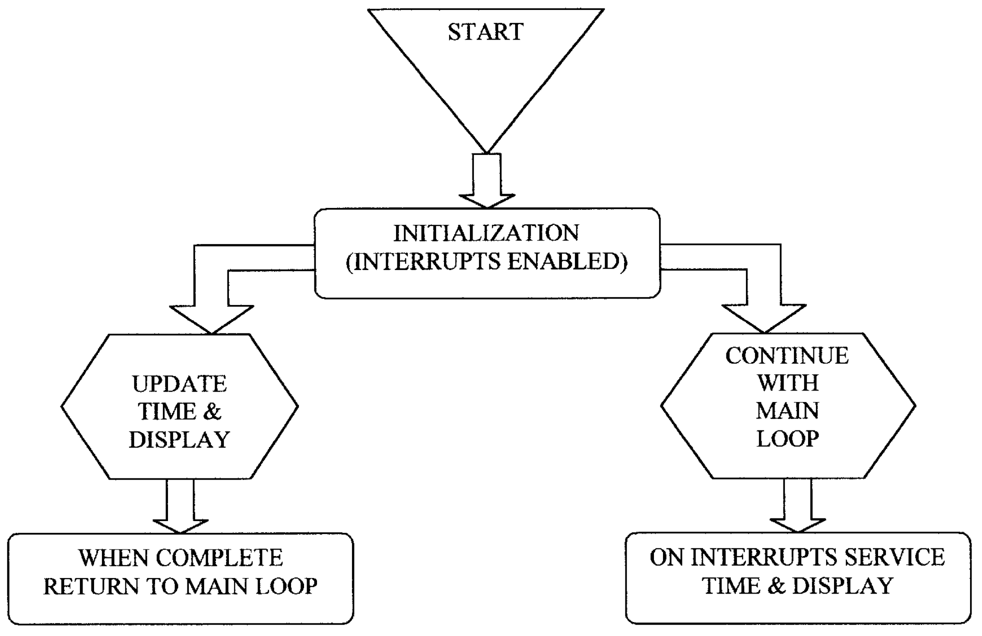

START
INITIALIZATION
(INTERRUPTS ENABLED)
UPDATE
TIME &
DISPLAY
CONTINUE
WITH
MAIN
LOOP
WHEN COMPLETE
RETURN TO MAIN LOOP
ON INTERRUPTS SERVICE
TIME & DISPLAY

FIG. 4

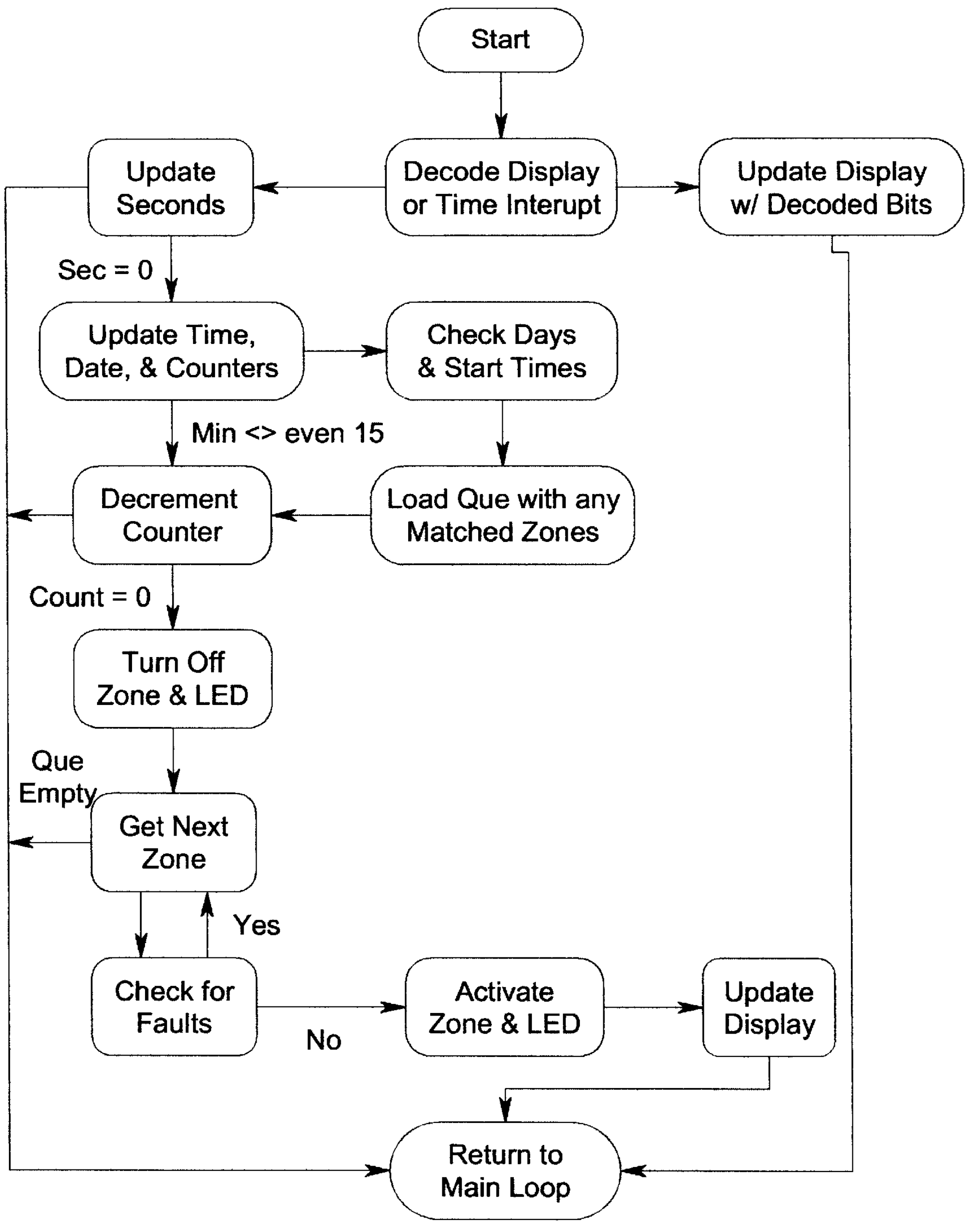
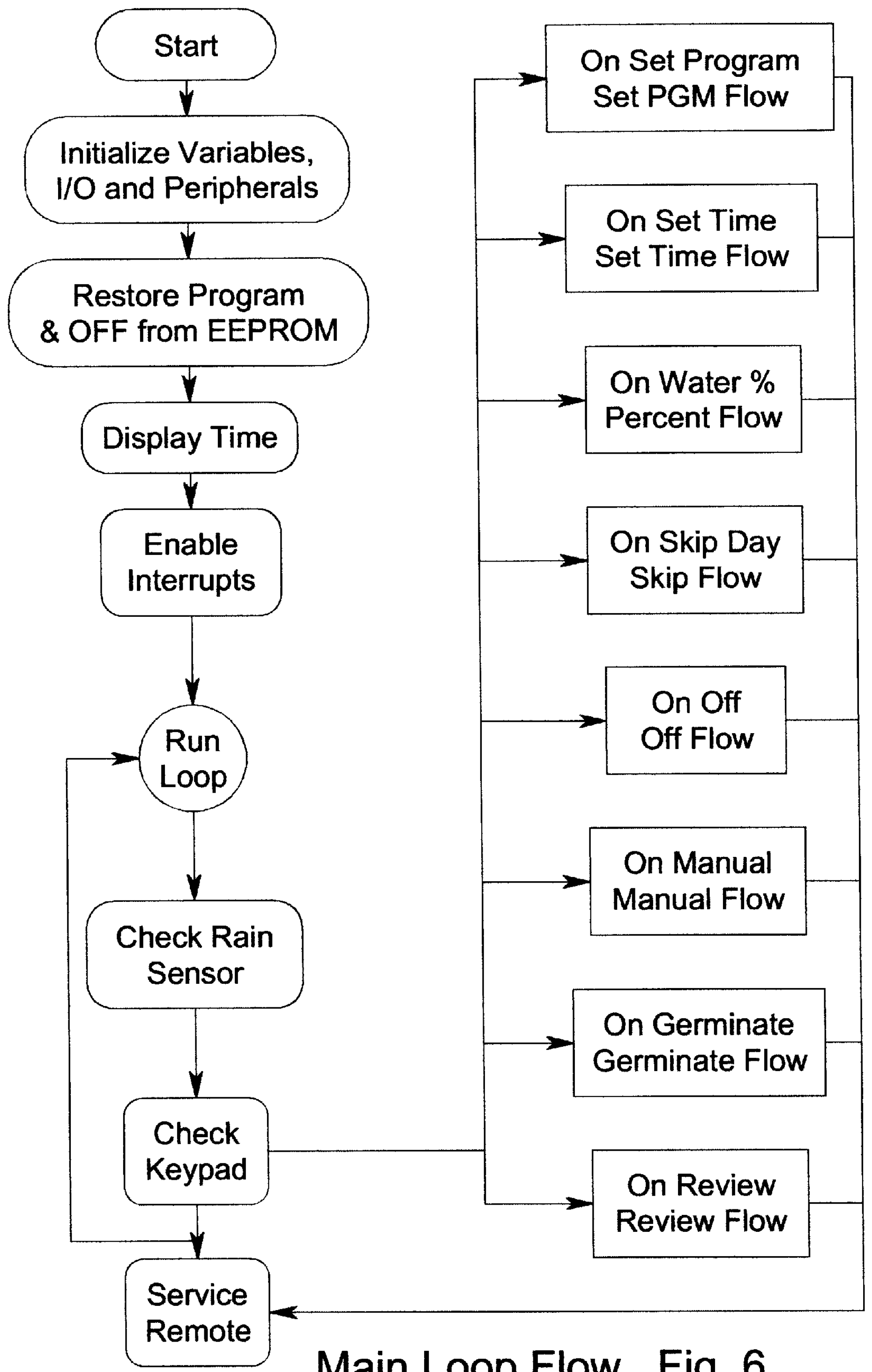

Start
Update Seconds
Decode Display or Time Interupt
Update Display w/ Decoded Bits
Sec = 0
Update Time, Date, & Counters
Check Days & Start Times
Min <> even 15
Decrement Counter
Load Que with any Matched Zones
Count = 0
Turn Off Zone & LED
Que Empty
Get Next Zone
Yes
Check for Faults
No
Activate Zone & LED
Update Display
Return to Main Loop

Fig. 5



Main Loop Flow Fig. 6

Set PGM Flow

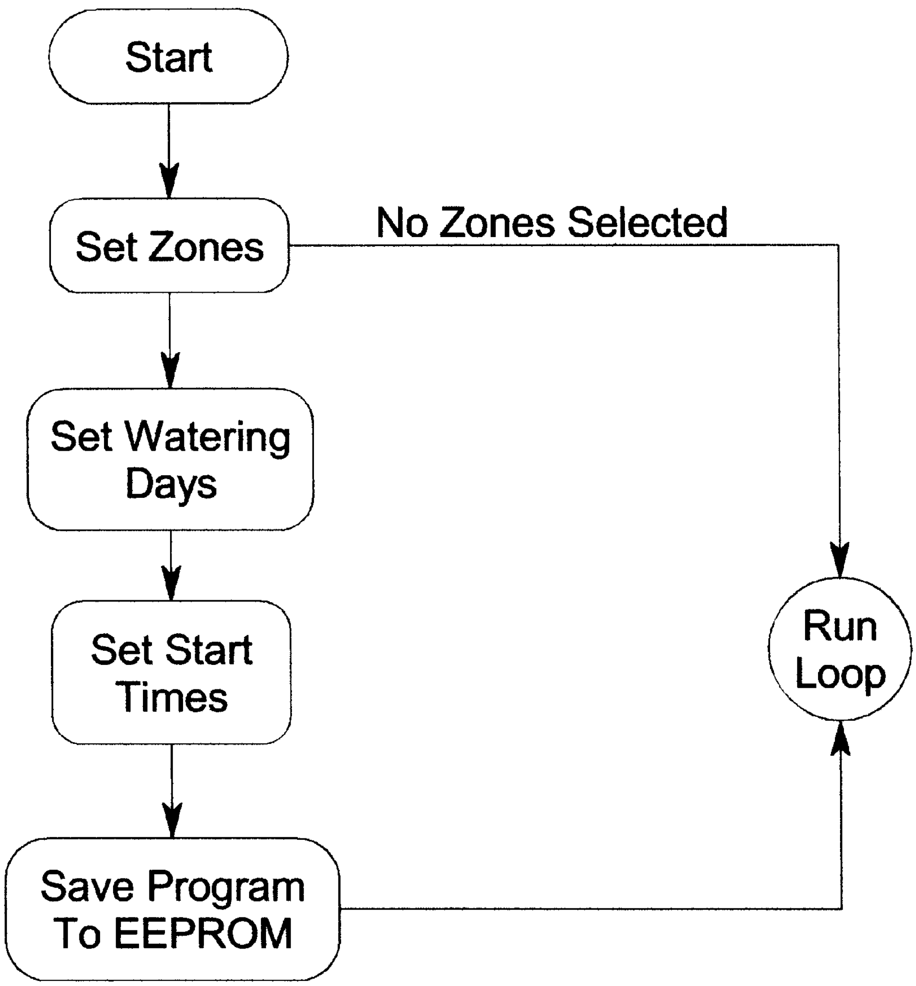


Fig. 7

Set Time Flow

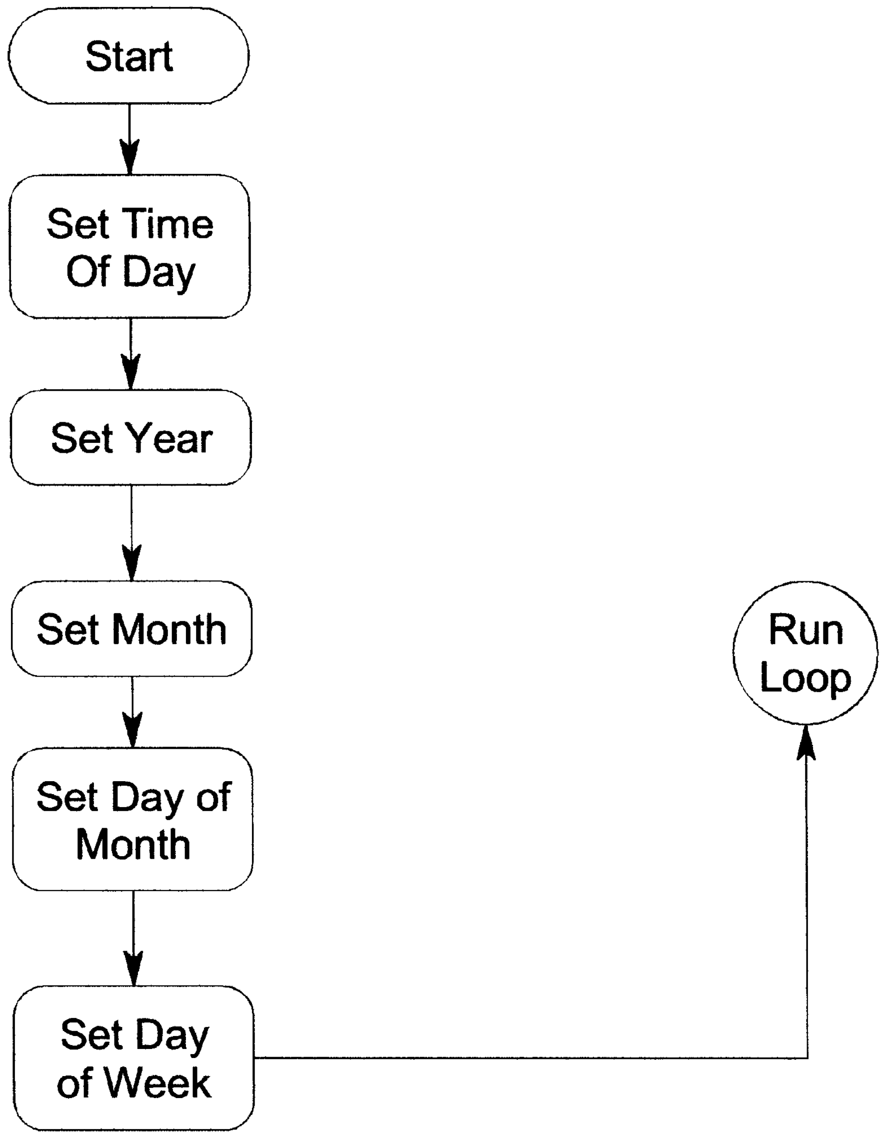


Fig. 8

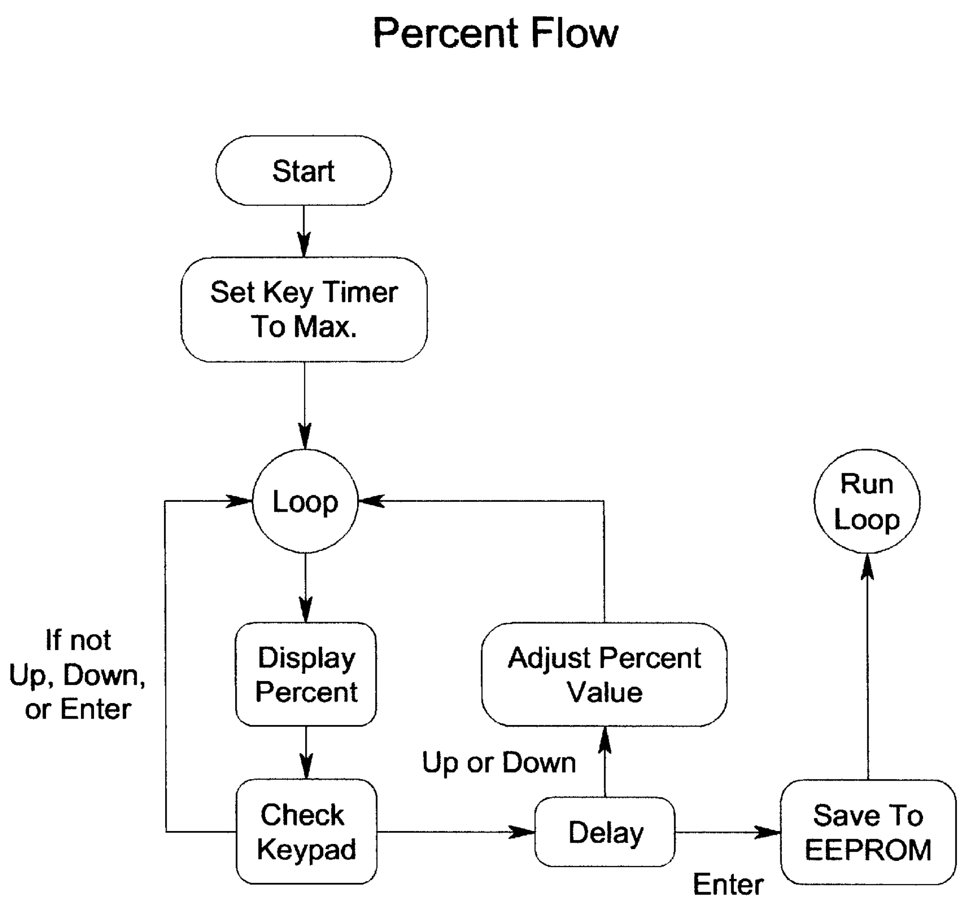

Percent Flow
Start
Set Key Timer To Max.
Loop
Run Loop
If not Up, Down, or Enter
Display Percent
Adjust Percent Value
Up or Down
Check Keypad
Delay
Save To EEPROM
Enter

Fig. 9

Skip Flow

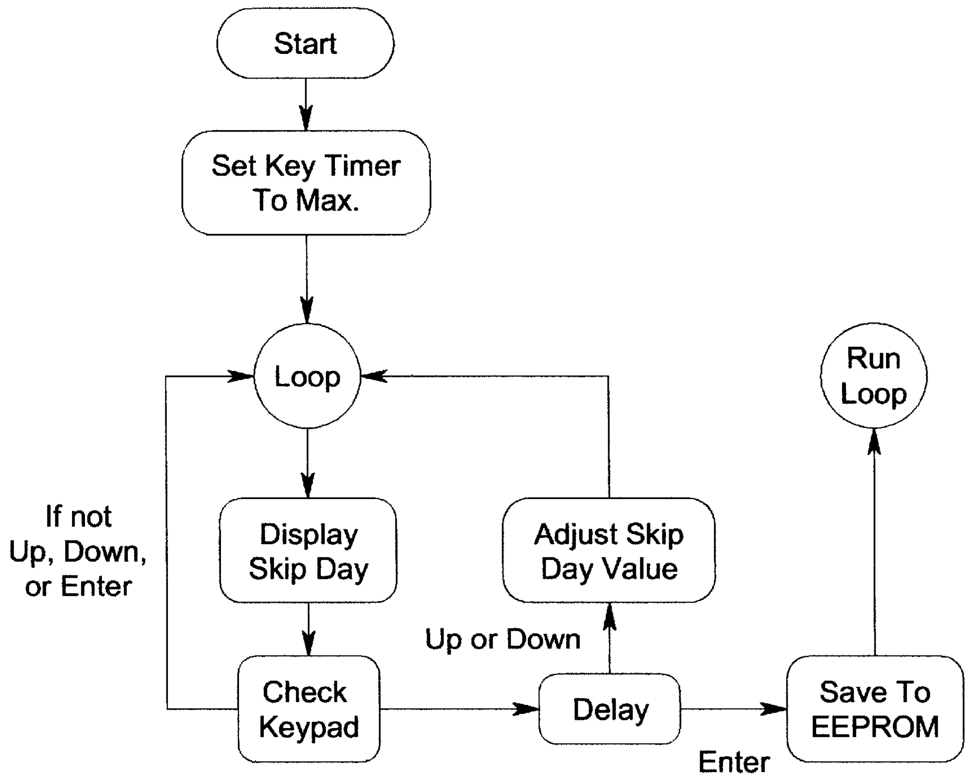


Fig. 10

Off Flow

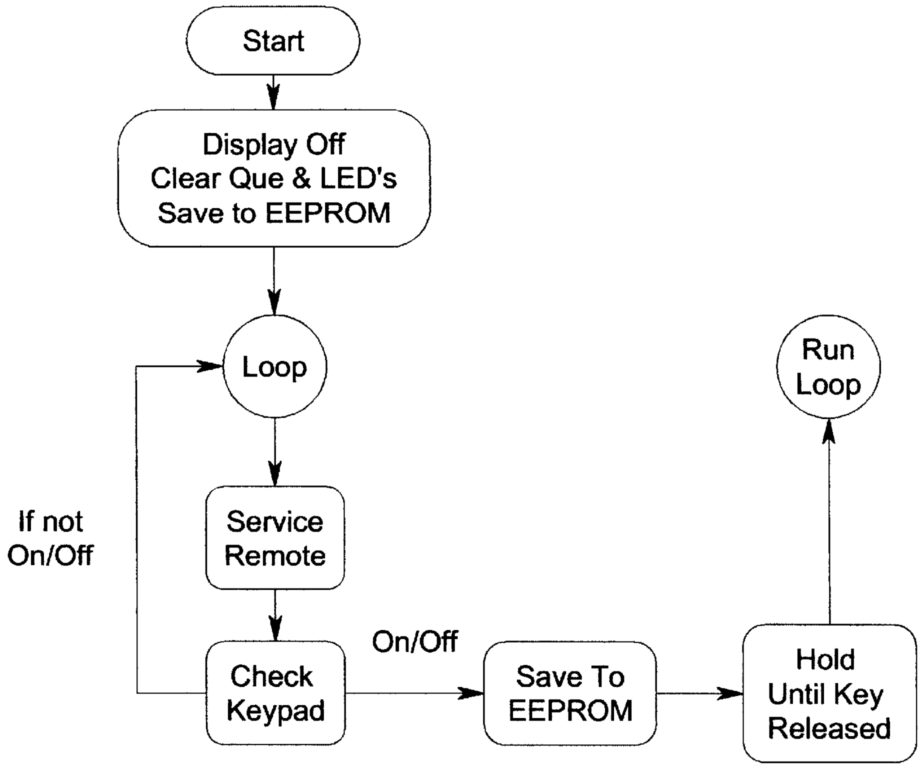


Fig. 11

Manual Flow

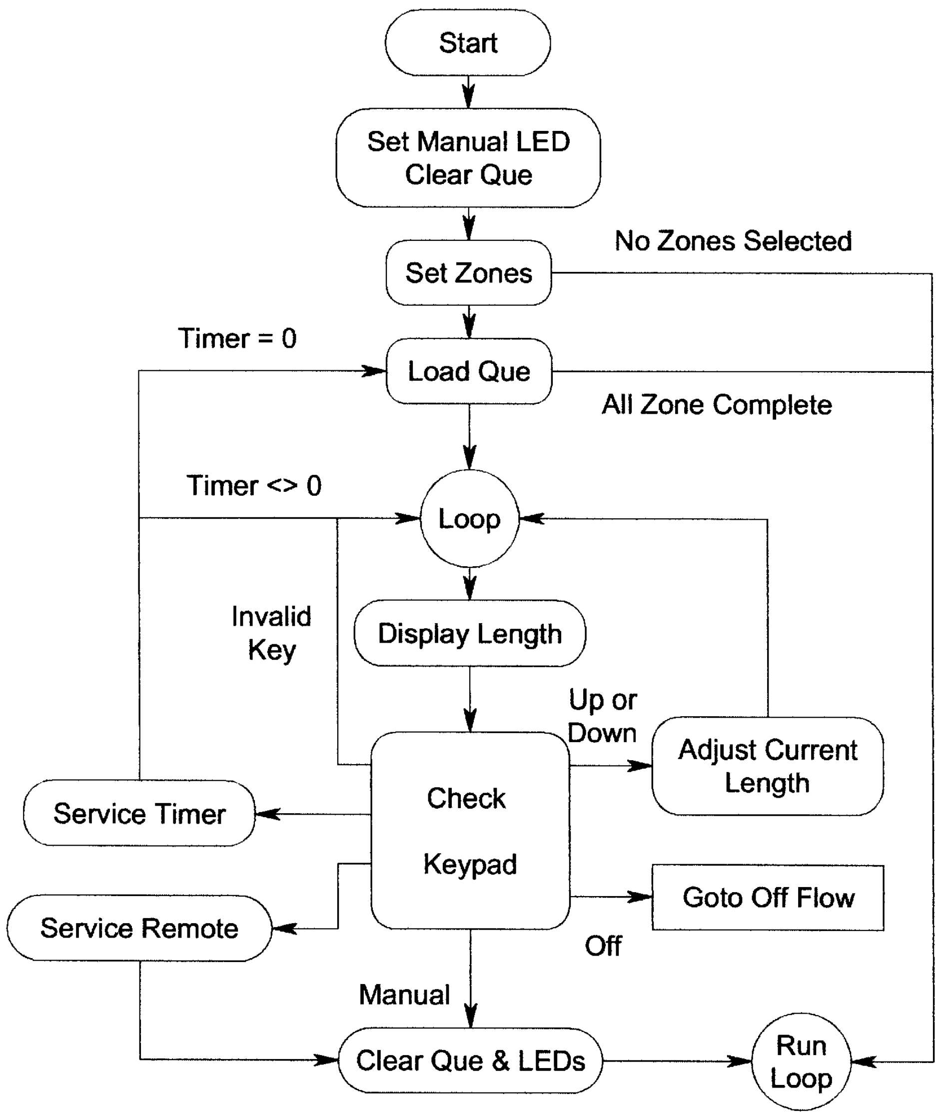
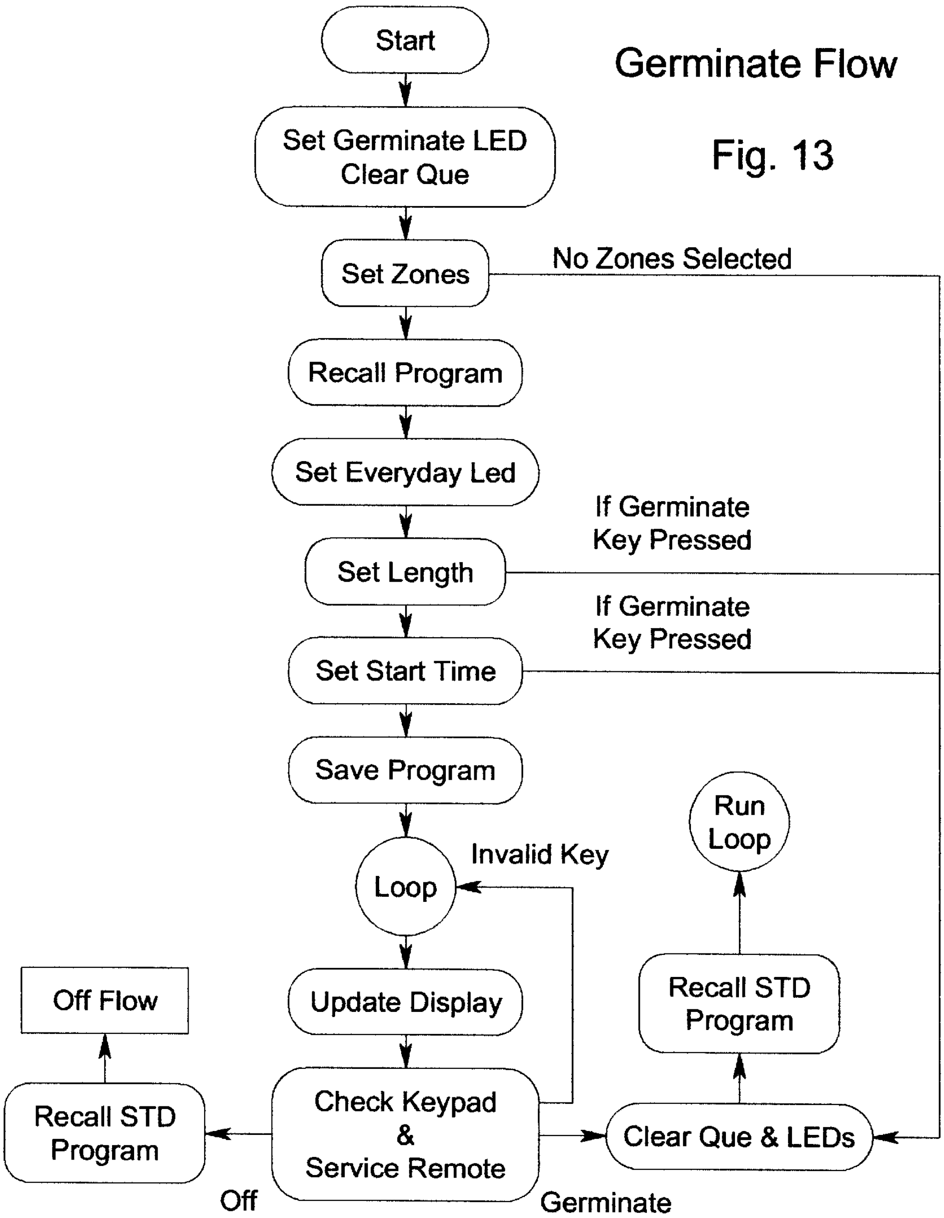


Fig. 12



Germinate Flow

Fig. 13

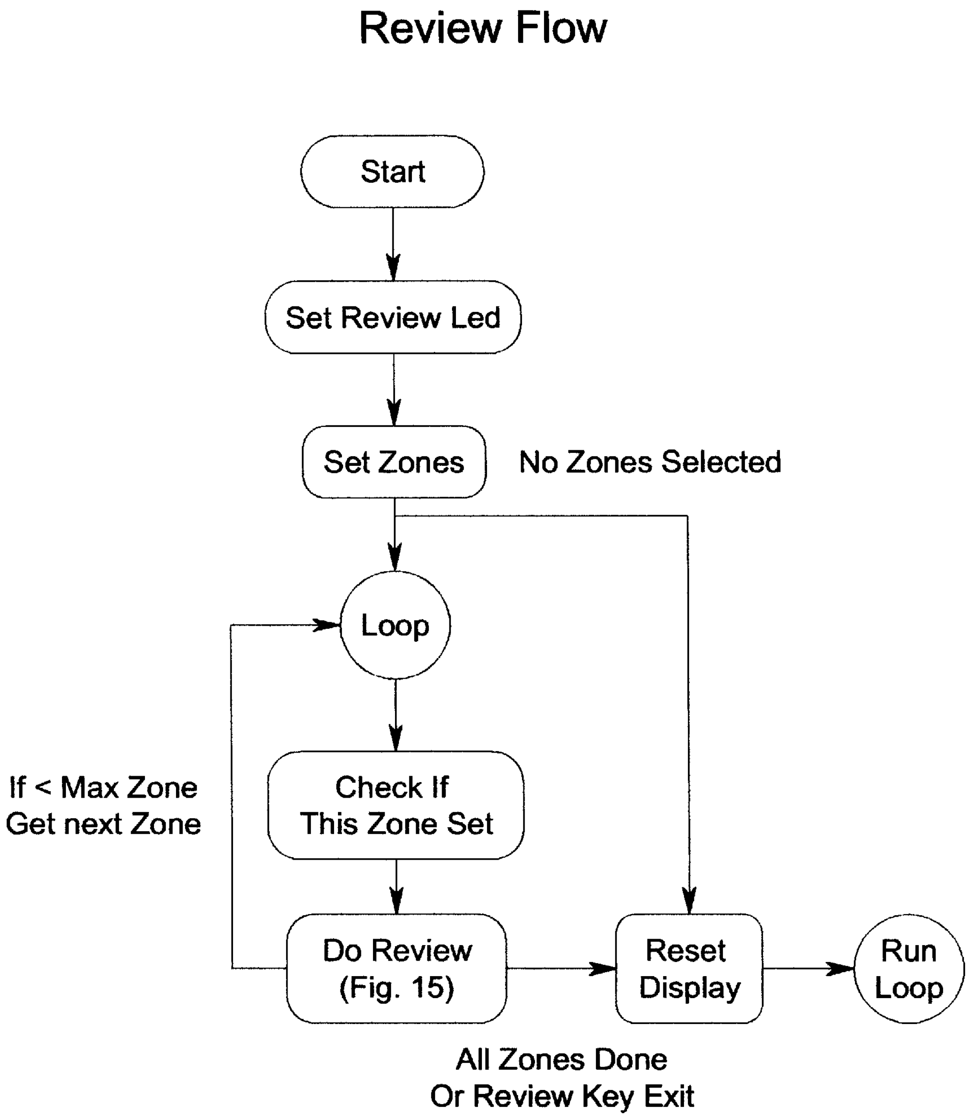
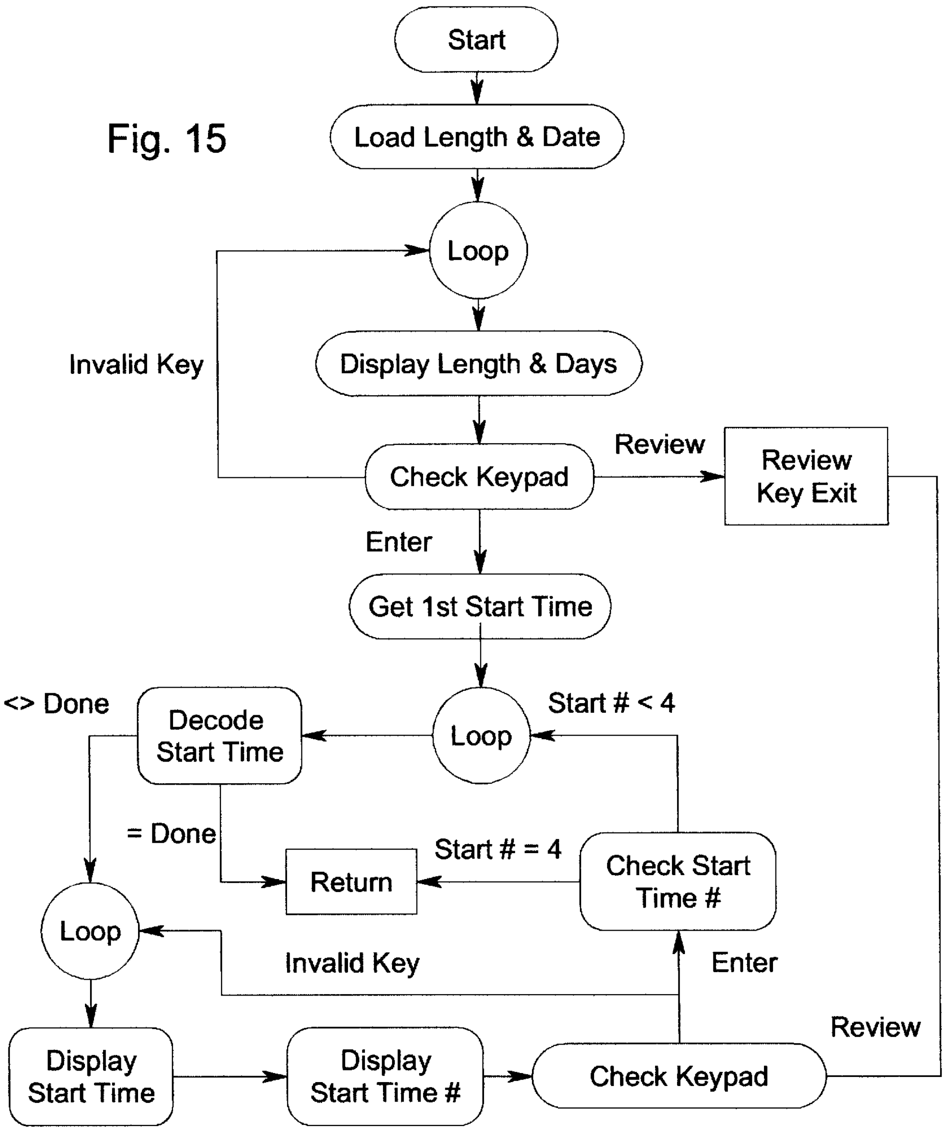

Review Flow
Start
Set Review Led
Set Zones
No Zones Selected
Loop
If < Max Zone
Get next Zone
Check If
This Zone Set
Do Review
(Fig. 15)
Reset
Display
Run
Loop
All Zones Done
Or Review Key Exit

Fig. 14

Do Review Flow

Fig. 15



IRRIGATION CONTROLLER

This application claims the benefit of U.S. Provisional Application No. 60/081,674 filing date Apr. 14, 1998.

FIELD OF THE INVENTION

The present invention relates generally to irrigation equipment. More particularly, the invention disclosed herein relates to a programmable irrigation controller for multiple watering zones.

BACKGROUND OF THE INVENTION

Vegetation typically grows in soil that has been watered by rain. However, normal and healthy growth of vegetation can be retarded and even prevented when natural rainfall fails to meet the requirements of that vegetation. Advantageously, artificial irrigation can compensate for the deficiencies of nature by supplying sufficient amounts of water directly to vegetation at predetermined intervals for predetermined lengths of time.

Early techniques for supplementing natural rainfall relative to vegetation located remote distances from a water source often comprised such rudimentary methods as a manual pouring of water directly onto vegetation by hand and bucket. Eventually, aqueduct systems simplified the task. A basic aqueduct systems typically comprises long furrows or pipes designed to transport water from a remote source, usually employing gravity, to an area immediately adjacent the vegetation sought to be watered. Eventually, diligent invention led to additional advances in irrigation. Animal power and mechanical lifting provided irrigation systems that were more efficient and less taxing on those who employed them.

Advances in generalized technology eventually led to still further improvements in irrigation. Steam power, the internal combustion engine, and electricity allowed irrigation systems to become fully mechanized. Previously state-of-the-art irrigation controllers gave way to mechanical devices with internal, often programmable, timers. These systems provided a means for automating the control of water flow from a pressurized water source through piping assemblies and the like to plural watering stations or zones.

Automatic electromechanical controllers for such systems typically incorporated conventional motor-driven electric clocks for allowing a user to program individual start times for particular irrigation cycles and watering stations. Calendar programs could provide the ability to select particular days for watering over a span of 14 days and more. With these electromechanical controllers, calendar programs would be operable by means of a disc that is rotated each 24 hours to a next-day position by a motor-driven clock. Unfortunately, such systems quickly become undesirably complex with increased numbers of watering zones, such as is required with golf courses, cemeteries, parks, and the like.

Again, innovation provided an incremental improvement with the development of solid state irrigation controllers thereby replacing the electric motors, mechanical switches, actuating pins, cams, levers, gears, and other mechanical devices with solid state electronic circuitry. With this, the systems allow programming of multiple start times and day programs for individual watering stations or zones, repeat cycles, and watering time selections in minutes or even seconds—all with increased accuracy coupled with a concomitant elimination of the complex interrelation of mechanical parts.

Generally, prior art solid state irrigation controllers incorporate a programmable microprocessor with a user interface that enables a programming of several watering stations or zones based on a plurality of timing variables such as daily, weekly, odd days, even days, start times, watering lengths, and still further variables. Each watering zone typically includes one or more sprinklers and a solenoid valve that is normally regulated by the microprocessor. The solenoid valves control the flow of water from a pressurized water source to a given watering zone. Certain systems visually communicate the current status of the system's programmable variables by use of such means as liquid crystal displays (hereinafter "LCD"). Some systems allow a user to override the preprogrammed automatic watering operations by manual intervention. This allows the system to account for unusual circumstances such as excessive rain or drought.

It will be immediately apparent that this lengthy evolution of irrigation systems has resulted in state-of-the-art systems that are exponentially more efficient, convenient, and effective than their predecessors. Unfortunately, however, as with nearly all things, even advanced systems remain imperfect.

For example, although known prior art irrigation controllers have enabled remote communication between a remote unit and a controller microprocessor, this communication has been decidedly one sided. Irrigation controllers have allowed for the remote operation of water valves and the like by a sending of information from the remote unit to the microprocessor. However, they have not allowed an opposite stream of communication—communication from the microprocessor to the remote unit. Accordingly, a remote user can not determine whether one or more watering zones is faulty (e.g., is in an open-circuit or closed circuit condition). Consequently, remote troubleshooting often becomes unduly burdensome.

Another shortcoming exhibited by prior art irrigation controllers is that they give a user insufficient flexibility. Although a user can select from multiple watering programs in prior art control systems, such systems do not allow a ready switching from one mode that employs one entire set of programs that the user has entered to a second or third mode that employs other sets of programs that the user has entered. Consequently, causing the irrigation controller to accommodate changes in seasons or the demands of germinating seeds are laborious tasks each and every time they must be accomplished.

Another shortcoming from which prior art irrigation controllers suffer relates to their current sensing circuitry, which is typically capable of sensing faulty valves within the irrigation system. Although such current sensing circuitry is useful for protecting an irrigation controller from harm from a faulty (i.e., shorted) valve, it is not capable of specifying how many valves are open in any given watering zone, which would allow the irrigation controller to adjust the maximum allowable current in the system. Furthermore, such systems are not able to determine when no valve is operational whereby the system may pump water with no valve open thereby causing damage to the pump and, possibly, other portions of the irrigation system.

A further deficiency in prior art irrigation controllers is that crucial information often is lost during extended periods when the overall system is without power, such as during winter months or extended periods of power failure. As a result, systems that lose their memory often will not recall whether they were on or off when they were last in use. When such a system again receives power, it may malfunction such as by activating water valves even while the system is down. Furthermore, such a system could lose all of the watering programs that had previously been entered such that a user would have to reenter each program sought to be employed.

Yet another drawback exhibited by irrigation controllers of the prior art is a common inability to provide a specialized mode that allows a user to activate multiple watering zones simultaneously. In day-to-day operation, this is a desirable restriction because having too many valves open during regular operation can cause malfunctions in the system such as from excessive loss in head. However, such an ability is highly desirable during such operations as winterizing procedures where a user seeks to blow the water from each of the zones to prevent damage from freezing water. As a result, with present-day irrigation controllers the user must activate each zone separately in an arduous and time-consuming procedure.

Finally, a most prevalent shortcoming exhibited by prior art irrigation controllers is that programming them is often a difficult and confusing task. For example, a user seeking to program a multiplicity of watering zones often is unable to determine which watering zone is presently selected for programming. Furthermore, other than by his or her own memory, users typically have no means of knowing which function of the irrigation controller he or she is programming. As a result, users typically are forced to program an irrigation controller blind whereby the programming procedure often proves arduous and frustrating.

Accordingly, it is clear that it would be advantageous if the evolution of irrigation controllers were to continue with an invention that could provide a solution to one or more of the deficiencies left by the prior art. However, it is still clearer than an irrigation controller presenting a solution to each and every one of the aforementioned deficiencies in the prior art while providing a number of heretofore-unrealized advantages would comprise a marked advance in the art.

SUMMARY OF THE INVENTION

Advantageously, the present invention sets about with the broadly-stated goal of providing an irrigation controller that meets each of the aforementioned needs that have been left unmet by the prior art and thereby presents a further step in the evolution of irrigation in general.

Stated more particularly, a principal object of the present invention is to provide an irrigation controller that is capable of sending diagnostic information and the like from a main irrigation control unit to a remote unit that can be retained by a user in the field to provide for efficient system diagnosis and repair.

A further object of the invention is to provide an irrigation controller that allows flexible shifting between a plurality of watering modes including specialized modes for germinating seeds and the like.

The invention has the still further object of providing an irrigation controller that does not lose memory even during extended periods without power. A resultant object is to provide an irrigation system that remembers whether it was on or off when it was last powered and that remembers irrigation programs that have been stored in its memory.

An additional object of the invention is to provide an irrigation controller that provides a specialized mode, which may be termed a winterize mode, wherein a user can manually activate a multiplicity of watering zones simultaneously whereby winterizing procedures can be carried out more efficiently and conveniently.

The invention also seeks to provide an irrigation controller that incorporates current sensing circuitry that can detect how many valves are operational in each watering zone to allow the irrigation controller to adjust the maximum allowable current in the system and can prevent damage to the irrigation system by detecting when no valve is operational.

A still further object of the invention is to provide an irrigation controller that guides a user through the programming process by providing an indication of presently selected altering zones and, possibly, programming functions.

In accomplishing the aforementioned and still further objects and advantages, a most basic embodiment of the irrigation controller includes a means for enabling an inputting of commands relating to watering programs, a means for processing commands relating to watering programs, a means for controlling a plurality of watering zones according to the commands, a means for retaining information relating to watering programs, and a means for displaying information relating to watering programs. In this embodiment, the means for enabling an inputting of commands, the means for receiving and processing commands and controlling a plurality of watering zones, and the means for retaining information in combination may be termed a means for allowing a user to establish watering programs.

Preferably, the means for allowing a user to establish watering programs will enable a programming of a selected start time and a selected watering length individually for each of the watering zones while further allowing a programming of a single selected start time and a single selected watering length for a plurality of watering zones. The means for processing commands relating to watering programs and the means for controlling the plurality of watering zones according to the commands may comprise a microprocessor.

The irrigation controller may be improved further by enabling a programming of a Skip Day command wherein the watering program skips one or more days, a Water Percent command wherein the watering program waters for a selected percentage of the selected watering length, and, additionally or alternatively, a Germinate command wherein a germinate watering program temporarily replaces a basic watering program.

Ideally, the irrigation controller will include a means for preventing simultaneous operation of a number of valves excessive of the maximum number of valves that allows for proper operation of the irrigation system during a normal operation of the irrigation controller. This means may comprise a power supply with a maximum current capability, a means for measuring current draw from the power supply, which may comprise an analog-to-digital converter, and a means for comparing the current draw from the power supply with the maximum current capability of the power supply.

Furthermore, a preferred means for allowing a user to establish watering programs will further enable an inputting of a Winterize command wherein a multiplicity of valves can be operated simultaneously. Further advantage may be had by providing a Review command that causes the irrigation controller to enter a review mode wherein the means for enabling an inputting of commands relating to watering programs is disabled whereby a user can review a given watering program without risk of accidentally altering the watering program.

Preferred embodiments of the irrigation controller will further include a means for retaining information relating to watering programs in the absence of power. With this, the irrigation controller can retain watering programs and an indication as to whether the irrigation controller was last on or off even during extended periods without power. This means may comprise an electrically erasable programmable read-only memory device (EEPROM) operably associated with the microprocessor. Ideally, the EEPROM will include sufficient read-only memory for simultaneously retaining a plurality of watering programs that can be selectively accessed.

A further refinement of the invention may be in the form of a means for detecting how many valves are operational in a given watering zone, which may comprise an analog precision rectifier, and a means for automatically adjusting a maximum allowable current in response thereto.

Yet another improvement to the irrigation controller may comprise a remote control unit in cooperation with a means for transmitting diagnostic information to the remote control unit regarding a status of the valves of the irrigation system. Preferably, such an irrigation controller would be further supplemented by a means for inducing remote operation of the valves of the irrigation system. The means for transmitting diagnostic information to the remote control unit ideally will comprise a means for sending a signal from the remote control unit to the microprocessor to induce the microprocessor to send a test signal to each valve in the irrigation system, a means for measuring a current across each valve, a means for determining based on the current across the valve whether each valve is open or shorted, a means for transmitting whether each valve is open or shorted to the remote control unit, and a means for displaying the status of the valves in the irrigation system on the remote control unit. The means for displaying the status of the valves on the remote control unit may comprise at least one LED numeric display in combination with a bi-color status LED. With this, the LED numeric display can display the number or numbers of any faulty zones, and the bi-color status LED can indicate with a first color whether the faulty zone is open and with a second color whether the faulty zone is shorted. The means for transmitting diagnostic information to the remote control unit may be founded on a communication port comprising a four wire interface with two wires sending power and ground and two wires providing a differential signal path.

To simplify programming of the irrigation controller and to eliminate blind programming, the preferred irrigation controller includes a means for selecting one or more of the plurality of watering zones to create a selected watering zone or zones in combination with a means for indicating the selected watering zone or zones. The means for selecting one or more of the plurality of watering zones may comprise a plurality of keys, such as membrane keypad keys. The means for indicating the selected watering zone or zones may comprise an indicator mechanism, such as an indicator light that may be an LED, disposed proximate to each key for indicating whether the watering zone that is selectable by that key is a selected watering zone. The means for indicating selected watering zones may be supplemented by a means for indicating an active programming function, such as the Start Time and Watering Length functions.

Of course, one should remain mindful that the foregoing discussion is designed merely to outline broadly the more important features of the invention to enable a better understanding of the detailed description that follows and to instill a better appreciation of the inventor's contribution to the art. Before an embodiment of the invention is explained in detail, it must be made clear that the following details of construction, descriptions of geometry, and illustrations of inventive concepts are mere examples of possible manifestations of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a diagram of an embodiment of the present invention for an irrigation controller;

FIG. **2** is a schematic of an analog current sense circuit according to the present invention;

FIG. **3** is a view in front elevation of an embodiment of the main controller of an irrigation controller according to the present invention;

FIG. **4** is a flow chart of the Initialization subroutine according to the present invention;

FIG. **5** is a flow chart of the Interrupt flow subroutine according to the present invention;

FIG. **6** is a flow chart of the Main Loop subroutine according to the present invention;

FIG. **7** is a flow chart of the Set Program subroutine according to the present invention;

FIG. **8** is a flow chart of the Set Time subroutine according to the present invention;

FIG. **9** is a flow chart of the Percent subroutine according to the present invention;

FIG. **10** is a flow chart of the Skip Day subroutine according to the present invention;

FIG. **11** is a flow chart of the Off subroutine according to the present invention;

FIG. **12** is a flow chart of the Manual subroutine according to the present invention;

FIG. **13** is a flow chart of the Germinate subroutine according to the present invention;

FIG. **14** is a flow chart of the Review subroutine according to the present invention; and

FIG. **15** is a flow chart of the embedded Do Review subroutine according to the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENTS

Looking more particularly to the figures, one sees a most basic embodiment of the invention depicted schematically in FIG. **1**. The irrigation controller **20** is founded on a microprocessor **22**, which controls all timing and switching functions. Included in the microprocessor **22** is a microcontroller integrated circuit with associated I/O lines for transfer of control signals for other elements of the irrigation controller **20**. As will be made most clear below, the microprocessor **22** may well be termed a means for receiving and processing commands relating to watering programs and also a means for controlling the plurality of watering zones according to those commands. It is conceivable, though not preferred, that the microprocessor **22** could be supplanted by mechanical switches and timing motors (not shown).

Current sense circuitry **24** is interposed between a triac drive **26** and the microprocessor **22**, and a power supply **36** is provided for powering the microprocessor **22** in particular and the irrigation controller **20** in general. A communication port **28** is bi-directionally coupled to the microprocessor **22** as is an electrically erasable programmable read-only memory device (EEPROM) **30**, which may be termed a means for retaining information relating to watering programs. Although the EEPROM **30** is preferred, it is possible that another means could be employed, such as RAM, which may be battery backed, a magnetic disc, an optical disk, flash RAM, or any other appropriate means, none of which are shown.

A further element of the irrigation controller **20** comprises a display **32**, which may be an LED display **32**, that receives display signals from the microprocessor **22**. The LED display **32** is operably coupled to a means for enabling a selecting of one or more watering zones and a means for enabling an inputting of commands relating to watering programs for the watering zones. Preferably these means comprise a membrane keypad keyboard **34** and function keys including those indicated at **38**, **44**, **46**, **48**, **50**, **52**, **54**, **60**, **62**, **64**, and **68**, which are in turn operably coupled to the microprocessor **22**. Certainly the means for enabling a selecting of one or more watering zones and the means for enabling an inputting of commands could assume a wide variety of forms other than the keyboard **34** and the respective function keys including those indicated at **38**, **44**, **46**, **48**, **50**, **52**, **54**, **60**, **62**, **64**, and **68**. For example, one or both of the means for enabling a selecting of one or more watering zones and the means for enabling an inputting of commands alternatively could comprise mechanical dial switches or buttons, a touch-sensitive screen, a voice recognition arrangement, resistive potentiometers, or any other effective means, none of which are shown.

Turning more particularly to the basic components of the irrigation controller **20**, the preferred power supply **36** is a 24 VAC transformer that supplies power to valves in an irrigation system that is controlled by the irrigation controller **20** and to regulated supplies for DC power to the solid state circuitry. The DC section of the power supply **36** should supply 250 mA of current into +6 VDC to run the microprocessor **22**, the EEPROM **30**, analog amplifiers, and the LED display **32**. It will be noted that the LED display **32** is likely to use most of the DC current from the power supply **36**. The analog amplifiers also use a negative supply. However, there are other implementations that do not require a negative supply. There are multiple methods of deriving a +6 VDC supply from the transformer output. Consequently, the exact configuration is left to the reader's discretion as it is non-critical provided that the current requirement is met. The power supply **36** also has a limited backup (not shown) to run a system clock (not shown) so the irrigation controller **20** can keep time during most power outages and brownouts.

The triac drive **26** comprises triacs for each watering zone for switching the 24 VAC power on for a given watering zone. The schematic can be found in almost any triac manufacturer's application notes and will be well known to one skilled in the art. A current sensing resistor (not shown) is used in the power line to allow the current sense circuitry **24** to measure the current that the triac **26** is supplying to the valves of the irrigation system.

A digital input (not shown) is used to connect a rain or moisture sensor. By using a digital input rather than breaking the common line to the valves, as is conventionally done, the irrigation controller **20** can tell the user when the sensor is active. The irrigation controller **20** can also override the sensor in certain modes, specifically manual and remote control mode so the user does not need to short the sensor to activate the clock during servicing. The rain sensor simply sends a digital high voltage out one terminal and senses that high voltage with a second terminal to detect if the sensor is closed.

Looking more particularly to the current sense circuitry **24**, which is depicted in FIG. **2**, one will appreciate that the present invention improves over even those prior art irrigation controllers that have over-current sensors that protect the controllers from faulty valves. To do so, the present irrigation controller **20** employs an analog precision rectifier that acts not only as a means for detecting a shorted valve, but also as a means for detecting how many valves are operational in a given watering zone and a means for measuring the current across each valve. Cooperation of the current sense circuitry **24** with the microprocessor **22** enables the microprocessor **22** to adjust the maximum allowable current from the power supply **36** automatically. The maximum allowable current alternatively could be adjusted automatically in response to how many valves are operational in a given watering zone by an analog compare circuit, digital discrete logic, or any other appropriate means, none of which are shown.

The irrigation controller **20** can also detect when no valve is present, which will cause the irrigation controller **20** to shut down. This is particularly advantageous in pump systems because it prevents the pump from running with no valve open, which would likely result in damage to the pump. This circuitry **24** also allows the irrigation controller **20** to sense if anything is connected to a master valve terminal. As will be described more fully below with reference to FIG. **3**, if the master valve terminal is open, a master valve status LED **72** does not light thereby indicating to the user that nothing is connected.

The ability of the current sense circuitry **24** to measure the current draw and to monitor this current draw against the output current capability of the transformer power supply **36** allows the irrigation controller **20** to let the user enter a mode that allows multiple zones to be activated simultaneously. This is useful when preparing an irrigation system for winter conditions. The preferred embodiment of this feature is a Winterize key (not shown) on the remote (not shown) to give easy, clear access to this feature while the system is serviced but to prevent this mode from being entered in normal operation of the irrigation controller **20**. By letting the user open several valves simultaneously during Winterize mode, water can be blown out of the system several times faster thereby reducing service time.

The irrigation controller **20** further provides a means for preventing simultaneous activation of multiple watering zones when the irrigation controller **20** is not in a Winterize mode so that the irrigation controller **20** still protects itself during normal operation from too many valves being open to operate correctly. This means may be considered to include the power supply **36** and the current sense circuitry **24** in cooperation with the microprocessor **22**, which acts as a means for comparing the current draw from the power supply **36** with the maximum current capability of the power supply **36**. Alternative means for comparing the current draw from the power supply **36** with the maximum current capability of the power supply **36** could comprise such means as an analog compare circuit (not shown) or digital discrete logic (not shown).

In the schematic for the analog current sense circuitry **24** of FIG. **3**, the current is given by the formula $I_{triac}=V_{a/d}/R_s(R_1/R_f)$. C_f filters the output to provide a peak measurement. The current sense circuitry **24** acts as an A/D converter to function as a means for measuring current draw from the power supply **36** and for supplying the microprocessor **22** with a digital reading of the current draw. By placing the diode in the feedback loop, forward drop is reduced by the open loop gain of the amplifier thereby nearly eliminating offset. Because the input is referenced to ground and the input signal is AC, the amplifier requires a positive and a negative supply. This current sense circuitry **24** is provided separately for the master valve circuit and zone circuits to allow the microprocessor **22** to measure the current of each circuit **24** independently.

One will note that the communication port **28** is provided with a bi-directional coupling to the microprocessor **22**. With this bi-directional communication, a remote unit not only can induce remote operation of the valves of an irrigation system, but it also can give remote diagnostic information to the user. With this, the irrigation controller **20** provides a means for displaying the status of all valves of an irrigation system without a need for physical access to the display **32**, the microprocessor **22**, and the like. When a scan key is pressed on the remote control unit, the microprocessor **22** sends a test signal to each valve, measures its current, and updates the status variables that indicate whether that valve's solenoid is drawing too much current, which would indicate that it is shorted, or too little current, which would indicate that it is open. These status variables are then sent through the communication port **28** to the remote. The remote then displays to the user any zones that are faulty by means of an LED numeric display. The remote further indicates whether that zone is shorted with a red indication or open with a yellow indication by means of a bi-color status LED. With this, the communication port **28** may be considered to comprise a means for transmitting diagnostic information to a remote unit regarding a status of the valves of the irrigation system and a means for sending a signal from the remote unit to the microprocessor **22** to induce the microprocessor **22** to send a test signal to each valve in the irrigation system.

In the preferred embodiment, the communication port **28** essentially comprises a wired data link with a four-wire interface wherein two wires send power and ground to the remote control unit's receiver and two wires provide a differential signal path. The signal is half-duplex differential zero to five volt. Many serial communication standards can be used without affecting overall performance, but it should be noted that this preferred embodiment was chosen to minimize wire count while providing excellent noise immunity. The preferred wired data link communication port **28** could be supplanted by a radio data link, an infra-light link, or any other appropriate communication port **28**, none of which are shown.

The EEPROM **30** is basically one integrated circuit designed to act as a means for retaining memory in the absence of power. Any EEPROM **30** integrated circuit can be utilized as long as it has sufficient memory to hold watering programs and a status variable indicating whether the irrigation controller **20** was on or off when last powered. In lieu of the EEPROM **30**, the means for retaining memory in the absence of power alternatively, although not presently preferred, could comprise battery backed RAM, flash memory, a magnetic disk, an optical disk, or any other appropriate means, none of which are shown. Advantageously, the EEPROM **30** stores multiple sets of programs thereby giving the user added flexibility. Although prior art irrigation controllers are able to retain multiple programs, the present invention is unique in this respect because its exploitation of the EEPROM **30** allows it to retain multiple watering programs interchangeably. For example, one can program the irrigation controller **20** to water for spring conditions where fewer start times or shorter run times are typical. Then, the irrigation controller **20** can be switched between modes to permit entry of an additional watering program such as a summer program where more start times or longer run times are required. With this, both programs can be saved in EEPROM **30** and the irrigation controller **20** need not be reprogrammed as the seasons change. Only one watering program is active in the microprocessor **22** at any one time, and the others are dormant and only become active when the mode is switched to access them.

A still more unique use of the EEPROM **30** and a unique aspect of the present invention overall is the provision of a Germinate program that is designed to retain an increased number of start times but has everyday watering selected automatically by default. With this, the irrigation controller **20** can be programmed with one or more normal watering programs and then switched to a Germinate mode designed for meeting the needs of a newly seeded lawn. When the grass starts to grow, the Germinate mode can be simply deselected, and the irrigation controller **20** will readily return to a normal watering program.

Advantageously, the memory retention ability of the EEPROM **30** also allows it to store whether the irrigation controller **20** is in an on or off mode when it last was powered so that it will prevent activation of the valves while the irrigation controller **20** is intended to be shut down. Such a long-term memory is needed where the irrigation controller **20** is off during a winter season or where the power fails long enough to drain the irrigation controller's **20** back-up power. The irrigation controller **20** accomplishes this by saving an off status variable in the EEPROM **30** when an off key is pressed on the keyboard **34**. This Off subroutine is shown in FIG. **11**. As a result, the irrigation controller **20** permanently remembers that it was turned off. When the irrigation controller **20** is toggled back on, the status variable is updated and saved to the EEPROM **30**. As a result, the EEPROM **30** always remembers the current status of the irrigation controller **20**. When initializing from a power failure or an extended shutdown period, this status variable is read from the EEPROM **30** thereby allowing the irrigation controller **20** to remember whether it was off or on before the power failure or shutdown occurred. Of course, the EEPROM **30** also stores all watering programs. With this, the watering programs are retained even during extended periods without power where any backup power fails. As with the status variable, the normal watering program is automatically read from EEPROM **30** during initialization.

Looking again to FIG. **1**, one sees yet another unique feature of the irrigation controller **20** in the form of the feedback from the display **32** to the keyboard **34** that allows a simplified programming procedure while providing superior flexibility. The arrow between the display **32** and the keyboard **34** in FIG. **1** indicates that the display **32** reacts to the keys **42** pressed and gives the user feedback. With this, each key **42** may be considered a means for selecting one or more of the watering zones to create a selected watering zone or zones. It is within the scope of the invention that the keys **42** could comprise any effective type including the preferred membrane keypad keys **42**, keys on a touch sensitive screen, traditional computer keyboard-type keys, or any other effective keys.

Looking to FIG. **3**, a depiction of the front panel **21** of the main controller **80** of the irrigation controller **20**, one sees that an indicator mechanism **40** or indicator light **40**, which preferably comprises LED **40**, is disposed proximate to each key **42**. Advantageously, when a watering zone represented by a given key **42** is selected, the LED adjacent to that key is activated to indicate the currently selected watering zone or zones. For example, if zones **2**, **5**, and **9** are selected, then each of the LED's **40** adjacent to the keys **42** for zones **2**, **5**, and **9** will light. Of course, providing an LED **40** adjacent to each key **42** comprises just one of a multitude of possible means for indicating a current selection, which means may be considered to be an element of a means for displaying information relating to watering programs. For example, a wide variety of other means could be employed to indicate a current selection or selections such as an LCD indicator, a touch-sensitive screen performing both keyboard and display functions, a CRT, or any other effective means, none of which are shown.

Advantageously, the irrigation controller **20** utilizes independent zone programming wherein each zone has its own set of start times, watering lengths, and day cycle. This allows maximum flexibility without confusing the end user with assigning zones to different programs. In addition, multiple zones can be selected together to simplify programming when full flexibility is not needed. When multiple zones are selected, the LED's **40** for each of the zones will light and the start times and cycle days are copied to each selected zone, but the watering length is always set separately for each zone. After Set Program **44** is pressed and the zones are selected, the programming sequence, which is shown in FIG. **7**, is preset to Set Cycle days for all zones, set each zone's length, and Set Start times for all zones. Getting lost in the middle of programming is minimized by not allowing the user to jump steps while programming.

By using LED's **40** adjacent to the keys **42** integrated with the display **32**, the irrigation controller **20** is able to guide the user to the next step, making the programming self-prompting. Although an LED display **32**, ideally in combination with the LED's **40**, presently is the preferred means for displaying information relating to watering programs, it is well within the scope of the invention for information relating to watering programs to be displayed by an LCD display, again ideally in combination with an indicator mechanism such as LED's **40**, by a touch-sensitive screen performing both keypad and display functions, by a CRT, or by any other effective means for displaying information relating to watering programs, none of which are shown.

To gain a better understanding of the programming of the present invention, which will be described particularly below, one may additionally have reference to FIGS. **4**–**15**, which depict flow charts for various routines and subroutines of the program that governs the operation of the irrigation controller **20**. Most informatively, FIG. **6** shows the flow of the Main Loop of the irrigation controller **20**. Also, FIG. **4** depicts the Initialization subroutine for the irrigation controller **20**. One may also refer to FIG. **5**, which sets forth the Interrupt subroutine.

In operation of the irrigation controller **20**, the display **32** will flash SET TIME to let the user know the time needs to be set. The subroutine for this Set Time function is depicted in FIG. **8**. In this mode, all functional keys **42** are acknowledged. However, the SET TIME display returns after each function is completed until the time is set. When Set Time **46** is pressed, the current time of day will flash in the display **32**. The Up and Down keys **48** and **50** will adjust the time until Enter **52** is pressed. After Enter **52** is pressed, the current year will flash and can be set the same way. Then the current month will flash and can be set the same way. The day of the month will flash and can be adjusted. Lastly, the day of the week is set. After Enter **52** is pressed, the time of day is displayed, with only the colon flashing. This is the Normal Run Mode for the irrigation controller **20**.

When Set Program **44** is pressed, the irrigation controller **20** enters the Set Program subroutine, which is shown in FIG. **7**. In this mode, the display **32** flashes SET ZONE until Enter **52** is pressed. During this time, any zone the user wishes to program can be toggled on or off by pressing the appropriate zone key **42**. Again, when a zone is selected, the LED **40** next to the zone key **42** lights. If pressed again, that zone LED **40** shuts off and that zone is deselected. Pressing Enter **52** with no zones selected brings the user back to Normal Run Mode. If multiple zones are selected, then they all are assigned the same start time and watering day cycle, but have independent watering lengths. After Enter **52** is pressed, the Display **32** flashes SET DAYS until Enter **52** is pressed again. Before Enter **52** is pressed, any day cycle can be selected by pressing the appropriate Day key **54**. All selected zone LED's **40** will still be lit for the user's information. After Enter **52** is pressed, the Length LED **56** and the first selected zone LED **40** will light. The display **32** will show that zone's current programmed length, which can be adjusted with the Up and Down keys **48** and **50**, from 0:00 to 4:00 (0–4 hours in 1 min. increments) until Enter **52** is pressed. The next selected zone LED **40** and length are then displayed. This continues through all selected zones. After the last zone is set, the Start Time LED **58** and all selected zone LED's **40** light to instruct the user that the watering program start time should be set. The display **32** shows the current first start time, which can be adjusted like the time of day, in 15-minute increments. When Enter **52** is pressed, a second start time flashes. Up to four start times can be set. The user selects DONE to set fewer. DONE can be found between 12:00 AM and 11:45 PM times. When DONE is entered for the time, the irrigation control system **20** is finished programming and stores the program to the EEPROM **30** and returns to Normal Run Mode. If DONE is not selected, programming finishes after the fourth start time is entered. In the procedure above, each zone may be programmed individually, or any combination of zones may be programmed together, giving high flexibility and ease of use.

Pressing Skip Day **60** initiates the Skip Day subroutine shown in FIG. **10**, which makes the display **32** flash the current day to be skipped. It can be adjusted with the Up and Down keys **48** and **50** until Enter **52** is pressed, which puts the irrigation controller **20** back into Normal Run Mode. The values of skip days are MON, TUE, WED, THU, FRI, SAT, SUN, and NONE. Selecting NONE disables the skip day feature. After Enter **52** is pressed, the value of skip day is saved to the EEPROM **30**.

Pressing Water % **62** will initiate the Percent subroutine of FIG. **9**, which brings the current value to the display **32**. This value flashes until Enter **52** is pressed. It can be adjusted from 10% to 200%, in 10% increments, with the Up and Down keys **48** and **50** until Enter **52** is pressed, which puts the irrigation controller **20** in Normal Run Mode. The percentage adjusts the watering length time to all zones (e.g., 50% instructs the irrigation controller to water for half the programmed time). After Enter **52** is pressed, the value of water % is saved to the EEPROM **30**. The algorithm does not allow water budgeting to set a time less then one minute. Accordingly, if a zone has a one-minute length programmed and the water % is set to 10%, then the watering length nonetheless will still be set to one minute. Whole minutes are used in the algorithm's calculations.

The Review key **64** acts much like the Set Program key **44** except that no values can be adjusted. This allows the user to see what has been programmed without being able to change the program accidentally. After pressing Review **64**, the Review subroutine of FIG. **14** is initiated, and SET ZONE flashes. The user selects all zones to be reviewed and presses Enter **52**. The LED **40** for the first selected zone will light up and the LED **66** for the days will be lit. The user hits Enter **52** to get the length and Enter **52** again to get the start times for that zone. FIG. **15** shows the embedded Review subroutine for each zone. When the zone has been reviewed, hitting Enter **52** again will bring the user to the next zone selected. Pressing Review **64** a second time stops the review process and returns the irrigation controller **20** to Normal Run Mode. This is not the case with Set Program subroutine, which requires the user to complete all steps in predetermined order.

A special germinate program provides a way to run an independent set of programs without affecting the normal program of the irrigation controller **20** (the normal program becomes temporarily inactive). When a Germinate key **68** is pressed, the Germinate subroutine of FIG. **13** is started, and a new program is recalled from the EEPROM **30**. The LED **70** is lit to show the user it is using the germinate program, and SET ZONES flashes on the display **32**. However, now only these zones will be watering and they will all have the same start time and will water every day. This allows more start times for germinating new lawn seed, which needs to be watered every day. The program will still ask for zone lengths for each zone and for the start times. The germinate program allows up to 9 start times instead of 4. This new program will be active until the germinate program is shut off with the Germinate key **68** or it is reprogrammed with the Set Program key **44**. If Set Program **44** is pressed again and different zones are selected, only these new zones will water because there is only one program in germinate mode as opposed to one program for each zone in normal mode. After the last start time is set, the Germinate program is stored in the EEPROM **30**. When the Germinate program is deactivated by pressing the Germinate key **68**, the normal program is retrieved from the EEPROM **30** and the Germinate LED **70** is turned off.

Pressing the Manual key **38** initiates the Manual subroutine shown in FIG. **12**, which makes the display **32** flash SET ZONE until Enter **52** is pressed. During this time any or all zones can be selected or deselected. After Enter **52** is pressed, the first selected zone and the main valve (MV) (if connected) is activated and will run for its normal programmed length. During this time that length can be temporarily changed with the Up and Down arrows **48** and **50** over a range of one minute to eight hours. Then each selected zone will sequentially water until all selected zones have run. If any zones have a short fault, they will be tried now if selected. If the short has been repaired, the LED **40**, which would have displayed red, will go out and the status will be cleared for the zone. This allows for an automatic resetting for short faults. In Normal Run Mode, shorting zones are not run thereby minimizing circuit stress.

Keeping in mind that each LED **40** proximate to each zone key **42** comprises a means for indicating whether that respective zone is selected, the astute observer may appreciate that the Length LED **56**, the Start Time LED **58**, each LED **66**, and each LED **70** each essentially comprise a means for indicating an active programming function, which may be considered an additional element of the means for displaying information relating to watering programs. With these means for indicating an active programming function, the user's programming of the irrigation controller **20** is further simplified and elucidated. Blind programming is effectively eliminated as the user is guided through the programming process by the combined benefits derived from the means for indicating selected watering zones and the means for indicating an active programming function.

The remote control unit or diagnostic receiver (not shown) consists of a hand held transmitter and receiver, which plugs into a remote jack **74** on the main controller **80**. This jack **74** can be extended to the outside to give the installer access to most of the irrigation controller's **20** features without having physical access to the main controller **80**. The remote control transmitter has a numeric 0–9 keypad with Enter and Off keys that activate the irrigation controller **20** manually. If a zone is pressed, that zone is turned on and any others are turned off. An Off key is provided for turning off all zones.

The receiver of the remote control unit has a Winter key and a Status key. The Status key tells the main controller **80** to send the receiver short and open value status indications so the installer can troubleshoot without having access to the main controller **80**. After being pressed, a numeric display on the diagnostic receiver will sequentially show zone numbers and the respective open or short status with a dual colored LED. A red LED means the zone matching the number in the display has a short. A yellow LED means the zone matching the number in the display has an open. Instead of the preferred LED numeric display in combination with the bi-colored status LED, the means for displaying the status of the valves in the irrigation system on the remote control device could comprise an LCD display, a CRT, a mechanical dial or dials, or any other appropriate means, none of which are shown.

The Winter key allows a multiplicity of zones (i.e., up to 6) to be turned on at the same time thereby allowing reduced time to blow out the system. When pressed, the irrigation controller **20** will allow a maximum permissible number of zones to be run simultaneously, which will depend on the current being drawn by the zones from the remote or from the Manual key **38**.

Normal Run mode includes checking program times to see if any zones need to be started. Only one zone can run at a time in this mode, so if another zone is scheduled to start before one is finished, then that zone will wait until time is available to run (industry standard: program stacking). If no zone is watering, then the current time is displayed. If a zone is running, then that zone's remaining length is displayed as well as its zone LED **40** being lit. If a short or open is found, the status LED **40** is updated and the irrigation controller **20** goes on to the next zone or back to Normal Run Mode. An open is tried whenever the zone is scheduled to run, but a short is tried only in Manual mode or during operation of the remote.

In this preferred embodiment, the means for inducing remote operation of the valves of the irrigation system by the remote control device essentially comprises the wired data link communication port **28** in combination with the microprocessor **22**. However, one will appreciate that the means could comprise any one of the wired data link, a radio data link, an infra-light link, or any other appropriate communication port **28** in combination with any one of the microprocessor **22**, an analog compare circuit, a discrete logic circuit, or any other appropriate such means.

Not running an open zone allows the irrigation controller **20** to protect a pump run from the MV zone. If the pump is started with the MV zone and the zone is not working or not present, the pump would overheat due to backpressure. This irrigation controller **20** senses a non-present valve and prevents the MV zone from being active when no zones are being run. The irrigation controller **20** continuously monitors the current being drawn by the valves, keys **42** on the keyboard **34**, and whether power is being supplied. If the rain sensor is active, then the display **32** reads RAIN to let the user know why the system is not watering. It also displays OFF when the irrigation controller **20** is turned off. If the power is off to the irrigation controller **20**, then all values are shut off, the display **32** goes blank, no keys **42** are read, and the irrigation controller **20** goes to a low power state and only keeps track of the current time as long as the power backup system is active.

In light of the foregoing, it will be apparent that the present invention provides a number of advantages over prior art irrigation controllers and thereby presents a further step in the evolution of irrigation in general. For example, the irrigation controller **20** is capable of sending diagnostic information and the like from the main controller **80** to a remote unit that can be retained by a user in the field to provide for efficient system diagnosis and repair. Furthermore, with the provision of the EEPROM **30**, the irrigation controller **20** allows flexible shifting between a plurality of watering programs including a specialized program for germinating seeds and the like. A further advantage of employing the EEPROM **30** is that the irrigation controller **20** does not lose memory even during extended periods without power so that watering programs and a status variable indicating whether the irrigation controller **20** was last on or off can be retained. Still further, the irrigation controller **20** provides a specialized winterize mode that permits activation of a multiplicity of watering zones simultaneously so that winterizing procedures can be carried out more efficiently and conveniently. Another advantage of the irrigation controller **20** is that it provides current sensing circuitry **24** that can detect how many valves are operational in each watering zone to allow the irrigation controller **20** to adjust the maximum allowable current and can prevent damage to the irrigation controller **20** by detecting when no valve is operational. Further still, the irrigation controller **20** clearly indicates selected zones and active programming functions thereby guiding a user during programming. Further advantages of the present invention will be readily obvious both to one who has reviewed the present disclosure and to one who has an opportunity to make use of an embodiment of the present invention.

It will be clear that the present invention has been shown and described with reference to certain preferred embodiments that merely exemplify the broader invention revealed herein. Certainly, those skilled in the art can conceive of alternative embodiments. For instance, those with the major features of the invention in mind could craft embodiments that incorporate those major features while not incorporating all of the features included in the preferred embodiments.

With the foregoing in mind, the following claims are intended to define the scope of protection to be afforded the inventor, and the claims shall be deemed to include equivalent constructions insofar as they do not depart from the spirit and scope of the present invention. A plurality of the following claims express certain elements as a means for performing a specific function, at times without the recital of structure or material. As the law demands, these claims shall be construed to cover not only the corresponding structure and material expressly described in the specification but also equivalents thereof.

I claim as deserving the protection of United States Letters Patent:

1. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for enabling an inputting of commands relating to watering programs;

a means for receiving commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands;

a means for retaining information relating to watering programs; and

a means for displaying information relating to watering programs;

wherein the means for enabling an inputting of commands, the means for receiving commands, the means for processing commands, the means for controlling the plurality of watering zones, and to means for retaining information in combination comprise a means for allowing a user to establish watering programs wherein each watering program comprises at least one selecting start time and at least one selected watering length; and

wherein the means for allowing a user to establish watering programs further enables a user to input a Review command to cause the irrigation controller to enter a review mode wherein the means for enabling an inputting of commands relating to watering programs is disabled whereby a user can review a given watering program without risk of accidentally altering the watering program.

2. The irrigation controller of claim **1** wherein the means for allowing a user to establish watering programs enables a user to establish a selected start time and a selected watering length individually for each of a plurality of watering zones and wherein the means for allowing a user to establish watering programs further enables a user to select simultaneously a single selected start time and a single selected watering length for a plurality of watering zones.

3. The irrigation controller of claim **2** wherein the means for allowing a user to establish watering programs further enables a user to input a Skip Day command wherein a user can induce the watering program to skip one or more days.

4. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for enabling an inputting of commands relating to watering programs;

a means for receiving commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands;

a means for retaining information relating to watering programs; and

a means for displaying information relating to watering programs;

wherein the means for enabling an inputting of commands, the means for receiving commands, the means for processing commands, the means for controlling the plurality of watering zones, and the means for retaining information in combination comprise a means for allowing a user to establish watering programs wherein each watering program comprises at least one selected start time and at least one selected watering length; and

wherein the means for allowing a user to establish watering programs further enables a user to input a Germinate command wherein a user can establish a germinate watering program that temporarily replaces a basic watering program that continues to be retained by the means for retaining information relating to watering programs, wherein the means for allowing a user to establish watering programs enables a user to input up to a given number of start times relative to the basic watering program while enabling a user to input a greater number of start times than the given number of start times relative to the germinate watering program, and wherein the germinate watering program automatically induces every day watering in the irrigation system whereby a user can temporarily replace a basic watering program with the germinate watering program that enables more frequent start times every day for enabling a germination of newly planted seed and whereby the user can supplant the germinate watering program with the basic watering program without a need for re-inputting the basic watering program.

5. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for enabling an inputting of commands relating to watering programs;

a means for receiving commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands;

a means for retaining information relating to watering programs; and

a means for displaying information relating to watering programs;

wherein the means for enabling an inputting of commands, the means for receiving commands, the means for processing commands, the means for controlling the plurality of watering zone, and the means for retaining information in combination comprise a means for allowing a user to establish watering programs wherein each watering program comprises at least one selected start time and at least one selected watering length; and

wherein the irrigation controller further comprises a means for preventing simultaneous operation of a number of valves excessive of the maximum number of valves that allows for proper operation of the irrigation system during a normal operation of the irrigation controller and wherein the means for allowing a user to establish watering programs further enables a user to input a Winterize command to cause the irrigation controller to enter a winterize mode wherein a multiplicity of the plurality of valves can be simultaneously operated at any one time whereby a user can winterize an irrigation system more quickly than the user could if only one valve of the plurality of valves could be operated at any one time.

6. The irrigation controller of claim **5** wherein the means for preventing simultaneous operation of a number of valves excessive of the maximum number of valves that allows for proper operation of the irrigation system during a normal operation of the irrigation controller comprises a power supply with a maximum current capability, a means for measuring current draw from the power supply, and a means for comparing the current draw from the power supply with the maximum current capability of the power supply.

7. The irrigation controller of claim **6** wherein the means for measuring current draw from the power supply comprises an analog-to-digital converter operably associated with the means for processing commands relating to watering programs and the means for controlling the plurality of watering zones according to the commands for providing a digital reading of current draw.

8. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for enabling an inputting of commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands;

a means for displaying information relating to watering programs; and

a means for retaining information relating to watering programs in the absence of power whereby the irrigation controller can retain watering programs even during extended periods without power wherein the means for retaining watering programs in the absence of power comprises an electrically erasable programmable readonly memory device operably associated with the means for processing commands relating to watering programs and the means for controlling the plurality of watering zones according to the commands.

9. The irrigation controller of claim **8** wherein the electrically erasable programmable read-only memory device comprises sufficient read-only memory for simultaneously retaining a plurality of watering programs whereby the means for processing commands relating to watering programs and the means for controlling the plurality of watering zones according to the commands can selectively access one or more of the plurality of watering programs at a given time.

10. The irrigation controller of claim **8** wherein the means for retaining watering programs in the absence of power further comprises a means for retaining whether the irrigation controller is on or off in the absence of power whereby the irrigation controller can remember whether it was on or off even after extended periods without power.

11. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for enabling an inputting of commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands;

a means for displaying information relating to watering programs;

a means for retaining information relating to watering programs; and

a means for detecting how many valves are operational in a given watering zone and a means for automatically adjusting a maximum allowable current in response to how many valves are operational in a given watering zone wherein the means for detecting how many valves are operational in a given watering zone comprises an analog precision rectifier.

12. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for enabling an inputting of commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands;

a means for displaying information relating to watering programs;

a means for retaining information relating to watering programs;

a remote control unit; and

a means for transmitting diagnostic information to the remote control unit regarding a status of the valves of the irrigation system.

13. The irrigation controller of claim **12** further comprising a means operably associated with at least the remote control unit for inducing remote operation of the valves of the irrigation system.

14. The irrigation controller of claim **12** wherein the means for transmitting diagnostic information to the remote control unit regarding a status of the valves of the irrigation system comprises a means for sending a signal from the remote control unit to the means for processing commands relating to watering programs and the means for controlling the plurality of watering zones according to the commands to induce the means for processing commands relating to watering programs and the means for controlling the plurality of watering zones according to the commands to send a test signal to each valve in the irrigation system, a means for measuring a current across each valve, a means for determining based on the current across the valve whether each valve is open or shorted, a means for transmitting whether each valve is open or shorted to the remote control unit, and a means for displaying the status of the valves in the irrigation system on the remote control unit.

15. The irrigation controller of claim **14** wherein the means for displaying the status of the valves in the irrigation system on the remote control unit comprises at least one LED numeric display in combination with a bi-color status LED wherein the LED numeric display displays any faulty zones and the bi-color status LED indicates with a first color whether the faulty zone is open and with a second color whether the faulty zone is shorted.

16. The irrigation controller of claim **12** wherein the means for transmitting diagnostic information to the remote control unit regarding a status of the valves of the irrigation system comprises a communication port comprising a four wire interface wherein two wires send power and ground and two wires provide a differential signal path.

17. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for selecting one or more of the plurality of watering zones to create a selected watering zone or zones wherein the means for selecting one or more of the plurality of watering zones comprising a key for each watering zone;

a means for displaying information relating to watering programs comprising a means for indicating the selected watering zone or zones wherein the means for indicating the selected watering zone or zones comprises an indicator light disposed proximate each key for indicating whether the watering zone that is selectable by that key is a selected watering zone;

a means for enabling an inputting of commands relating to watering programs for the plurality of watering zones;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands; and

a means for retaining information relating to watering programs;

wherein the means for enabling an inputting of commands, the means for processing commands relating to watering programs, the means for controlling the plurality of watering zones according to the commands, and the means for retaining information in combination comprise a means for allowing a user to establish watering programs wherein each watering program comprises at least one selected start time and at least one selected watering length.

18. The irrigation controller of claim **17** wherein the indicator light proximate each key comprises an LED.

19. The irrigation controller of claim **17** wherein each key comprises a membrane keypad key.

20. The irrigation controller of claim **17** wherein the means for displaying information relating to watering programs further comprises a means for indicating an active programming function.

21. An irrigation controller for controlling watering programs in an irrigation system that comprises a plurality of watering zones with a plurality of valves, the irrigation controller comprising:

a means for selecting one or more of the plurality of watering zones to create a selected watering zone or zones;

a means for displaying information relating to watering programs comprising a means for indicating the selected watering zone or zones;

a means for enabling an inputting of commands relating to watering programs;

a means for processing commands relating to watering programs;

a means for controlling the plurality of watering zones according to the commands; and

a means for retaining information relating to watering programs;

wherein the means for enabling an inputting of commands, the means for processing commands relating to watering programs, the means for controlling the plurality of watering zones according to the commands, and the means for retaining information in combination comprise a means for allowing a user to establish watering programs wherein each watering program comprises at least one selected start time and at least one selected watering length;

wherein the means for allowing a user to establish watering programs enables a user to establish a selected start time and a selected watering length individually for each of a plurality of watering zones;

wherein the means for allowing a user to establish watering programs further enables a user to select simultaneously for a plurality of watering zones a single selected start time and a single selected watering length;

wherein the means for allowing a user to establish watering programs further enables a user to input a Skip Day command wherein a user can induce the watering program to skip one or more days;

wherein the means for allowing a user to establish watering programs further enables a user to input a Water Percent command wherein a user can induce the watering program to water one or more watering zones for a selected percentage of a length of the selected watering length for the one or more watering zones whereby a user can alter an actual watering time of the one or more watering zones without changing the selected watering length for the one or more watering zones;

wherein the means for allowing a user to establish watering programs further enables a user to input a Germinate command wherein a user can establish a germinate watering program that temporarily replaces a basic watering program that continues to be retained by the means for retaining information relating to watering programs, wherein the means for allowing a user to establish watering programs enables a user to input up to a given number of start times relative to the basic watering program while enabling a user to input a greater number of start times than the given number of start times relative to the germinate watering program, and wherein the germinate watering program automatically induces every day watering in the irrigation system whereby a user can temporarily replace a basic watering program with the germinate watering program that enables more frequent start times every day for enabling a germination of newly planted seed and whereby the user can replace the germinate watering program with the basic watering program without a need for re-inputting the basic watering program;

a means for preventing simultaneous operation of a number of valves excessive of the maximum number of valves that allows for proper operation of the irrigation system during a normal operation of the irrigation controller;

wherein the means for allowing a user to establish watering programs further enables a user to input a Winterize command to cause the irrigation controller to enter a winterize mode wherein a multiplicity of the plurality of valves can be simultaneously operated at any one time whereby a user can winterize an irrigation system more quickly than the user could if only one valve of the plurality of valves could be operated at any one time; and

wherein the means for allowing a user to establish watering programs further enables a user to input a Review command to cause the irrigation controller to enter a review mode wherein the means for enabling an inputting of commands relating to watering programs is disabled whereby a user can review a given watering program without risk of accidentally altering the watering program.

* * * * *

US006529589B1

(12) **United States Patent**
Nelson et al.

(10) **Patent No.: US 6,529,589 B1**
(45) **Date of Patent: Mar. 4, 2003**

(54) **METHOD AND SYSTEM FOR MONITORING AND CONTROLLING AUTOMATION EQUIPMENT BY MODEM**

(75) Inventors: **Jon A. Nelson**, Magna, UT (US); **Tim Urry Price**, Salt Lake City, UT (US)

(73) Assignee: **3Com Corporation**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **May 20, 1999**

(51) **Int. Cl.**[7] **H04M 11/00**
(52) **U.S. Cl.** **379/102.01**; 340/310.01
(58) **Field of Search** 379/102.01–106.01; 340/310.02, 310.08, 310.07

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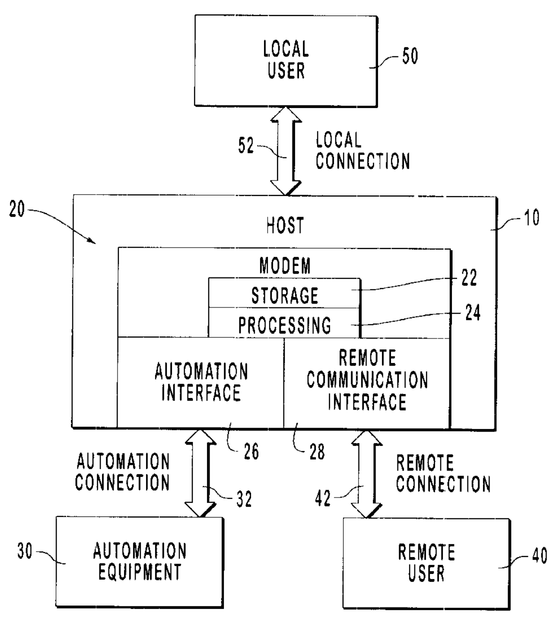
* cited by examiner

Primary Examiner—Wing F. Chan
(74) *Attorney, Agent, or Firm*—Workman, Nydegger & Seeley

(57) **ABSTRACT**

Methods, systems, and computer program products for monitoring and controlling automation equipment. The present invention uses a modem's processing and memory resources to interpret and translate data and commands associated with automation equipment. When receiving data from the automation equipment, the modem interprets the data using its own processing power and stores the interpreted results in its own memory for subsequent retrieval. Commands for control are translated into a compatible format by the modem and then transmitted to the automation equipment. The present invention also allows for remote access through the modem for both monitoring and controlling without requiring any host interaction. A modem according to the present invention further provides for its host to operate in a mode of reduced processing and power consumption while the modem continues to monitor and control automation equipment.

43 Claims, 6 Drawing Sheets



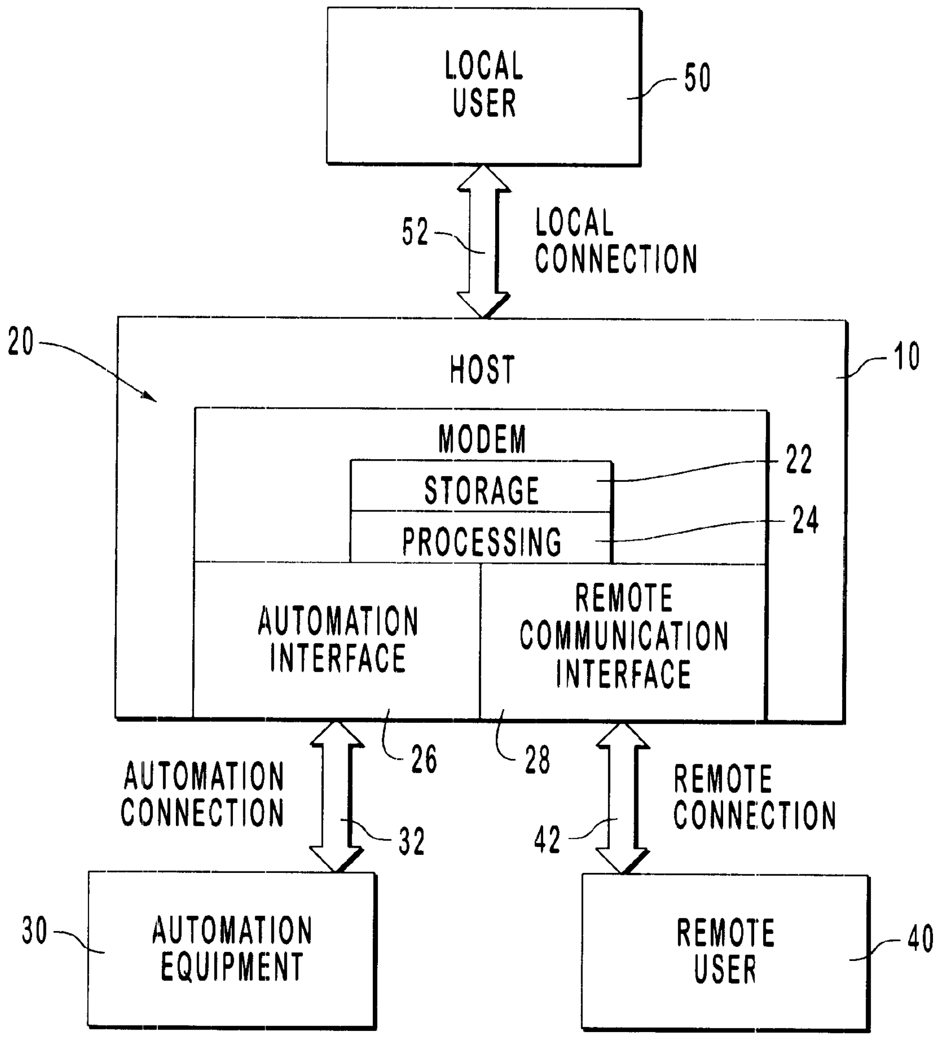
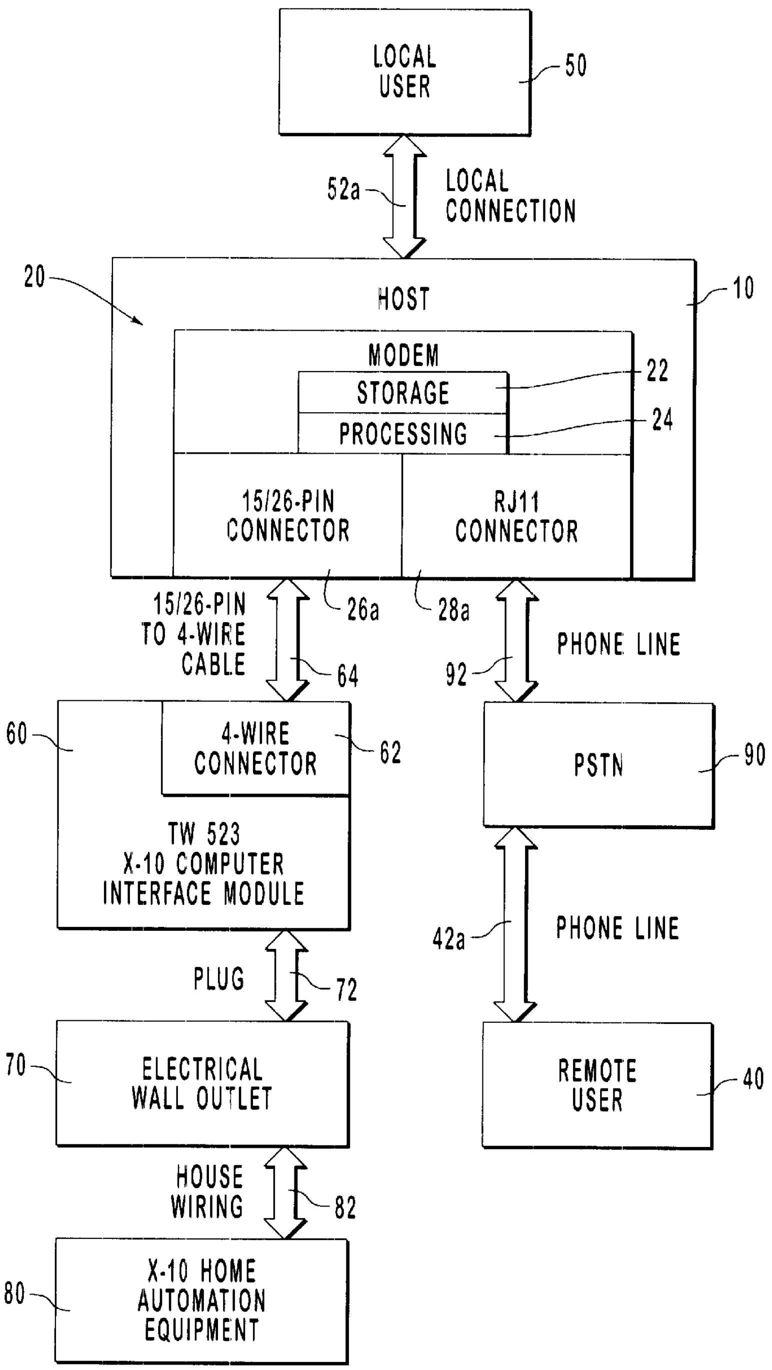

LOCAL
USER
50
52
LOCAL
CONNECTION
20
HOST
10
MODEM
STORAGE
22
PROCESSING
24
AUTOMATION
INTERFACE
REMOTE
COMMUNICATION
INTERFACE
26
28
AUTOMATION
CONNECTION
32
42
REMOTE
CONNECTION
30
AUTOMATION
EQUIPMENT
REMOTE
USER
40

FIG. 1


LOCAL
USER
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52a
LOCAL
CONNECTION
20
HOST
10
MODEM
STORAGE
22
PROCESSING
24
15/26-PIN
CONNECTOR
RJ11
CONNECTOR
15/26-PIN
TO 4-WIRE
CABLE
26a
28a
PHONE LINE
64
92
60
4-WIRE
CONNECTOR
62
PSTN
90
TW 523
X-10 COMPUTER
INTERFACE MODULE
42a
PHONE LINE
PLUG
72
70
ELECTRICAL
WALL OUTLET
REMOTE
USER
40
HOUSE
WIRING
82
80
X-10 HOME
AUTOMATION
EQUIPMENT

FIG. 2

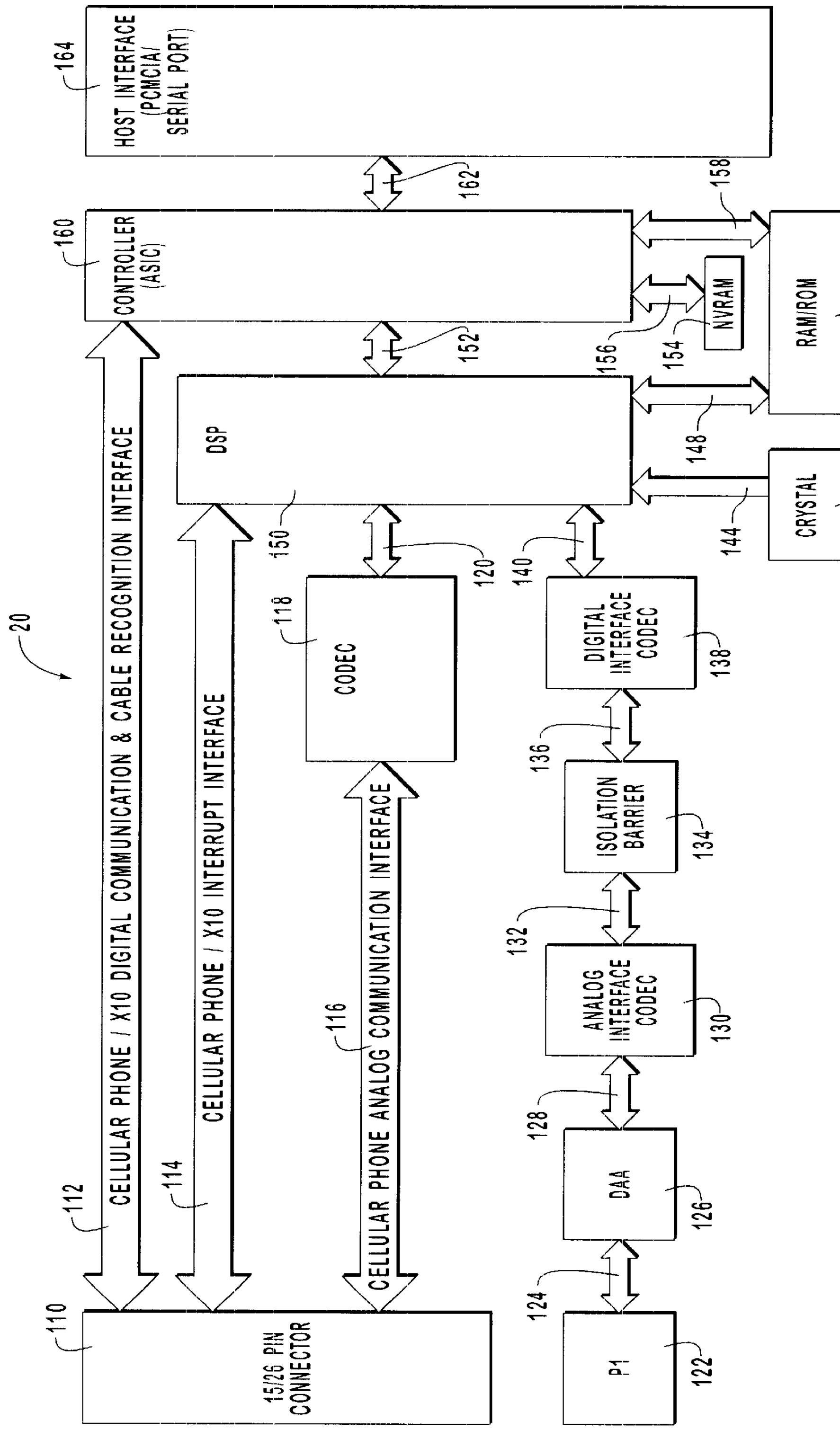
20
HOST INTERFACE (PCMCIA/ SERIAL PORT)
164
162
CONTROLLER (ASIC)
160
158
NVRAM
154
156
RAM/ROM
146
152
DSP
150
148
CRYSTAL
142
144
120
140
CODEC
118
DIGITAL INTERFACE CODEC
138
136
ISOLATION BARRIER
134
132
ANALOG INTERFACE CODEC
130
128
DAA
126
124
P1
122
CELLULAR PHONE / X10 DIGITAL COMMUNICATION & CABLE RECOGNITION INTERFACE
112
CELLULAR PHONE / X10 INTERRUPT INTERFACE
114
CELLULAR PHONE ANALOG COMMUNICATION INTERFACE
116
15/26 PIN CONNECTOR
110

FIG. 3

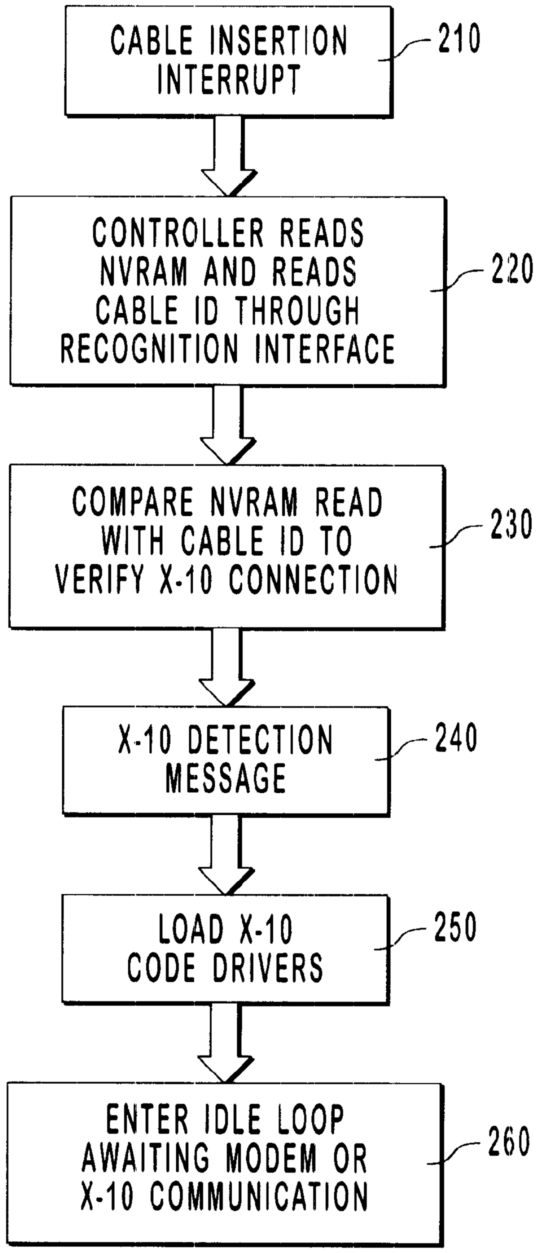
CABLE INSERTION INTERRUPT
210
CONTROLLER READS NVRAM AND READS CABLE ID THROUGH RECOGNITION INTERFACE
220
COMPARE NVRAM READ WITH CABLE ID TO VERIFY X-10 CONNECTION
230
X-10 DETECTION MESSAGE
240
LOAD X-10 CODE DRIVERS
250
ENTER IDLE LOOP AWAITING MODEM OR X-10 COMMUNICATION
260

FIG. 4

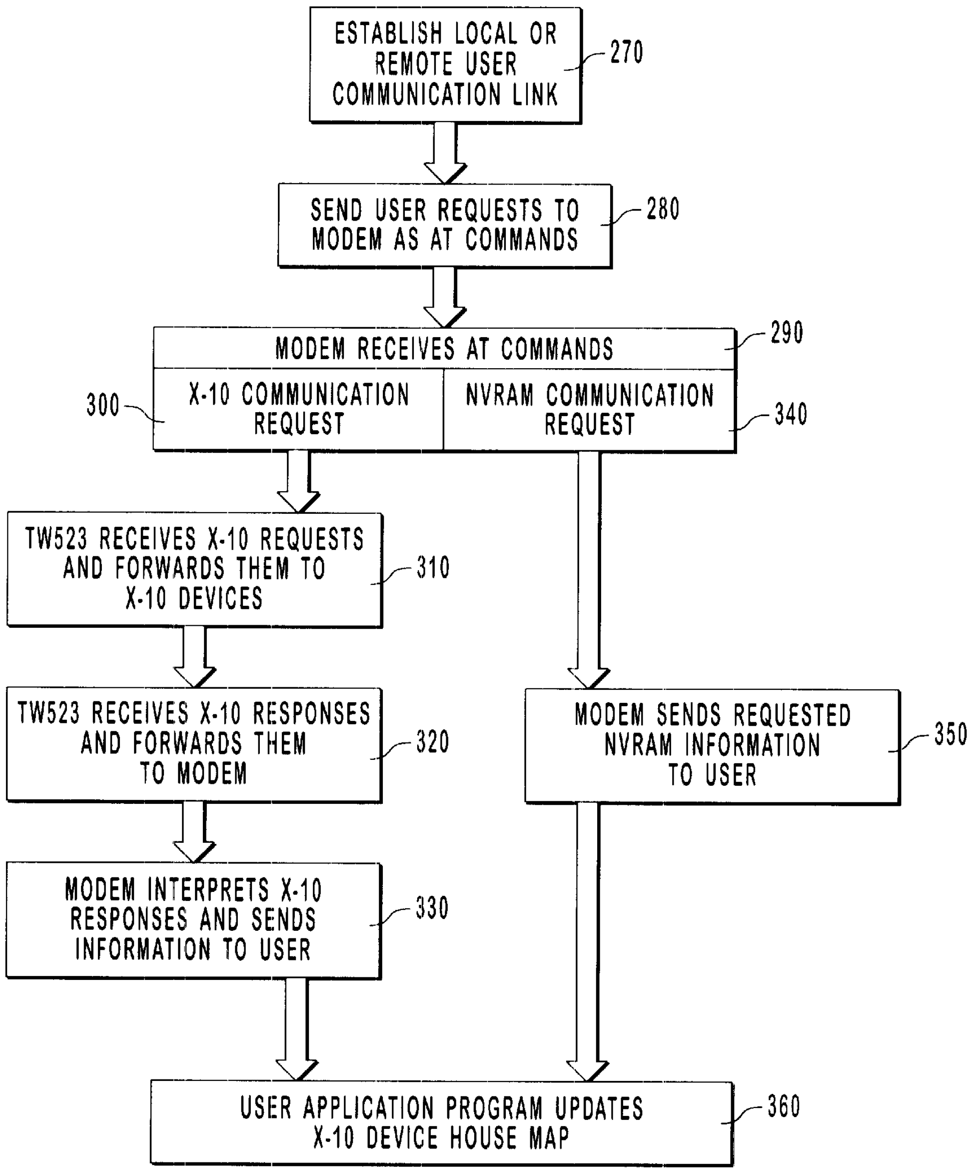
ESTABLISH LOCAL OR REMOTE USER COMMUNICATION LINK
270
SEND USER REQUESTS TO MODEM AS AT COMMANDS
280
MODEM RECEIVES AT COMMANDS
290
X-10 COMMUNICATION REQUEST
300
NVRAM COMMUNICATION REQUEST
340
TW523 RECEIVES X-10 REQUESTS AND FORWARDS THEM TO X-10 DEVICES
310
TW523 RECEIVES X-10 RESPONSES AND FORWARDS THEM TO MODEM
320
MODEM SENDS REQUESTED NVRAM INFORMATION TO USER
350
MODEM INTERPRETS X-10 RESPONSES AND SENDS INFORMATION TO USER
330
USER APPLICATION PROGRAM UPDATES X-10 DEVICE HOUSE MAP
360

FIG. 5

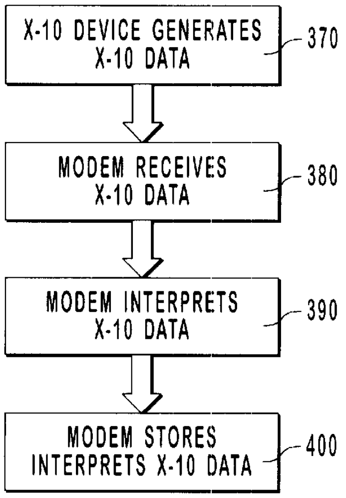
X-10 DEVICE GENERATES X-10 DATA
370
MODEM RECEIVES X-10 DATA
380
MODEM INTERPRETS X-10 DATA
390
MODEM STORES INTERPRETS X-10 DATA
400

FIG. 6

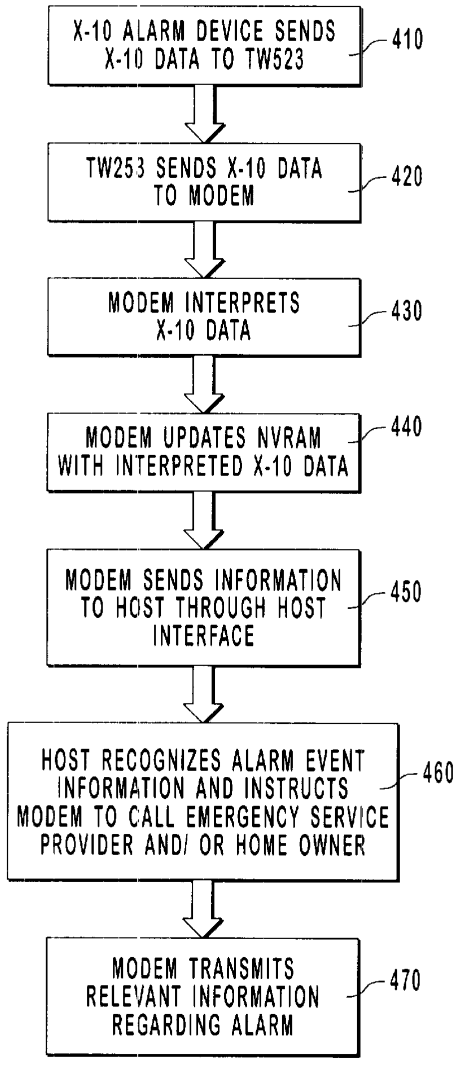
X-10 ALARM DEVICE SENDS X-10 DATA TO TW523
410
TW253 SENDS X-10 DATA TO MODEM
420
MODEM INTERPRETS X-10 DATA
430
MODEM UPDATES NVRAM WITH INTERPRETED X-10 DATA
440
MODEM SENDS INFORMATION TO HOST THROUGH HOST INTERFACE
450
HOST RECOGNIZES ALARM EVENT INFORMATION AND INSTRUCTS MODEM TO CALL EMERGENCY SERVICE PROVIDER AND/ OR HOME OWNER
460
MODEM TRANSMITS RELEVANT INFORMATION REGARDING ALARM
470

FIG. 7

METHOD AND SYSTEM FOR MONITORING AND CONTROLLING AUTOMATION EQUIPMENT BY MODEM

BACKGROUND OF THE INVENTION

1. The Field of the Invention

The field of the present invention is network communications. More specifically, the present invention relates to methods, systems and computer program products for monitoring and controlling network connected automation equipment using the processing and memory resources of a modem.

2. The Prior State of the Art

At least in a primitive sense, automation equipment has existed for some time. Among the earliest and most familiar devices of general application were simple timers for turning appliances on and off. These timers are simple in design, amounting to little more than a device that plugs into an ordinary electrical socket with a corresponding electrical socket for the appliance to be controlled. By supplying and cutting off the flow of electricity, the timer can automatically turn a light on at dusk and then automatically turn the light off around bedtime. For many consumers, the primary value of these timers is not in saving the labor required to turn on a light or other appliance, but rather in giving the illusion that "someone is home."

Over the years, the applications for timers have greatly multiplied. For example, timers are used to control heating and air conditioning systems, lights, coffee makers, ovens, radios, television sets, VCRs, sprinkling systems and other devices. Unfortunately, most timers have been completely autonomous, requiring individual attention to set the correct time or change the operation of the device they control. For example, power outages may require the time to be reset in certain devices and changes in daylight hours from winter to summer may alter the desired operating times of those same devices. Furthermore, normal changes in day to day circumstances exacerbate these deficiencies. Someone planning a trip needs to place individual timers for each light to be controlled and may want to change the settings of heating and air conditioning to conserve energy while a dwelling is unoccupied.

Moreover, the process must be reversed upon return. Moving beyond the rudimentary automation offered by timers, more sophisticated devices have been developed to provide a greater degree of information and control. For example, a fire alarm system may include temperature sensors at several locations; a security system may provide a network of contact and motion sensors to identify open and/or occupied areas; a lighting system may control both natural and artificial light sources to maintain a particular luminosity. Common to the increase in sophistication of automation devices is the need for collecting and measuring data from multiple sources, and implicit in the multiple sensor paradigm is the need for interconnection. Having sensors interconnected naturally leads to the possibility of centralized monitoring and controlling for all automation systems. It is now possible to set a dwelling to "vacation mode" at a central panel rather than physically manipulating individual automation devices.

For new construction, interconnecting each of the sensors is relatively simple, but nevertheless may exact a significant expense. However, adding sensors and interconnections to existing structures presents a much more substantial problem and therefore a much greater expense. Because of the

expense, automation systems with dedicated communication lines may be restricted to a fairly small portion of their potential market. One solution is provided by the X-**10** protocol for controlling home automation equipment. X-**10** uses standard electrical wiring, providing power to standard electrical sockets, for transmitting automation equipment signals. By eliminating the expense and effort of running dedicated communication channels, X-**10** significantly expands the market for home automation systems.

Another simplification of home automation systems may include using a personal computer for monitoring and controlling various devices in place of a dedicated control panel. Personal computers are advantageous is this regard because a household contemplating home automation may already own a personal computer and be familiar with the various user interface components such that learning to use the system will be more intuitive. Unfortunately, traditional systems for monitoring home automation with a personal computer typically require the computer to be operating constantly, offsetting some of the energy conservation benefits that might otherwise accrue and possibly leading to other problems. For example, the noise and light generated by a computer is negligible under many circumstances but may prove undesirable during the night where other background noise and light it at a minimum.

BRIEF SUMMARY AND OBJECTS OF THE INVENTION

The foregoing problems in the prior state of the art have been successfully overcome by the present invention, which is directed to methods, systems and computer program products that enable the monitoring and controlling of automation equipment through a modem attached to a host. The invention is particularly useful given the increasing numbers of personal computers available in residential and commercial settings to fill the role of host. Furthermore, the development of improved technology and standards for adding automation equipment to existing facilities without requiring the installation of dedicated communication links provides an expanding market for the present invention.

In accordance with the monitoring aspect of the invention, a modem includes an automation interface capable of receiving data from the automation equipment. The automation interface includes means for recognizing a connection that has been established with the automation equipment. Once connected, the modem's processing means receives and interprets various automation equipment data. The interpreted automation equipment data are in a format that is amenable to storage. Having interpreted the data, the modem then stores the received data so that it may be retrieved later to give the automation equipment's status.

To allow for the controlling aspect of the present invention, the modem's automation interface also provides means for transmitting commands to the automation equipment. The modem includes means for receiving a command that is directed to the automation equipment. After receipt, the modem translates the command into a format that is suitable for transmission to the automation equipment. The means for transmitting then transmits the translated command so that it may be received by the automation equipment.

Another aspect of the invention is related to the modem having a remote communication interface for connecting to a remote user. Although the essence of modem communication is that of remote operation, the remote communication interface of the present invention offers significant advantages. Specifically, connecting through the remote communication interface allows a remote user to interact directly with the modem and the information it contains, as opposed to the typical host-to-host communication provided by prior art modems. This direct modem interaction allows the invention to be practiced when the host operates in a reduced capacity, such as a power saving mode wherein the host need only provide power to the modem. In this arrangement, the remote user can send and receive information, allowing for both remote monitoring and remote controlling of the home automation equipment.

Accordingly, it is an object of the present invention to monitor and control automation equipment by using a modem's processing and memory resources.

Another object of the present invention is to provide remote access to automation equipment without requiring the interaction of a host.

Yet another object of the present invention is to allow for a modem to monitor automation equipment while the host operates in a mode of reduced power consumption.

Still another object of the present invention is to provide for a modem to receive commands from a remote user and control automation equipment while the host operates in a mode of reduced processing and power consumption.

These and other objects, features and advantages of the present invention will be set forth in the description which follows, and in part will be more apparent from the detailed description of a preferred embodiments, and/or from the appended claims, or may be learned by actual practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the above-recited and other advantages and objects of the invention are obtained, a more particular description of the invention briefly described above will be rendered by reference to the specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only the typical embodiments of the invention and are not therefore to be considered limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1** is a block diagram illustrating the basic elements of an environment suitable for monitoring and controlling automation equipment according to the present invention;

FIG. **2** is a more detailed block diagram presenting a typical environment for monitoring and controlling automation equipment according to the present invention;

FIG. **3** is a block diagram showing the functional elements of a modem, according to a preferred embodiment of the present invention, for use in monitoring and/or controlling automation equipment;

FIG. **4** is a flow chart illustrating the steps taken by a preferred embodiment of the present invention to detect the insertion of a cable for connecting automation equipment;

FIG. **5** is a flow chart showing the steps performed by a preferred embodiment of the present invention in fulfilling a user's automation equipment information request;

FIG. **6** is a flow chart depicting the steps executed by a preferred embodiment of the present invention in monitoring automation equipment; and

FIG. **7** is a flow chart presenting the steps followed by a preferred embodiment of the present invention in response to an alarm signal generated by the automation equipment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is related to monitoring automation equipment using a modem attached to a host. The modem includes an automation interface for connecting to automation equipment, a processing means, and a storage means. Receiving data through its automation interface, the modem processing means interprets the received data and stores the result in the storage means. The stored interpretations may be retrieved later to obtain status information regarding the automation equipment.

A modem operating according to the present invention may also control automation equipment through its automation interface. The modem receives a command destined for the automation equipment. In order to transmit the command, the modem processing means translates the command into a format that is compatible with the communication channel used to connect the modem and automation equipment. The modem then transmits the translated command.

In addition, the present invention contemplates a modem having a remote communication interface. The remote communication interface allows the monitoring and controlling features described above to be accessed by a remote user. Unlike traditional remote access, the present invention may not require any participation on the part of the host. That is, a modem of the present invention is capable of establishing a remote user communication link as well as providing monitoring and control features to a remote user, all without depending on host processing resources.

The invention is described in further detail below by using diagrams to illustrate either the structure or processing of embodiments implementing the methods, systems and computer program products of the present invention. Using the diagrams in this manner to present the invention should not be construed as limiting of its scope. The embodiments of the present invention may comprise a special purpose or general purpose computer including various computer hardware, as discussed in greater detail below. The embodiments may further comprise multiple computers linked in a network environment.

In addition, embodiments within the scope of the present invention include computer readable media, or computer program products, storing computer-executable instructions or data structures. Such computer readable media may be any available media accessible by a general purpose or special purpose computer. By way of example, and not limitation, such computer readable media may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices. Computer readable media may also comprise any other medium capable of storing computer-executable instructions or data structures that can be accessed by a general purpose or special purpose computer, including instances where such access is accomplished via a public (e.g., the Internet) or a private network. Combinations of the above should also be included within the scope of computer readable media.

Turning now to FIG. **1**, the functional components of a preferred embodiment implementing the present invention are illustrated. The basic functional components include host **10**, modem **20**, automation equipment **30**, remote user **40**, and/or local user **50** along with their corresponding interconnections. Host **10** may be selected from many possible computer system configurations, including personal computers, hand-held devices,multi-processor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention may also be practiced in distributed computing environments where tasks are performed by local and remote processing devices that are linked through a communication network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

In a preferred embodiment, host **10** is a general purpose computing device in the form of a conventional computer that includes a processing unit, system memory, and a system bus for coupling various system components, such as modem **20**, to the processing unit. The system bus may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. Additionally, the system bus may also connect a variety of input devices to the processing unit using interfaces such as serial ports, parallel ports, game ports, universal serial bus ports, etc. Preferably, modem **20** connects to host **10** through either a PCMCIA system bus interface or through an available serial port.

Similarly, local user **50** is also connected to the processing unit of host **10** through an interface. Local user **50** may include a video monitor or other display device for receiving data from host **10** and a keyboard and/or mouse for inputting data to host **10**. In the case of a video monitor, the host connection may be made through a video adapter interface attached to the system bus, where local connection **52** includes the video monitor cable. Keyboards are also generally connected through a dedicated interface, whereas a mouse may be connected through an available serial port or some other interface specific to the mouse. For a keyboard and mouse, Local connection **52** includes the corresponding keyboard and mouse cable.

However, given the wide variety of computing systems from which host **10** may be selected, an equally wide variety of options for local user **50** and local connection **52** should be considered. For example, local user **50** may also comprise a hand-held computing device with a wireless link for local connection **52**. The only requirement for local user **50** and local connection **52** is the ability to exchange data and/or commands with host **10**. Furthermore, there is no requirement that local user **50** necessarily includes a person. For example, local user **50** may comprise a log of automation equipment activity, a graphical display of the automation equipment's current status, programmed instructions to control the automation equipment, or any combination of the foregoing.

Modem **20** is also connected to host **10** and includes storage **22**, processing **24**, automation interface **26** and remote communication interface **28**. Storage **22** is exemplary of means for storing the interpretation of data received from automation equipment **30**. In a preferred embodiment, storage **22** comprises non-volatile RAM or NVRAM. However, storage **22** contemplates a variety of possible storage means, including all types of RAM, as well as any other means suitable for recording electronic data. The stored data may include a log of recent activity or the identification and/or status of certain connected automation equipment.

Processing **24** is exemplary of means for interpreting and means for translating the commands and data associated with the automation equipment. There are many means for processing that are well-known in the computer related arts, including general purpose central processing units, microprocessors having limited functionality, and special purpose

controllers. A preferred embodiment of the present invention uses an application-specific integrated circuit or ASIC as processing **24**. Nevertheless, the presence of an ASIC in a preferred embodiment should not be construed as a limitation; the current invention contemplates use of the above-named processor types as well as comparable processing means for other embodiments that are within the present invention's scope.

Likewise, automation interface **26** is not necessarily restricted to any particular specification, but is preferably an interface that may perform a variety functions. For example, automation interface **26** may provide means for interfacing with a cellular phone and/or a network. The only requirement for automation interface **26** is that it be capable of connecting automation equipment **30** with modem **20** through automation connection **32**. Automation interface **26** provides means for receiving data from automation equipment **30**. In certain preferred embodiments, automation interface **26** is a 15- or 26-pin connector commonly used to connect modems with cellular telephones. In addition to the many physical forms that are within the scope of the present invention, automation connection **32** may include a wireless link as well.

Automation equipment **30** may comprise a wide variety of residential and commercial devices for monitoring and controlling heating and air conditioning systems, lighting, irrigation systems, appliances, fire alarm and security systems, etc. The foregoing examples of automation equipment are only illustrative of some devices that are available and should not be interpreted as limiting the scope of the present invention. Like automation interface **26**, automation equipment **30** needs to be capable of communicating through automation connection **32**.

Although automation connection **32** appears as a single element, in practice it may comprise various components to provide a connection between automation equipment **30** and automation interface **26**. For example, automation connection **32** may include a wireless component, requiring antennas and related circuitry. Automation connection **32** may include one or more modules for interfacing with electrical wiring (see the discussion of FIG. **2**). It may include one or more dedicated cables; it may include combinations of the foregoing. Automation connection **32** is the means for establishing a connection between automation equipment **30** and modem **20**.

Remote communication interface **28** includes means for connecting modem **20** with a remote user **40** using remote connection **42**. Commonly, remote connection **42** includes a cable with RJ-type connectors for coupling the modem to a telephone line. However, remote communication interface **28** and remote connection **42** are not limited to any particular technology or layout. It is only necessary that remote connection **42** and remote communication interface **28** provide a means for remote user **40** to access modem **20**. Although shown as a single element, remote connection **42** includes relatively sophisticated communication links, such as public switched telephone networks or PSTN, cable and satellite systems, Internet communication, wireless links, and the like. Thus, in addition to the variety of suitable connections for telephone lines, remote communication interface **28** also may be capable of connecting remote user **40** to modem **20** through a cable or satellite system or through some type of wireless link. Remote communication interface **28** is one example of means for receiving commands to be directed to the automation equipment. A preferred embodiment implements remote communication interface **28** as an RJ11 telephone line connector. However, this implementation is merely illustrative of a preferred embodiment and should not be interpreted as limiting the present invention's scope.

Remote user **40** is similar to local user **50** in functionality, the primary difference between the two being the form taken by remote connection **42** and local connection **52** and the resulting connection. Remote user **40** connects directly to modem **20** through remote communication interface **28** whereas local user **50** connects to modem **20** through host **10**. Like local user **50**, remote user **40** may comprise a wide variety of computing systems, including personal computers, hand-held devices, multi-processor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, etc. The only requirement for remote user **40** and remote connection **42** is the ability to exchange data and/or commands with modem **20**. Like local user **50**, there is no requirement that remote user **40** necessarily includes a person. For example, remote user **40** may comprise a log of automation equipment activity, a graphical display of the automation equipment's current status, programmed instructions to control the automation equipment, or any combination of the foregoing.

Connecting automation equipment **30** and remote user **40** directly to modem **20** through automation interface **26** and remote communication interface **28** allows modem **20** to operate somewhat independently of host **10**. By including processing **24** and storage **22**, modem **20** is capable of exchanging data and commands with automation equipment **30** and remote user **40** without necessarily requiring the participation of host **10**. For example, host **10** may be capable of operating in a "sleep" mode characterized by reduced processing and power consumption. In this mode, host **10** would continue providing power to modem **20**, but one or more other components of host **10** would cease active operation.

New personal computers provide power-saving sleep modes in recognition that users are unwilling to shut down their machines during periods of inactivity due to the inconvenience imposed by restarting. Typically, personal computers used in a business setting are powered up upon the user's arrival and turned off only at the end of the day. Personal computers in other settings, such as those in homes or schools, may experience similar patterns of use. Likewise, laptop computers have long offered power-saving modes to prolong battery life. Most commonly, these power-saving modes are characterized by video displays shutting down, processors entering idle states while awaiting a signal to resume full operation, and drives spinning down.

With processing **24** and storage **22** accessible, modem **20** may interact with both automation equipment **30** and remote user **40** while host **10** remains in a sleep mode. In contrast, traditional modems are unable to function in this manner because they require host **10** to provide constant instructions and/or continuous storage and processing resources. Where host **10** is inactive, modem **20** may depend on processing **24** and storage **22**, allowing host **10** to enter and remain in its sleep mode. Referring next to FIG. **2**, a typical operating environment for a preferred embodiment of the present invention is illustrated. FIG. **2** focuses on the physical components that may be present in an X-**10** home automation system, leaving the interaction between those components for a more detailed description in regard to FIGS. **4**–**7**. Host **10** is a personal computer interfacing with local user **50** through a display, keyboard, mouse, and the associated cables as indicated by reference **52***a*. Modem **20** includes processing **24**, storage **22**, RJ11 connector **28***a* for communicating with remote user **40** through telephone line **92**, and 15- or 26-pin connector **26***a* for communicating with X-**10** home automation equipment **80** through 15- or 26-pin to 4-wire cable **64**. In a preferred embodiment, cable **64** includes means for identifying its type (i.e., X-10, cellular, etc.). For example, cable **64** may include ROM that modem **20** reads to determine the type of data that can be expected through connector **26***a*.

As described earlier, X-**10** is a communication protocol for home automation equipment that uses ordinary household electrical wiring as its transmission medium. Reference **60** identifies a TW**523** X-**10** computer interface module that connects to electrical wall outlet **70** through plug **72**. Computer interface module **60** includes 4-wire connector **62** for receiving 15- or 26-pin to 4-wire cable **64**. Cable **64** provides the connection between modem **20** and computer interface module **60**. Computer interface module **60** reduces the processing burden that would otherwise be imposed on modem **20** to continuously monitor the power line and check all incoming signals, including noise, for validity. Any signals passed by computer interface module **60** are guaranteed to be valid X-**10** codes. Furthermore, computer interface module **60** reads all codes it transmits. This allows modem **20** to verify that the code actually transmitted and the code that should have been transmitted are identical, any difference indicating either corruption by noise on the power line or a collision between multiple devices attempting to transmit at the same time. There is nothing in the present invention that requires using TW 523 X-**10** computer interface module **60**, the advantage is simply that it reduces the complexity and sophistication of the processing performed by modem **20**.

Similarly, X-**10** home automation equipment **80** may connect to house wiring **82** through an interface module to reduce the processing requirements that must be part of the home automation equipment, although FIG. **2** shows a direct connection. Interface modules, such as TW 523 X-**10** computer interface module **60**, may serve to reduce the development costs associated with automation equipment by limiting the functionality that must be provided. With a computer interface module eliminating extraneous signals, X-**10** home automation equipment **80** need only understand X-**10** codes provided by the module. However, the present invention is not limited in any manner by presence or absence of an interface module between X-**10** home automation equipment **80** and house wiring **82**.

Likewise, the exact components that connect remote user **40** to RJ11 connector **28***a* impose no limitation on the present invention. In a typical environment, RJ11 connector **28***a* connects to plain switched telephone network or PSTN **90** through an ordinary phone line **92**. Remote user **40** makes a similar connection with PSTN **90** through phone line **42***a*.

It should be remembered that FIG. **2** presents an environment suitable for operating a preferred embodiment of the present invention, modem **20**. The details for connecting local user **50**, remote user **40**, and X-**10** home automation equipment **80** are all well-known in the art and are intended to provide context only. Moreover, the environment of FIG. **2** is exemplary only and should not be interpreted as limiting the invention's scope. For instance, the current invention could be used in connection with other automation environments instead of the X**10** protocol. Other example environments include the LonWorks protocol, which is used for a distributed control system, or the CEBus (Consumer Electronics Bus) standard.

Referring now to FIG. **3**, a preferred embodiment of a modem implementing the present invention is illustrated.

Modem **20** includes three physical interfaces: host interface **164**, 15- or 26-pin connector **110**, and phone line interface **122**. Host interface **164**, through interconnections **162**, enables communication between modem **20** and a host. In the preferred embodiment shown, host interface **164** may conform to either a PCMCIA or serial port interface. In the case of a serial port interface, modem **20** may also include a separate power connection, whereas as a PCMCIA interface would also function to power modem **20**. Host interface **164** is another example of means for receiving commands to be directed to the automation equipment.

Telephone line interface **122** is preferably an RJ11 connector. The other functional components, DAA **126**, analog interface Codec **130**, isolation barrier **134**, digital interface Codec **138**, and DSP **150**, as well as the interconnections between them, referenced as **124**, **128**, **132**, **136**, and **140**, are well-know in the art of modem communication through a telephone line. Typically, a remote host uses telephone line interface **122** and the other functional components to establish a connection with modem **20**. However, the telephone line interface **122** of the present invention is distinct from typical telephone interfaces in that it is able to function while the host for modem **20** operates in a state of reduced power consumption and processing. In contrast, a prior art telephone interface would only be operable in conjunction with a fully functioning host.

The operation of telephone line interface **122** is determined by controller **160**. Controller **160** communicates with DSP **150** through interconnections **152**. In a preferred embodiment as shown in FIG. **3**, controller **160** is an application-specific integrated circuit or ASIC and is an example of the means for interpreting and means for translating that are part of modem **20**. However, the invention poses no limitations that controller **160** be any particular type of processor or processing device and many other devices could be interchanged with the ASIC embodiment of controller **160**, such as general purpose central processing units, microprocessors having limited functionality, and special purpose controllers.

Controller **160** accesses both instructions and data that are stored in RAM/ROM **146** through interconnections **158**. RAM/ROM **146** includes instructions for controlling the operation of modem **20** and provides working memory for controller **160**. For example, RAM/ROM **146** has instructions for establishing modem communication, perhaps with a remote user, through telephone line interface **122**, for interacting with X-**10** automation equipment and cellular telephones through connector **110**, and for transferring information with a host through host interface **164**. Furthermore, controller **160** may store information in non-volatile RAM or NVRAM **154**, where NVRAM **154** is an example of the means for storing that is associated with the modem.

DSP **150** also has access to RAM/ROM **146**, but through interconnections **148**. RAM/ROM **146** includes instructions for performing certain signal processing operations by DSP **150** as well as some working memory. Additionally, crystal **142** provides DSP **150** with needed timing signals through interconnections **144**. Controller **160** uses DSP **150** both in communicating through telephone line interface **122** as well as for communicating through connector **110**.

For analog cellular telephone communication, DSP **150** transfers data through interconnections **120** to Codec **118**. Codec **118** is specific to analog cellular telephone data and interfaces with connector **110** through cellular phone analog communication interface **116**. Using modem **20** for analog cellular telephone communication is well-known in the art of modems and will not be described further.

To interact with X-**10** automation equipment, modem **20** includes two additional interfaces with connector **110**: cellular phone/X-**10** interrupt interface **114** and cellular phone/X-**10** digital communication & cable recognition interface **112**. The discussion of FIGS. **4**–**7**, below, describes the operation of these two interfaces in greater detail. Nevertheless, for purposes of FIG. **3** and its representation of a preferred embodiment of the present invention, these interfaces will be described functionally here. Cellular phone/X-**10** interrupt interface **114** generates an interrupt when a cable is inserted into or withdrawn from connector **110**. The interrupt signals controller **160** to determine the type of connection to be supported through connector **110**. For example, inserting a cable that carries X-**10** automation equipment commands and data will generate an interrupt on interface **114**. Controller **160** will then use cellular phone/X-**10** digital communication & cable recognition interface **112** to determine the type of connection, X-**10** versus cellular, etc., and run the appropriate code for X-**10** automation equipment. As described in regards to FIG. **2**, above, a preferred embodiment of the cable will include means for determining the type of data that will pass through the cable. Similarly, withdrawal of a cable from connector **110** generates an interrupt so that controller **160** can recognize that a connection has been terminated.

Moving next to FIG. **4**, a flow chart including the steps taken by a modem, according to a preferred embodiment of the present invention, in establishing a communication link with X-**10** automation equipment is shown. The modem first receives an interrupt signal, in step **210**, that some type of cable has been inserted into an interface that supports X-**10** automation equipment. The interface preferably supports other communication, such as cellular telephone data transmission. Upon receiving the interrupt signal, in step **220** a controller reads the cable ID, for example through recognition interface **112** of FIG. **3**, and reads one or more identifiers from non-volatile RAM or NVRAM for use in determining the connection type. In step **230**, the cable ID is compared with a corresponding identifier read from NVRAM to verify that an X-**10** connection has been made through the inserted cable. The modem next provides an X-**10** detection message as shown in step **240**. For example, where host or remote software is actively monitoring any X-**10** communication, the message may state that an X-**10** module has been inserted. At this point, the modem knows that it likely will be sending and receiving X-**10** data and commands, so the modem controller loads X-**10** code drivers in step **250**. Once the X-**10** code drivers are loaded, the modem enters an idle loop in step **260** and waits for X-**10** or modem communication.

FIG. **5** shows the steps performed in a preferred embodiment of the present invention to fulfill a user's automation equipment request. In step **270**, a communication link with either a local or remote user is established for receiving and sending X-**10** automation equipment information. The user generates AT commands corresponding to the desired X-**10** action as shown in step **280**. (The AT command set is well-known in the art of modems.) In step **290**, the modem receives the AT commands and divides each request into either of two possible alternatives. If the request can be met with information already stored by the modem, step **340** routes the request to the modem's NVRAM. (FIG. **6** describes how information is stored in the modem's NVRAM.) The modem then reads NVRAM and sends the requested information to the user in step **350**.

If the modem determines that the desired information requires interaction with the X-**10** automation equipment, step **300** identifies the request as an X-**10** communication request. In step **310**, the TW523 X-**10** computer interface module, identified as reference **60** in FIG. **2**, receives the X-**10** requests and forwards it on to one or more X-**10** devices. Next, in step **320**, the TW523 receives X-**10** responses from one or more X-**10** devices and forwards the responses onto the modem. The modem interprets the received X-**10** responses in step **330** and sends the information to the user. As shown in step **360**, the user, whether local or remote, receives the requested information, either from step **330** or from step **350**. Having received a response, an application program can report any results to the user, preferably by updating an X-**10** device house map, but other means for reporting this information to a user are not precluded by the invention.

Considering next FIG. **6**, the steps performed by a preferred embodiment in monitoring X-**10** automation equipment is depicted. First, an X-**10** automation device generates X-**10** data, in step **370**, that represents the status of the X-**10** device. In step **380**, the modem receives the X-**10** data through a connection or communication channel linking the X-**10** device and the modem. The modem then interprets received X-**10** data in step **390**. Finally, in step **400**, the modem stores the interpreted X-**10** data. The stored data in step **400** corresponds to the requested NVRAM information sent to a user in step **350** of FIG. **5**.

Referring now to FIG. **7**, a flow chart presenting the steps followed by a preferred embodiment of the present invention in response to an alarm signal generated by the X-**10** automation equipment is presented. In FIG. **7**, step **410** corresponds to the generation of data by an X-**10** alarm device and sent to TW**523** computer interface module, like the one identified as reference **60** in FIG. **2**. The X-**10** alarm device may be a burglar alarm, smoke detector, and the like. In step **420**, computer interface module TW523 sends the received X-**10** data to the modem. Next, the modem interprets the received X-**10** data in step **430**. Having interpreted the X-**10** data, in step **440** the modem updates NVRAM so that the status of the automation equipment may be monitored. Additionally, in step **450** the modem sends information regarding the alarms to the host through a host interface like host interface **164** of FIG. **3**. As discussed earlier the host is capable of operating in a sleep mode. Therefore step **450** may also include waking the host. In step **460**, the host recognizes the received information as an alarm event and instructs the modem to call an emergency service provider and/or the home or business owner. Finally, in step **470**, the modem transmits relevant information regarding the alarm. For example, the modem may transmit address information, the alarm type, phone number of the alarm location, etc.

The invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed and desired to be secured by United States Letters Patent is:

1. A method for monitoring automation equipment through a modem attached to a host wherein the automation equipment includes at least one device, the method comprising the steps of:

establishing a connection between the automation equipment and the modem; and

the modem performing the steps of:

receiving at least one data item from the at least one automation equipment device;

interpreting the received data item; and

storing the interpretation of the received data item.

2. A method as recited in claim **1** wherein the modem stores the interpretation of the received data item in memory associated with the modem.

3. A method as recited in claim **1** wherein the host operates in a mode of reduced processing and power requirements while providing power to the modem.

4. A method as recited in claim **1** wherein the modem further performs the step of receiving from the host a request for information regarding the at least one automation equipment device.

5. A method as recited in claim **4** wherein the modem further performs the step of querying the at least one automation equipment device to fulfill the host's request for information.

6. A method as recited in claim **4** wherein the modem further performs the step of reading the stored interpretation to fulfill the host's request for information.

7. A method as recited in claim **1** wherein the modem performs the step of communicating, to a monitoring component, the interpretation of the received data item.

8. A method as recited in claim **1** further comprising the step of accessing the modem by a remote user.

9. A method as recited in claim **8** wherein the modem performs the step of receiving, from the remote user, a request for information regarding the at least one automation equipment device.

10. A method as recited in claim **8** wherein the modem performs the step of querying the at least one automation equipment device to fulfill the remote user's request for information.

11. A method as recited in claim **8** wherein the modem performs the step of reading the stored interpretation to fulfill the remote user's request for information.

12. A method as recited in claim **1** wherein the modem further performs the step of automatically sensing when it is connected to the at least one home automation equipment device.

13. A method for controlling automation equipment through a modem attached to a host wherein the automation equipment includes at least one device, the method comprising the steps of:

establishing a connection between the automation equipment and the modem; and

the modem performing the steps of:

receiving at least one command to be directed to the at least one automation equipment device;

translating the received at least one command; and

transmitting the translated command to the at least one automation equipment device.

14. A method as recited in claim **13** wherein the host provides power to the modem while the host operates in a mode of reduced power consumption and processing.

15. A method as recited in claim **13** wherein the modem further performs the step of automatically sensing when it is connected to the automation equipment.

16. A method as recited in claim **13** wherein the modem receives the at least one command to be directed to the at least one automation equipment device from the host.

17. A method as recited in claim **13** further comprising the step of accessing the modem by a remote user, wherein the modem receives the at least one command to be directed to the at least one automation equipment device from the remote user.

18. A method for monitoring and controlling home automation equipment through a modem attached to a host wherein the home automation equipment includes at least one device, the method comprising the steps of:

establishing a connection between the home automation equipment and the modem; and

the modem performing the steps of:

receiving at least one command to be directed to the at least one home automation equipment device;

translating the received at least one command;

transmitting the translated command to the at least one home automation equipment device;

receiving at least one data item from the at least one home automation equipment device;

interpreting the received data item; and

storing the interpretation of the received data item.

19. A method as recited in claim **18** wherein the modem stores the interpretation of the received data item in memory associated with the modem.

20. A method as recited in claim **19** wherein the modem performs the step of communicating, to a monitoring component, the interpretation of the received data item.

21. A method as recited in claim **20** wherein the modem receives the at least one command to be directed to the at least one automation equipment device from a monitoring component.

22. A method as recited in claim **20** wherein the modem receives the at least one command to be directed to the at least one automation equipment device from a remote user.

23. A method as recited in claim **22** wherein the host, while operating in a mode of reduced power consumption and processing, provides power to the modem.

24. A system for monitoring automation equipment wherein the automation equipment includes at least one device, the system comprising:

a host;

a modem connected to the host, the modem further comprising:

means for receiving at least one data item from the at least one automation equipment device;

means for interpreting the received data item; and

means for storing the interpretation of the received data item; and

means for establishing a connection between the automation equipment and the modem.

25. A system as recited in claim **24** wherein the means for storing the interpretation of the received data item is memory associated with the modem.

26. A system as recited in claim **24** wherein the host further comprises:

means for operating in a reduced power consumption mode; and

means for delivering power to the modem while operating in the reduced power consumption mode.

27. A system as recited in claim **24** wherein the modem further comprises means for querying the at least one automation equipment device in response to a request for information regarding the at least one automation device.

28. A system as recited in claim **24** wherein the modem further comprises means for reading the stored interpretation of the received data item.

29. A system as recited in claim **24** wherein the modem further comprises means for receiving a request for information regarding the at least one automation equipment device.

30. A system as recited in claim **24** wherein the modem further comprises means for allowing access to the modem by a remote user.

31. A system as recited in claim **24** wherein the modem further comprises means for communicating the stored interpretation of the received data to a monitoring component.

32. A system as recited in claim **24** wherein the modem further comprises means for automatically sensing when it is connected to the home automation equipment.

33. A system for controlling automation equipment wherein the automation equipment includes at least one device, the system comprising:

a host;

a modem connected to the host, the modem further comprising:

means for receiving at least one command to be directed to the at least one automation equipment device;

means for translating the received at least one command; and

means for transmitting the translated command to the at least one automation equipment device; and

means for establishing a connection between the automation equipment and the modem.

34. A system as recited in claim **33** wherein the host further comprises:

means for operating in a reduced power consumption mode; and

means for delivering power to the modem while operating in the reduced power consumption mode.

35. A system as recited in claim **33** wherein the means for receiving the at least one command to be directed to the at least one automation equipment device comprises means for receiving the command from the host.

36. A system as recited in claim **33**, the modem further comprising means for access by a remote user, wherein the modem receives the at least one command to be directed to the at least one automation equipment device from the remote user.

37. A computer program product for implementing a method for monitoring automation equipment via modem wherein the automation equipment includes at least one device, the computer program product comprising:

a computer-readable medium carrying computer-executable instructions for implementing the method wherein the computer-executable instructions comprise:

program code means for receiving at least one data item from the at least one automation equipment device;

program code means for interpreting the received data item; and

program code means for storing the interpretation of the received data item; and

program code means for establishing a connection between the automation equipment and the modem.

38. A computer program product as recited in claim **37** wherein the computer-executable instructions further comprise program code means for allowing access to the modem by a remote user.

39. A computer program product as recited in claim **37** wherein the computer-executable instructions further comprise program code means for communicating the stored interpretation of the received data item to a monitoring component.

40. A computer program product as recited in claim **37** wherein the computer-executable instructions further comprise program code means for automatically sensing when the modem is connected to the home automation equipment.

41. A computer program product for implementing a method for controlling automation equipment via modem

wherein the automation equipment includes at least one device, the computer program product comprising:

a computer-readable medium carrying computer-executable instructions for implementing the method wherein the computer-executable instructions comprise:

program code means for receiving at least one command to be directed to the at least one automation equipment device;

program code means for translating the received at least one command;

program code means for transmitting the translated command to the at least one automation equipment device; and

program code means for establishing a connection between the automation equipment and the modem.

42. A computer program product as recited in claim **41** wherein the computer-executable instructions further comprise program code means for receiving the at least one command to be directed to the at least one automation equipment device from the host.

43. A computer program product as recited in claim **41** wherein the computer-executable instructions further comprise program code means for allowing access by and receiving the at least one command from a remote user.

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(54) **SMART REMOTE MONITORING SYSTEM AND METHOD**

(75) Inventors: **Robert N. Johnson**, Silver Spring, MD (US); **Ronald D. Smith**, Columbia, MD (US); **Charlotte K. Smith**, Columbia, MD (US); **Edward C. Kight**, Baltimore, MD (US); **George H. Harrop**, Washington, DC (US)

(73) Assignee: **Telemonitor, Inc.**, Columbia, MD (US)

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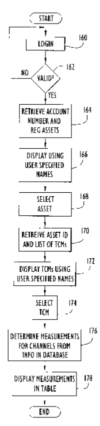
Primary Examiner—Marc S. Hoff
Assistant Examiner—Carol S Tsai

(57) **ABSTRACT**

A remote monitoring system includes transducers, a transducer control module, a communications device, a monitoring system and end-user display terminals. The transducers are disposed on the property and/or equipment in a manner to measure specific characteristics or parameters and communicate with the transducer control module via a wireless communication protocol. The transducer control module receives and analyzes transducer measurements and detects alarm conditions. The transducer control module communicates with the monitoring system via a wide area network and the communications device. The monitoring system receives, stores and analyzes information received from the transducer control module and reports the information to the end-user terminals via a wide area network, such as the Internet, in response to user requests.

99 Claims, 9 Drawing Sheets



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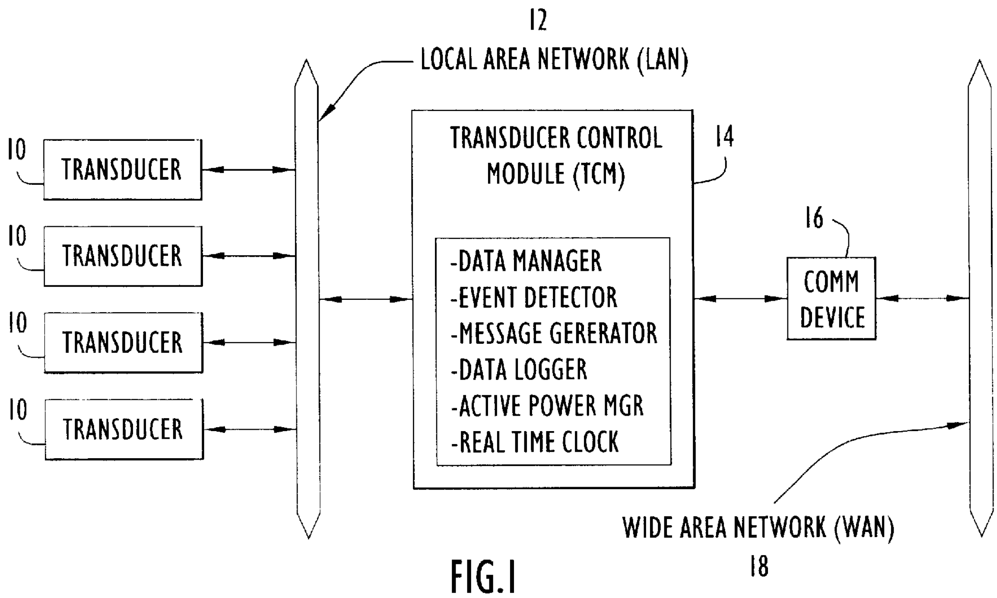

12
LOCAL AREA NETWORK (LAN)
10
TRANSDUCER
10
TRANSDUCER
10
TRANSDUCER
10
TRANSDUCER
TRANSDUCER CONTROL MODULE (TCM)
14
-DATA MANAGER
-EVENT DETECTOR
-MESSAGE GERERATOR
-DATA LOGGER
-ACTIVE POWER MGR
-REAL TIME CLOCK
16
COMM DEVICE
WIDE AREA NETWORK (WAN)
18

FIG.1

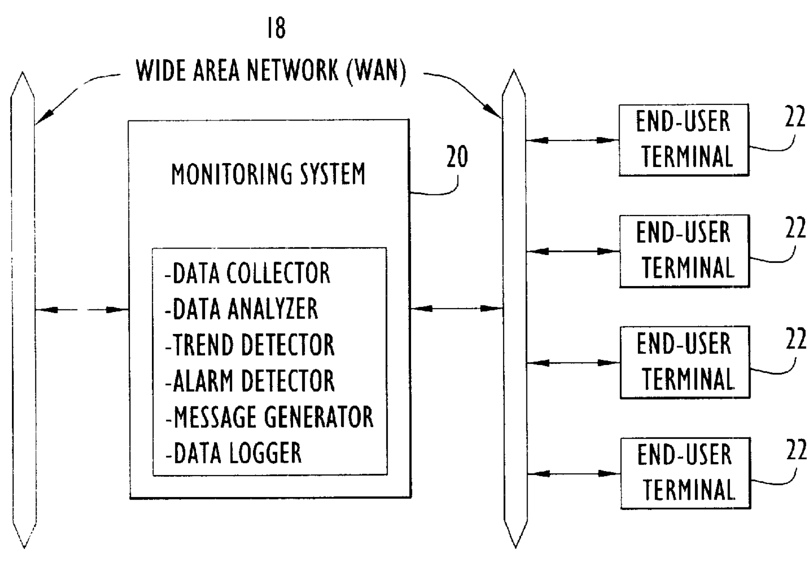
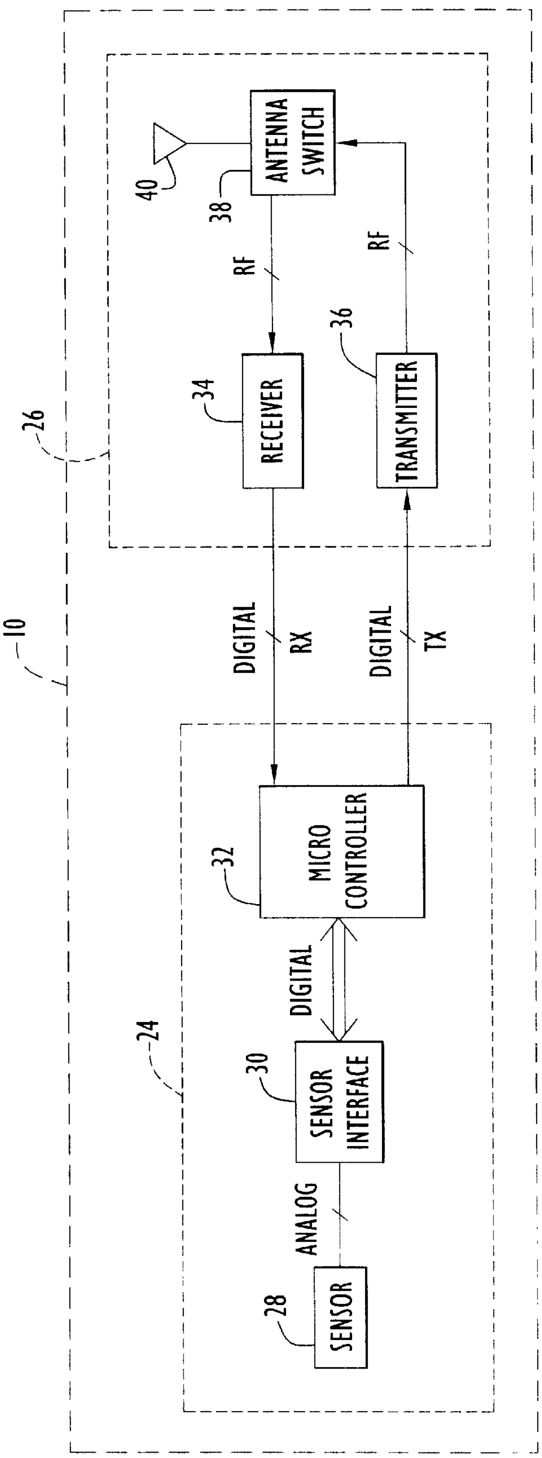

18
WIDE AREA NETWORK (WAN)
MONITORING SYSTEM
20
-DATA COLLECTOR
-DATA ANALYZER
-TREND DETECTOR
-ALARM DETECTOR
-MESSAGE GENERATOR
-DATA LOGGER
END-USER TERMINAL
22
END-USER TERMINAL
22
END-USER TERMINAL
22
END-USER TERMINAL
22

FIG.2



ANTENNA SWITCH
40
38
RF
RF
RECEIVER
34
TRANSMITTER
36
26
DIGITAL RX
DIGITAL TX
10
MICRO CONTROLLER
32
DIGITAL
SENSOR INTERFACE
30
24
ANALOG
SENSOR
28

FIG.3

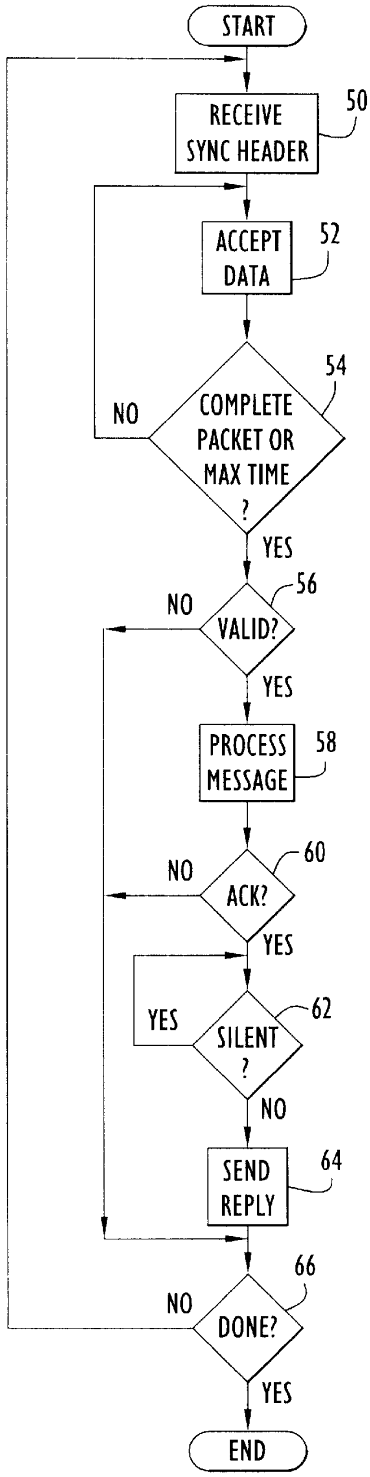

START
RECEIVE SYNC HEADER
50
ACCEPT DATA
52
COMPLETE PACKET OR MAX TIME ?
54
NO
YES
VALID?
56
NO
YES
PROCESS MESSAGE
58
ACK?
60
NO
YES
SILENT ?
62
YES
NO
SEND REPLY
64
DONE?
66
NO
YES
END

FIG.4

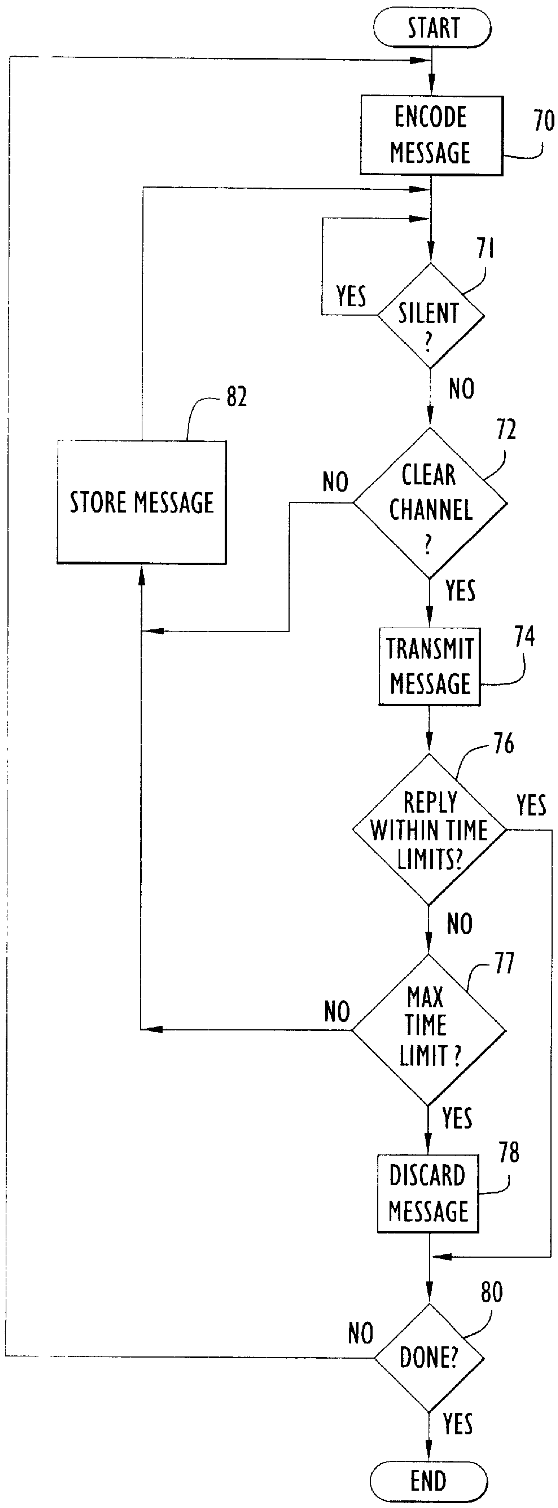

START
ENCODE MESSAGE
70
71
YES
SILENT ?
NO
82
STORE MESSAGE
72
NO
CLEAR CHANNEL ?
YES
TRANSMIT MESSAGE
74
76
REPLY WITHIN TIME LIMITS?
YES
NO
77
NO
MAX TIME LIMIT ?
YES
DISCARD MESSAGE
78
80
NO
DONE?
YES
END

FIG.5

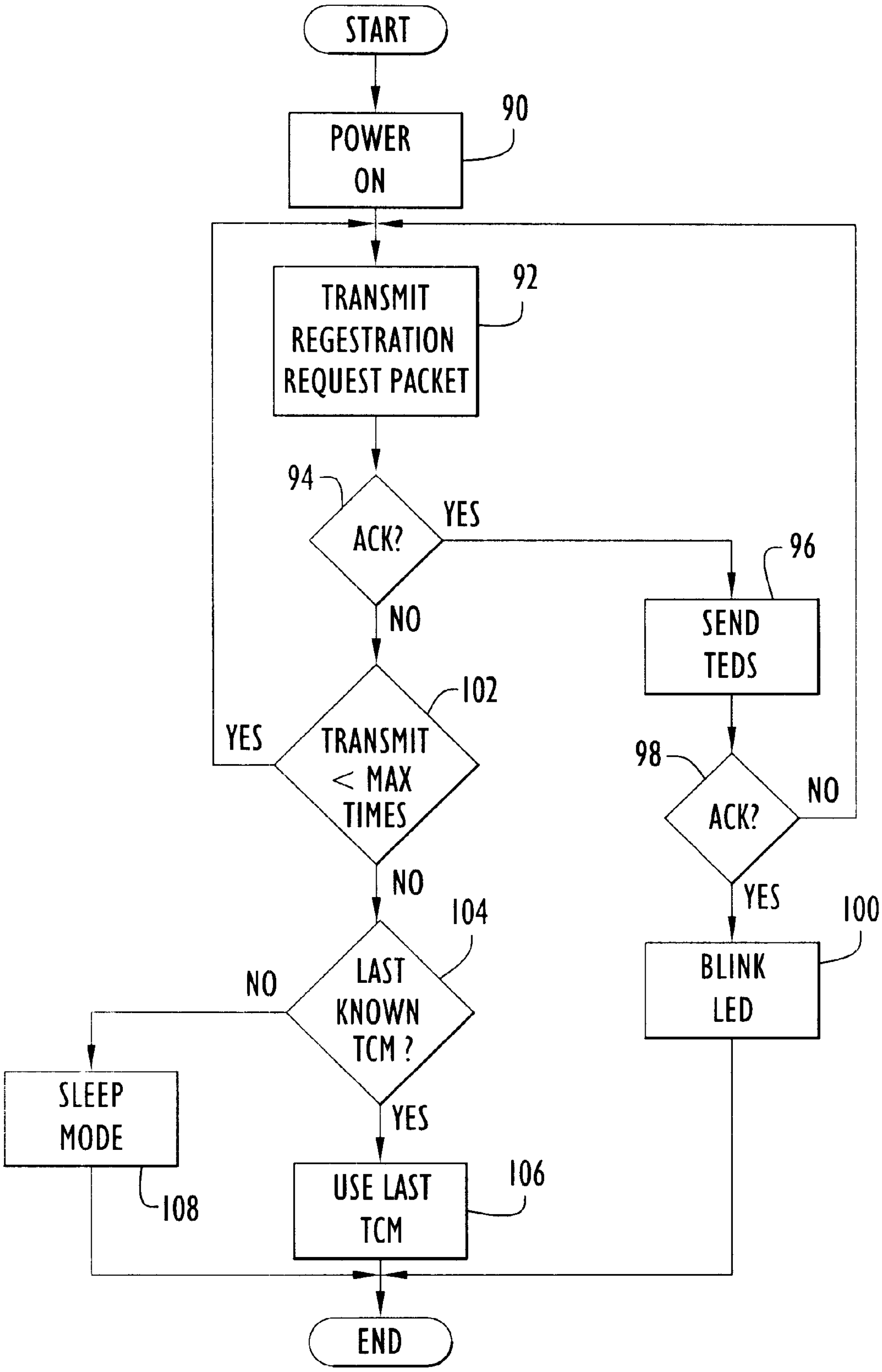

START
POWER ON
90
TRANSMIT REGESTRATION REQUEST PACKET
92
94
ACK?
YES
NO
SEND TEDS
96
TRANSMIT < MAX TIMES
102
YES
NO
98
ACK?
NO
YES
LAST KNOWN TCM ?
104
NO
YES
BLINK LED
100
SLEEP MODE
108
USE LAST TCM
106
END

FIG.6

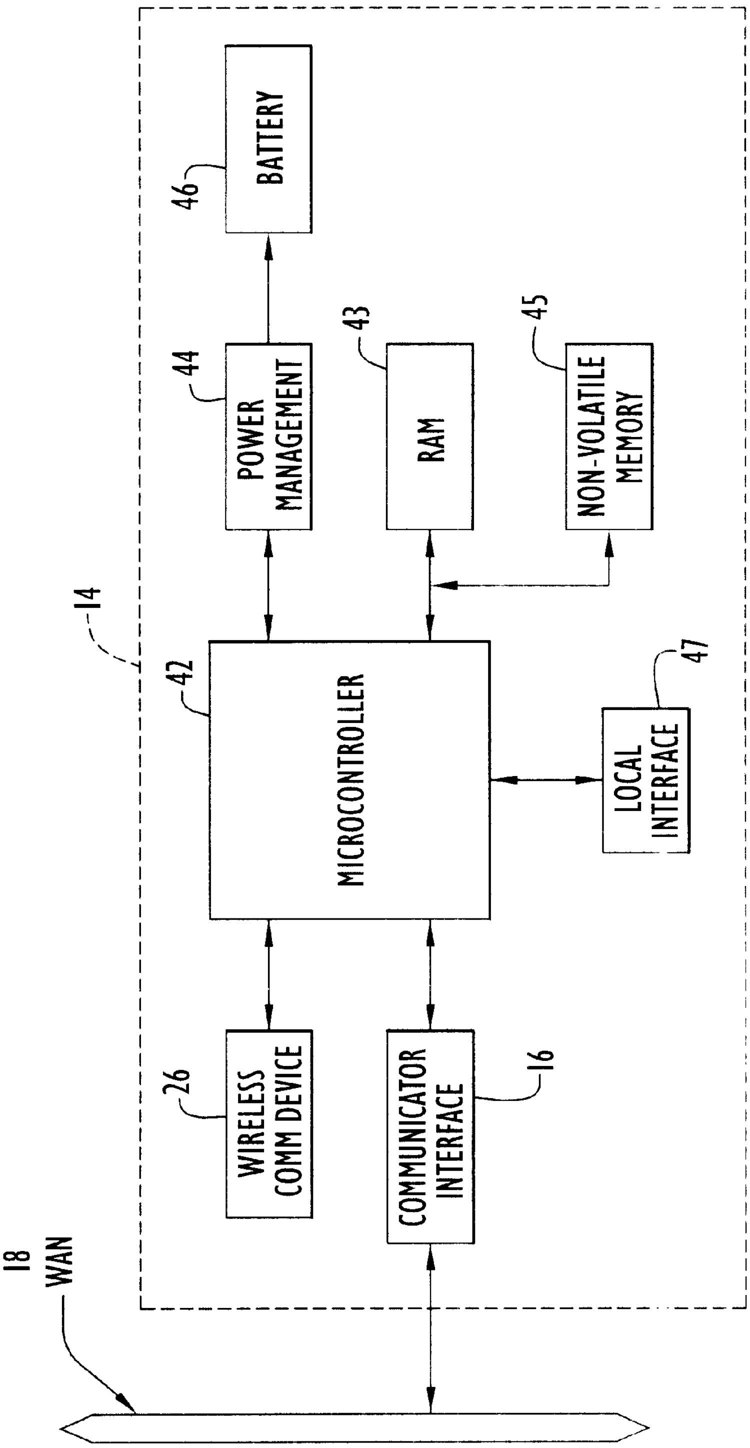

BATTERY
46
POWER MANAGEMENT
44
RAM
43
NON-VOLATILE MEMORY
45
14
MICROCONTROLLER
42
LOCAL INTERFACE
47
WIRELESS COMM DEVICE
26
COMMUNICATOR INTERFACE
16
18
WAN

FIG.7

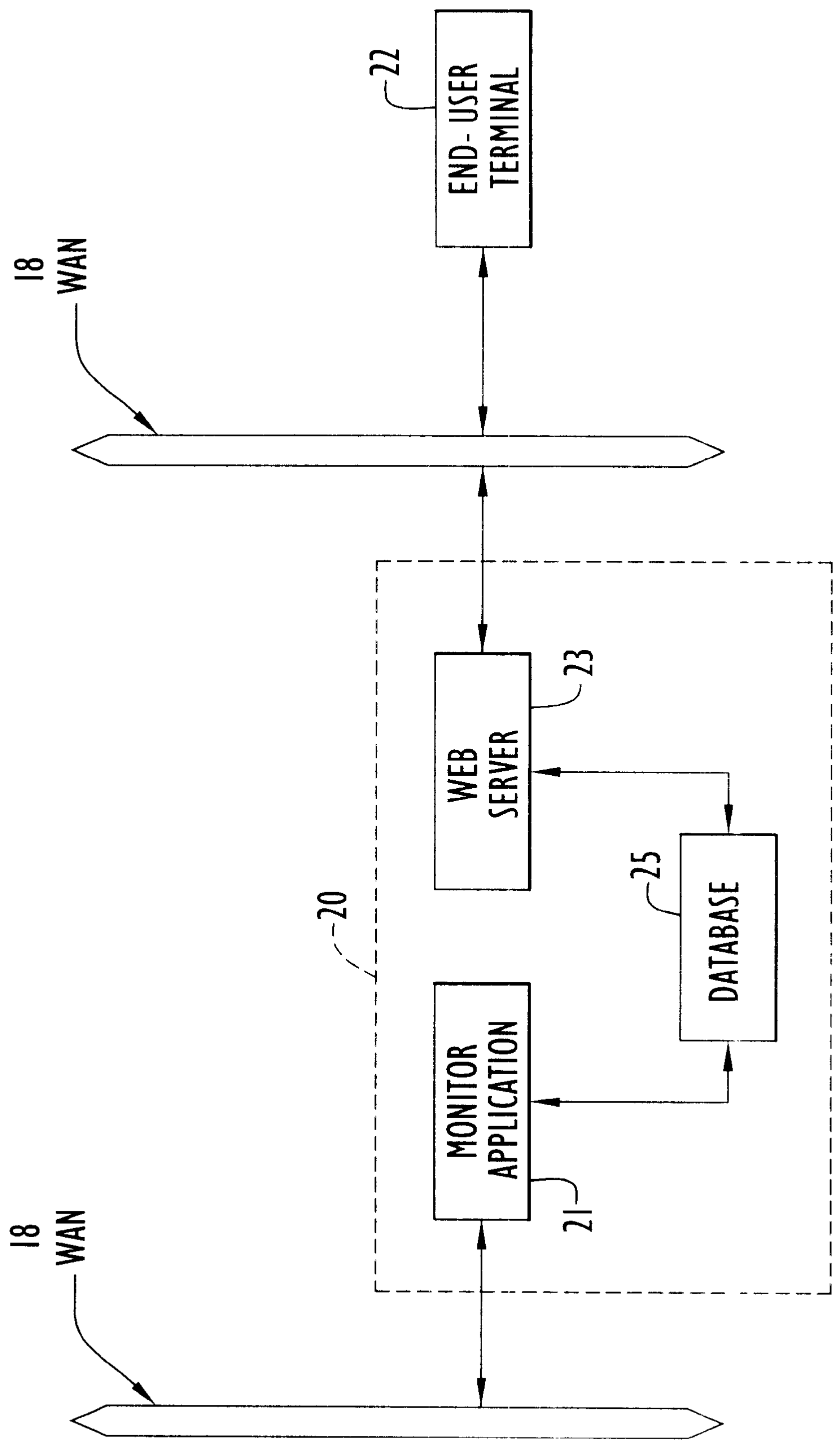

22
END-USER TERMINAL
18
WAN
23
WEB SERVER
20
25
DATABASE
MONITOR APPLICATION
21
18
WAN

FIG.8

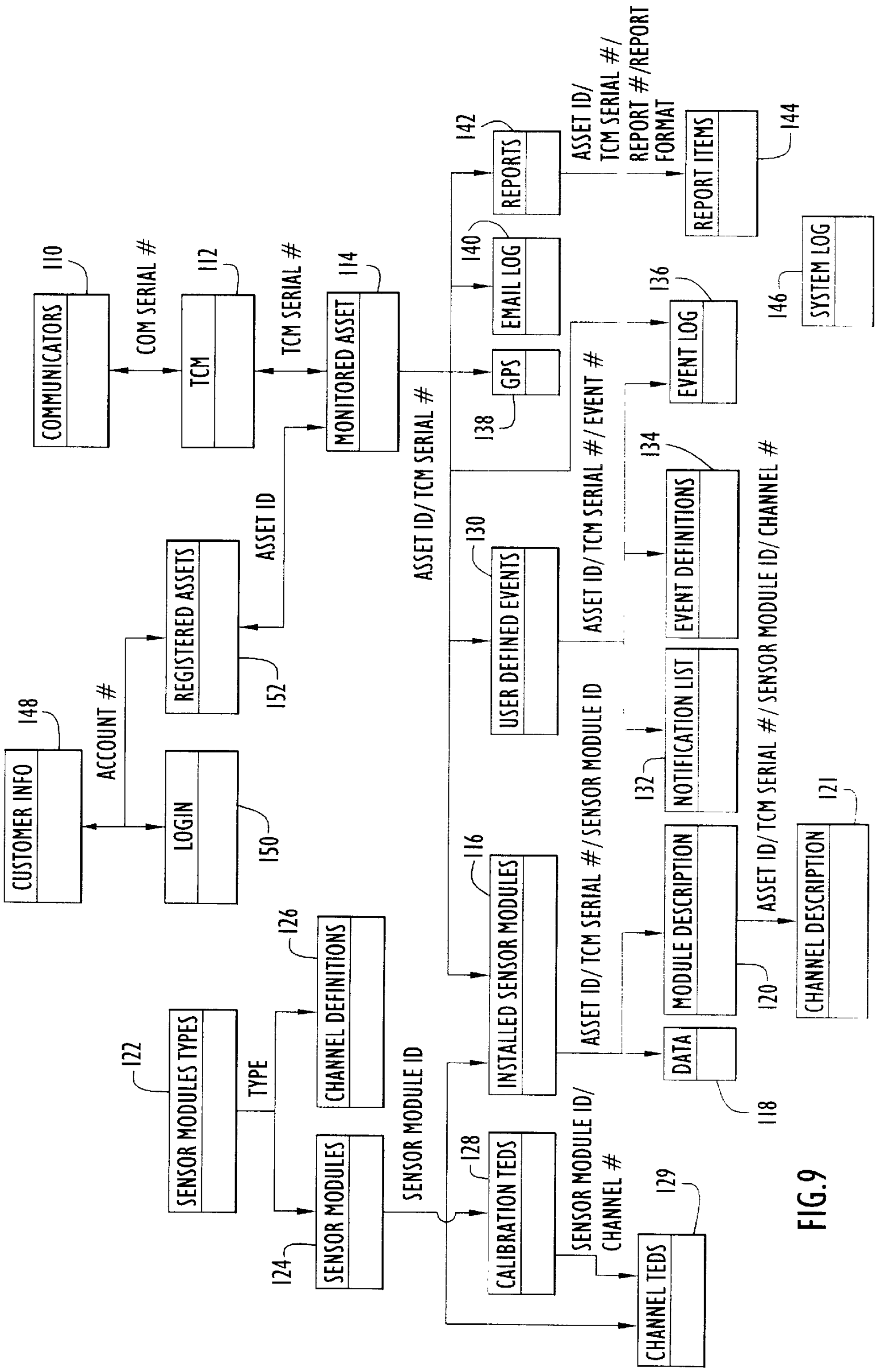

COMMUNICATORS
110
COM SERIAL #
TCM
112
TCM SERIAL #
MONITORED ASSET
114
ASSET ID
REGISTERED ASSETS
152
CUSTOMER INFO
148
ACCOUNT #
LOGIN
150
ASSET ID/TCM SERIAL #
GPS
138
EMAIL LOG
140
REPORTS
142
ASSET ID/
TCM SERIAL #/
REPORT #/REPORT
FORMAT
REPORT ITEMS
144
SYSTEM LOG
146
EVENT LOG
136
ASSET ID/TCM SERIAL #/ EVENT #
EVENT DEFINITIONS
134
USER DEFINED EVENTS
130
ASSET ID/TCM SERIAL #/SENSOR MODULE ID
NOTIFICATION LIST
132
INSTALLED SENSOR MODULES
116
MODULE DESCRIPTION
120
ASSET ID/TCM SERIAL #/SENSOR MODULE ID/CHANNEL #
CHANNEL DESCRIPTION
121
DATA
118
SENSOR MODULES TYPES
122
TYPE
CHANNEL DEFINITIONS
126
SENSOR MODULES
124
SENSOR MODULE ID
CALIBRATION TEDS
128
SENSOR MODULE ID/
CHANNEL #
CHANNEL TEDS
129

FIG.9

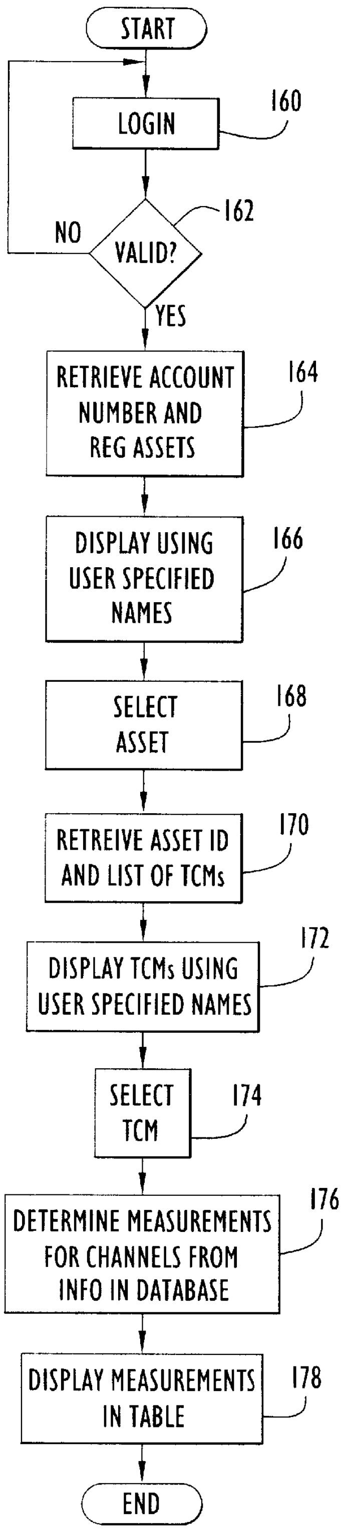

START
LOGIN
160
VALID?
162
NO
YES
RETRIEVE ACCOUNT NUMBER AND REG ASSETS
164
DISPLAY USING USER SPECIFIED NAMES
166
SELECT ASSET
168
RETREIVE ASSET ID AND LIST OF TCMs
170
DISPLAY TCMs USING USER SPECIFIED NAMES
172
SELECT TCM
174
DETERMINE MEASUREMENTS FOR CHANNELS FROM INFO IN DATABASE
176
DISPLAY MEASUREMENTS IN TABLE
178
END

FIG.10

SMART REMOTE MONITORING SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Patent Application Serial No. 60/140,793, entitled "Smart Remote Monitoring System and Method" and filed Jun. 25, 1999. The disclosure of that provisional application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to a system and method used for the remote monitoring and control of property and equipment. The primary application is for absentee owners of yachts and vacation homes, however, the present invention also can be used for commercial and industrial monitoring and control.

2. Discussion of Related Art

Property and equipment are generally valuable assets of an owner. The value of these items to the owner or authorized user may be derived from the monetary worth and/or the utility provided to the owner or authorized user, such as in the cases of a home, boat or automobile. As such, it is imperative that the condition of these items be maintained to provide the upmost worth and utility. In order to maintain the items in a proper condition, the items should be monitored by the owner or authorized user to ensure the presence of acceptable item conditions and to identify situations that may lead to item damage. Monitoring of an item is a tedious task and typically requires the owner or authorized user to be in the vicinity of the item. However, various property, such as vacation homes and vehicles, are usually remote from the owner or authorized user, thereby enabling monitoring at infrequent intervals. Thus, improper item conditions may arise without notice to an owner or authorized user, thereby tending to cause damage to the item. The related art attempts to overcome the above problem by providing various remote monitoring systems. For example, U.S. Pat. No. 4,831,558 (Shoup et al) discloses a system for monitoring physical phenomena and changes in structures. The system includes a plurality of programmable intelligent transducers arranged in an array with each being uniquely addressable by a remote controller to perform its functions (i.e., measure, translate analog measurement into digital signals and transmit the digital signals to the controller). The monitoring is selective to each individual intelligent transducer. The intelligent transducers combine measurement, microprocessor and communication functions that are programmed and actuated from the controller.

U.S. Pat. No. 5,790,977 (Ezekiel) discloses a system providing remote access from a remote host system to an instrument. Control and data acquisition software is stored in the instrument and forwarded to the host system. The software is executed on the host system and provides commands to control data acquisition of the instrument. In response to a request from the executed software, acquired data is forwarded from the instrument to the host.

U.S. Pat. No. 5,854,994 (Canada et al) discloses an apparatus including one or more machine monitors which attach to one or more machines to sense a physical machine characteristic, such as vibration or temperature, and produce wireless transmissions corresponding to the sensed characteristic, and a command station for receiving transmissions from the machine monitors and processing the information to provide an indication of a machine condition. A repeater receives the sensor data transmissions from the machine monitors and retransmits the data to the command station A when, due to site conditions, the machine monitors are beyond the receiving range of, or out of the line of sight to, the command station.

U.S. Pat. No. 5,917,405 (Joao) discloses a control apparatus for a vehicle including a first, second and third control devices. The first control device generates and transmits a first signal for one of activating, deactivating, enabling and disabling one of a vehicle component, device system and subsystem. The first control device is located at the vehicle and is responsive to a second signal generated by and transmitted from the second control device. The second control device is located remote from the vehicle and is responsive to a third signal generated by and transmitted from the third control device. The third control device is remote from the vehicle and second control device.

The related art suffers from several disadvantages. In particular, the above-described systems generally require special programming of system monitor devices or sensors prior to system operation. This increases complexity of installation and further complicates incorporation of additional sensors into the system. Further, this specific programming is typically accomplished by personnel familiar with the system, thereby requiring special personnel to install the system and subsequent sensor additions. Moreover, the above-described systems generally detect alarm conditions based on measurements of specific individual sensors. This limits the conditions that may trigger an alarm and may possibly lead to reporting of false alarms or missing an actual alarm condition when such conditions are indicated by a combination of sensor measurements. In addition, the above-described systems are typically not available in a kit form for installation by a consumer.

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to remotely monitor and control various property and/or equipment.

It is another object of the present invention to enable users to remotely monitor and control property or equipment via a network, such as the Internet.

Yet another object of the present invention is to remotely monitor property and/or equipment and detect user specified alarm conditions based on measurements of a combination of sensors.

Still another object of the present invention is to provide remote monitoring kits including sensor modules and a controller for installation by a user to monitor user property and/or equipment.

A further object of the present invention is to utilize a wireless on/off keyed protocol for communication between sensors and a sensor control module to facilitate remote monitoring of property and/or equipment.

The aforesaid objects are achieved individually and/or in combination, and it is not intended that the present invention be construed as requiring two or more of the objects to be combined unless expressly required by the claims attached hereto.

According to the present invention, a remote monitoring system includes transducers, a transducer control module, a communications device, a monitoring system and end-user display terminals. The transducers are disposed on the property and/or equipment in a manner to measure specific characteristics or parameters and communicate with the transducer control module via a wireless communication protocol. The transducer control module receives and analyzes transducer measurements and detects alarm conditions. The transducer control module communicates with the monitoring system via a wide area network and the communications device. The monitoring system receives, stores and analyzes information received from the transducer control module and reports the information to the end-user terminals via a wide area network, such as the Internet, in response to user requests.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of specific embodiments thereof, particularly when taken in conjunction with the accompanying drawings wherein like reference numerals in the various figures are utilized to designate like components.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram of an initial portion of the remote monitoring system of the present invention disposed in the proximity of the monitored property or equipment.

FIG. **2** is a schematic block diagram of the remaining portion of the remote monitoring system of the present invention for analyzing measured information and processing end-user requests.

FIG. **3** is a schematic block diagram of a smart transducer of the system of FIG. **1** employing a wireless communication device.

FIG. **4** is a procedural flowchart illustrating the manner in which messages are received in accordance with a wireless protocol according to the present invention.

FIG. **5** is a procedural flowchart illustrating the manner in which messages are transmitted in accordance with the wireless protocol according to the present invention.

FIG. **6** is a procedural flowchart illustrating the manner in which a transducer is registered with a transducer control module according to the present invention.

FIG. **7** is a schematic block diagram of the transmitter control module of FIG. **1** according to the present invention.

FIG. **8** is a block diagram of the monitoring system of FIG. **2** according to the present invention.

FIG. **9** is a diagrammatic illustration of the association of data tables within the database of FIG. **8**.

FIG. **10** is a procedural flowchart illustrating the manner in which the monitoring system processes user requests according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A smart remote monitoring system according to the present invention is illustrated in FIGS. **1–2**. Specifically, the system includes one or more smart, self-identifying, "plug-and-play" transducers or sensor modules **10**, a wired or wireless local area network (LAN) **12** for connecting to the transducers, a transducer control module **14** which connects to the transducers via LAN **12**, a communications device **16** which connects the transducer control module through a wide area network (WAN) **18** to a monitoring system or station **20** and end-user display terminals **22** which connect to the monitoring system through the same or a different wide area network. The system can be used to provide real-time on-demand status information to end-users, as well as alarm notifications to the end-user and other appropriate entities if certain pre-defined conditions and/or events are detected. These alarm notifications can take the form of telephone, telegraph, facsimile, pager, electronic mail, or other type of communications. End-user terminals **22** are used for obtaining real-time on-demand status information, for entering real-time control instructions, and for programming the monitoring system characteristics, such as setting the alarm notification conditions, communications media, message destinations (e.g., telephone number or e-mail addresses), and message content.

Transducers **10** can be sensors and/or actuators. Transducer actuators may be utilized to control the state of an object, for example, controlling power to a device remotely via terminal **22**. In a preferred embodiment, plural transducers are used and connected by wireless local are network (LAN) **12**. The transducers are preferably "smart" transducers using technology such as that represented by the IEEEE 1451.2 standard, the contents of which are incorporated herein by reference. Generally, a smart transducer is a transducer having intelligence and processing raw sensor data to provide a useful end result. Referring to FIG. **3**, each smart transducer **10** preferably includes a sensing device **24** and a wireless communications device **26**. Device **24** includes an actual sensing or actuation element **28**, a microcontroller **32** providing signal conditioning, a digital communications interface (software and protocol) compatible with the wireless LAN and a Transducer Electronic Data Sheet (TEDS), and a sensor interface **30** disposed between the sensing element and microcontroller for converting analog signals from the sensing element to digital signals compatible with the microcontroller. The sensing element is typically a conventional transducer for measuring a particular parameter and provides analog signals indicating the measured parameter to the interface for conversion to digital signals compatible with the microcontroller. The microcontroller is preferably a PIC processor manufactured by Microchip, but may be any conventional processor. Transducers **10** are wireless for quick and easy installation by a user. Each transducer **10** is typically powered by a battery, preferably a standard nine volt battery, and has an expected operating life of approximately one-year. The transducers communicate with a corresponding transducer control module that receives transducer measurement information and performs various functions in accordance with the realized information as discussed below.

Simple analog transducers (both sensors and actuators) can be used as is or converted to smart transducers for use with the smart remote monitoring system. Transducers **10** typically include technology such as that described in U.S. Pat. No. 6,032,109 and U.S. patent application Ser. No. 09/167,465, filed on Oct. 7, 1998, the disclosures of which are incorporated herein by reference in their entireties.

Each transducer is designed to be "self-identifying" and preferably has a unique identifier (UID) for use in registering that transducer with the monitoring system. The UID is generally factory programmed and is used to distinguish each smart transducer. By way of example only, a maximum of sixteen transducers **10** may be in communication with a transducer control module. Since the transducers are "self-identifying", a transducer may be added to the system at any time via a registration process discussed below. Further, the system may include any quantity of any type of sensor (e.g., two bilge pump sensors and three high water sensors for use in a boating application).

The transducer "self-identification" is preferably accomplished using a modified version of the IEEE 1451.2 Transducer Electronic Datasheet, although some items can be omitted or added as needed for specific monitoring applications. Each transducer **10** includes an electronic datasheet that describes transducer characteristics. The datasheet preferably includes transducer information in the form of a serial number or UID, quantity of control outputs and a description of transducer function. An exemplary TEDS is illustrated in Table I below. Additional information relating to calibration of channel data is stored in the monitoring system database as described below.

the transducer returns to the sleep state and saves the message for later transmission.

The transducer control module is primarily in an awake state and can receive messages from the transducers at virtually any time. However, since the transducer is primarily in the sleep state, the transducer control module may only send messages to the transducer during the time interval where the transducer is awaiting an acknowledge message. The transducer control module buffers control and actuator channel messages (e.g., actuators are used to control objects, such as an output or switch) until the intended transducer initiates communications. The transducer further

TABLE I

Transducer TEDS

Field Name	Field Type	Description
Length	Unsigned 8-bit	Length of TEDS block.
TEDS Version	Unsigned 8-bit	TEDS version code
Module Function	Unsigned 8-bit	Sensor module function. 1 = For TCM use only 2 = Object 1 3 = Object 2 4 = Object 3 5–255 = Currently undefined
Module Serial Number	Unsigned 32-bit	Serial number of the module.
Channel Type	Unsigned 8-bit	Type of channel. 0 = Sensor (input) 1 = Actuator (output) 2–255 = Currently undefined
Lower Channel Limit	Float 32-bit	Minimum physical value of channel
Upper Channel Limit	Float 32-bit	Maximum physical value of channel Repeat outlined section for each channel.
Checksum	Unsigned 8-bit	Checksum computed on all previous fields.

This information is utilized by the transducer control module to distinguish between plural transducers that may have the same function, and to permit additional transducers to be installed by the user at any time (e.g., without having to configure the transducer or transducer control module). An install button is disposed on the transducer control module housing to ensure that a single transducer control module responds to transducer actuation or installation as described below. In addition, the TEDS information indicates to other systems the manner in which to interpret transducer data to obtain parameter measurements.

Transducers **10** each basically include a low-power sleep state, an active state and an install state. The primary state is the sleep state, where the transducer preferably remains a majority of the time to maximize battery life. The transducer automatically enters the active state from the sleep state periodically (e.g., approximately every fifteen seconds) to sample sensing element input, to determine the presence of a state change for the monitored asset or object and to track the passage of time. The transducer inputs and outputs are organized as channels, where each monitored input is a sensor channel, and each output is an actuator channel. A state change occurs when an input for the monitored object changes between off and on conditions. When a state change is detected on any of the monitored channels, the transducer sends a channel update message or report to the transducer control module as described below. The transducer transmitter is not activated unless a message is to be transmitted in order to conserve battery power. After sending this message, the transducer waits for an acknowledge message from the transducer control module. The transducer may update an output channel or transmit additional information to the transducer control module in accordance with the acknowledge message type received. When an acknowledge message is not received within an appropriate time interval,

periodically transmits a status message to the transducer control module to indicate the state of its internal system (e.g., approximately every fifteen minutes to conserve power, but this may be adjusted by the transducer control module). This status message interval may be used to assign transmit time slots to transducers (e.g., which are typically asynchronous), and further sets the minimum update rate for actuator channels. During the status message update, the transducer control module may transmit control information to the sensor in an acknowledge message.

The install state is basically a separate mode that is entered when a transducer is being installed. In this state, the transducer is actively searching for a transducer control module. The transducer identifies itself to a transducer control module and provides corresponding TEDS information in order to be used in a network and be registered with that transducer control module. A transducer does not monitor input during registration, but does enter the sleep state between search requests. The various transducer states and operations are controlled by microcontroller **32**.

Transducer LAN **12** can be wired or wireless. Preferably, the LAN uses a multi-drop architecture to support the use of plural transducers in a single system. Representative wired LANs include the EDC 1451.2-NA network node and the Controller Area Network (CAN) described in ISO 11898 and ISO 11519-2. Representative wireless LANs include the digital spread-spectrum units used in wireless home security systems and cordless phones, IEEE 802.11 (wireless Ethernet), and any one of a number of available wireless networking products intended for use with office computers and related equipment. The range and extent of the transducer LAN is generally limited to the equipment or premises being monitored. For yachts or other vehicles including boats and aircraft, this range can be limited to the vehicle being monitored, or it can encompass the entire marina, port, or airport. For industrial monitoring applications, it can encompass the entire factory or site being monitored. For homes, this range can be limited to just the premises being monitored, or it can encompass the entire neighborhood, development, or resort.

In the preferred embodiment, LAN **12** is wireless, while transducers **10** and transducer control module **14** employ wireless communications device **16** and a wireless protocol to communicate. Communications device **26** includes a receiver **34**, a transmitter **36**, an antenna switch **38** and an antenna **40**. These components are typically implemented by commercially available or conventional devices. The receiver and transmitter are each connected to antenna switch **38** that provides access to antenna **40**. Receiver **34** receives transmitted RF signals (e.g., approximately 432 MHz) from antenna **40** via switch **38** and converts those signals to digital signals compatible with microcontroller **32** for processing. Transmitter **36** receives data from the microcontroller and converts the data to RF signals (e.g., approximately 432 MHz) for transference to antenna **40** via antenna switch **38** for transmission. The receive and transmit lines between the microcontroller, receiver and transmitter are preferably serial having a bandwidth of approximately 4800 bits per second with data arranged having eight data bits, one stop bit and no parity bit (i.e., 8 N 1 format).

The communications between the transducers and the transducer control module are reliable due to the monitoring nature of the system. A wireless protocol employing on/off keyed (OOK) transmissions is employed to provide reliable communication at low cost between the transducers and transducer control module. Basically, the on/off keyed approach generates a signal when the transmitter is on, and is silent when the transmitter is off.

The protocol utilizes several techniques to reliably transmit data with the on/off keyed approach. In particular, the protocol implements Manchester encoding, message error checking and redundancy and carrier signal status checks. Manchester encoding converts data from single binary digits (e.g., a one or a zero) into two binary digits (e.g., a one-zero or zero-one pair). Although this technique increases the amount of data transmitted, the electrical characteristics of the RF signal are improved while effects of outside interference are reduced. In addition, this encoding scheme resolves ambiguities by requiring transmitters to send signals for each bit. For example, if a series of logical zeros are to be transmitted, the on/off keyed approach requires the transmitter to be silent. Thus, a receiver may not be able to determine whether or not a series of logical zeros is being transmitted or no message is transmitted. Similarly, a series of logical ones produces a continuous signal in the on/off keyed scheme, and a receiver may not be able to determine the presence of a message from interference or jamming. The encoding forces an on/off transition for each bit such that a receiver may receive and analyze signals to determine the presence of a valid message.

Error checking and redundancy requires that each transmitted message have an associated reply. When a message is transmitted and no reply is received, the message is re-transmitted. Further, the transmitted message and associated reply must include a valid checksum. The checksum ensures validity of data in a message, while messages and replies having invalid checksums are discarded.

In addition, the protocol ensures that only one transducer is transmitting at a time. In particular, the transducer monitors the status of the radio or wireless link to check for a carrier signal. The presence of the carrier signal indicates that another device is transmitting. This device may be a transducer or other device transmitting in the same RF band. When a carrier signal is detected by a transducer, the message is saved and transmission is attempted at a next active transducer state.

The protocol preferably utilizes packets to transfer data. An exemplary packet format is illustrated in Table II below, and includes a synchronization field, a source address field, a destination address field, a packet identifier field, a data length field, an optional data field and a checksum field.

TABLE II

Packet Format

Field Name	Size (bytes)	Required	Description
Synchronization	2	Yes	Synchronization header.
Source address	4	Yes	Serial number of sender.
Destination address	4	Yes	Serial number of recipient.
Packet identifier	1	Yes	Type of packet.
Data length	1	Yes	Size of the data field. Zero indicates empty data field.
Data	0 to 128	No	Optional data.
Checksum	2	Yes	Fletcher checksum calculated on all packet fields except header.

In particular, the synchronization field includes a synchronization header or pattern that is primarily used to provide a startup time for the transmitter and receiver. The pattern is two bytes and preferably contains the value 'FFFF' hexadecimal. The source address field contains four bytes of data that include the serial number (e.g., thirty-two bits) of the device (e.g., transducer or transducer control module) sending the message. The destination address field contains four bytes of data that include the serial number (e.g., thirty-two bits) of the device (e.g., transducer or transducer control module) to receive the message. This field is set to zero when a transducer is in installation mode, and typically contains the serial number of the transducer control module to which the transducer is registered. However, the field may contain the serial number of another transducer for peer to peer communications. The packet identifier field contains one byte and includes a code (e.g., eight bits) that indicates the type of information contained in packet. Exemplary packet identifiers are illustrated in Table III below.

TABLE III

Packet Identifiers

Identifier Code (Hex)	Function	Data	Description
10	Sensor status or global channel report	Channel value list	The current value of each sensor channel. A list of the current value of every channel from 1 to n. Each value is the length specified in the TEDS.

TABLE III-continued

Packet Identifiers

Identifier Code (Hex)	Function	Data	Description
			Typically sent as a status message.
12	State change or single channel report	Channel number Channel value	The current value of the channel. Typically sent to indicate that a channel has changed to a new value.
14	Channel update request	Channel number	The sensor is requesting a new value for the specified channel.
20	Registration request	None	Sensor is requesting registration by a TCM. Sent when the sensor module is first powered on.
22	Send TEDS	TEDS	Sends the TEDS data for all channels to the TCM.
80	Acknowledge	None	Message received and processed.
82	Acknowledge with channel update	Channel number New value	Message received. Update the specified channel with the new value. Read only channels will not be affected.
84	Acknowledge with global update	New value list	Message received. Update each channel with the new value. Read-only channels will not be affected. Each value is the length specified by the TEDS.
86	Acknowledge with status interval update	Status interval	Message received. Update the status report interval for the sensor. The interval is set in increments of 15 seconds. (1 = 15 sec, 2 = 30 sec, 10 = 150 sec etc.)
88	Acknowledge with TEDS update	TEDS	Message received. Update the TEDS information for the sensor.

The data length field contains one byte and includes the size in bytes of the optional data field. This field is set to zero if data is not included in the message. The maximum message length is one-hundred forty-two bytes. Transducers are not required to accommodate the maximum message size, and ignore messages having data length values that they do not support. The transducer control module supports messages of the maximum size. The optional data field contains a maximum of one-hundred twenty-eight bytes of data, or the amount permitted for the intended transducer. The checksum field contains two bytes including a checksum for the packet. The checksum is preferably a sixteen bit checksum that is determined by applying a conventional Fletcher checksum algorithm on packet data bytes except for the synchronization pattern.

FCC requirements indicate that the maximum transmission time for each communications device be approximately one second, where each device is silent for an interval approximately thirty times the transmission period or ten seconds, whichever is greater. This limits the amount of data that can be transferred, while other requirements limit the apparent transmitter power (e.g., power over time). The present invention protocol is designed to satisfy these requirements.

Packet data is transmitted with the least significant bits (LSB) first at a rate of approximately 4800 bits per second. The data format includes eight data bits, one stop bit and no parity bit (e.g., 8 N 1). The data is transmitted employing an on/off keyed (OOK) scheme as described above where the transmitter is on to represent a logic one and off to represent a logic zero. This scheme may provide ambiguities with respect to a series of logical ones or zeros as described above, and may increase apparent transmitter power for long intervals of continuous transmission.

The protocol employs pseudo-Manchester encoding to overcome these problems. In particular, Manchester encoding is typically used to encode the clock and data of a synchronous serial stream into a single bit of information, resulting in a logic level transition for each transmitted bit. Since the system is using asynchronous serial data, the transducer and transducer control module pseudo-encode the data in this scheme. Basically, each logical zero bit in a byte is transmitted as a one-zero pair, while each logical one bit in a byte is transmitted as a zero-one pair. An example of this encoding is illustrated in Table IV below.

TABLE IV

Manchester Encoded Data

Binary Value	Hex Nibble	Encoded Binary	Encoded Hex
0000	0	10101010	AA
0001	1	10101001	A9
0010	2	10100110	A6
0011	3	10100101	A5
0100	4	10011010	9A
0101	5	10011001	99
0110	6	10010110	96
0111	7	10010101	95
1000	8	01101010	6A
1001	9	01101001	69
1010	A	01100110	66
1011	B	01100101	65

TABLE IV-continued

Manchester Encoded Data			
Binary Value	Hex Nibble	Encoded Binary	Encoded Hex
1100	C	01011010	5A
1101	D	01011001	59
1110	E	01010110	56
1111	F	01010101	55

This results in an approximate fifty percent duty cycle for the carrier signal, thereby reducing the apparent transmitter power. In addition, the encoding provides a logic level transition for virtually every transmitted bit. However, the amount of data transmitted increases with this encoding scheme. Generally, the system requires approximately 552 milliseconds to transmit the maximum sized packet (e.g., 142 bytes) and a maximum silent interval of approximately 16.6 seconds.

The manner in which messages are received within the protocol is illustrated in FIG. **4**. Specifically, a message synchronization header is received by a recipient (e.g., a transducer or transducer control module) at step **50**. Data is accepted at step **52** until the complete packet is received or a prescribed time interval, preferably one second, has elapsed as determined at step **54**. The message is decoded and inspected for validity based on the checksum. When a valid message is received as determined at step **56**, the message is processed at step **58**. If an acknowledgment is required to be transmitted to the sender is determined at step **60**, the recipient waits until expiration of a silent interval as determined at step **62** and transmits the reply at step **64**. After transmission of a reply, or if an invalid message has been received as determined at step **56**, the recipient repeats the above process to receive additional messages. Similarly, if an acknowledgment is not required in response to a valid received message as determined at step **60**, the above process may be repeated to receive additional messages as determined at step **66**. If additional messages are not to be received as determined at step **66**, the process terminates.

The manner in which messages are transmitted in accordance with the protocol is illustrated in FIG. **5**. Initially, a message is encoded by the sender (e.g., transducer or transducer control module) as described above at step **70**. The sender waits for an active state as determined at step **71**. Prior to transmission, a sender listens during a prescribed interval, preferably 250 milliseconds, to determine the presence of a clear channel at step **72**. If a clear channel is determined, the message is transmitted at step **74**. If the channel is not clear as determined at step **72**, the sender stores the message at step **82** and enters sleep mode to wait for the next interval to enter an active state and attempt re-transmission. Transducers generally may store only a single message, where a second message may not be stored until the first message is removed. After a message is transmitted at step **74**, the sender waits for a reply. If a reply is not received within a prescribed time interval, generally two seconds, as determined at step **76**, and the prescribed reply interval, preferably fifteen minutes, has not expired as determined at step **77**, the message is re-transmitted at prescribed intervals during the active state approximately every fifteen seconds. When a reply is not received within the prescribed reply time interval, the stored message is discarded at step **78**. After discarding the message, or if a reply is received within the time interval as determined at step **76**, the above process may be repeated to transmit additional messages as determined at step **80**; otherwise the process terminates.

The transducers typically operate as a master device to permit the transducers to remain in the sleep state a substantial portion of the time. The transducers may request a channel update from the transducer control module or channel update information may be sent to a transducer within an acknowledge packet. In addition, new TEDS may be sent to a transducer within an acknowledge packet.

Each transducer is registered with a corresponding transducer control module. Registration occurs during the first enablement of the transducer. Initially, transducers may be installed by users at any time. Accordingly, plural transducer control modules may receive request messages from a transducer, thereby enabling a transducer to register with an incorrect control module. In order to overcome this problem, the control module only responds to registration requests when manually placed in an installation mode. This mode is initiated by an install button disposed on the transducer control module front panel or housing. The transducer attempts registration in response to an initial power-up and registration requests occur as part of normal battery maintenance of transducers. Since transducers default to the last known control module in response to a failed registration attempt, registration is not required subsequent to replacement of a transducer battery.

The manner in which registration is accomplished is illustrated in FIG. **6**. Specifically, power is enabled to a transducer at step **90** and the corresponding transducer control module is placed in installation mode as described above. The transducer transmits a registration request packet at step **92**. The destination address field is set to zero to indicate that the transducer is searching for a control module as described above. If an acknowledge message is not received as determined at step **94**, the packet may be transmitted for a maximum amount of times, preferably eight, as determined at step **102**. If an acknowledge message is received by the transducer after verification by the transducer control module receiving the message, the transducer sends its TEDS information to the transducer control module at step **96** to identify itself to the control module. When an acknowledgment is received in response to the TEDS information as determined at step **98**, the transducer indicates registration at step **100** by blinking LEDS approximately four times at approximate half-second intervals. The transducer control module generates an installation message for transmission to the monitoring system to indicate the newly installed sensor. The appropriate information is stored in the monitoring system database as described below to enable reporting of the new sensor to an end-user. If a TEDS acknowledgment is not received as determined at step **98**, the transducer re-transmits registration request packets a described above.

When an acknowledgment is not received with the maximum transmissions of a registration request packet as determined at step **102**, the transducer utilizes the previous transducer control module at step **106**. If the transducer does not have a prior control module (e.g., at initial power-up from manufacture) as determined at step **104**, the transducer enters sleep mode at step **108** and requires a power cycle to restart the above registration process.

Transducer control module **14** includes the physical and protocol interface to the transducers over sensor LAN **12**, the event detection and reporting logic, and the physical and protocol interface to communications device **16**. The transducer control module can be implemented as an application specific device having a microprocessor, memory and appropriate communication ports, or as a standard personal computer running application specific software. A preferred embodiment of transducer control module **14** is illustrated in FIG. **7**. Specifically, the transducer control module includes a microcontroller **42**, wireless communications device **26**, communicator interface or communications device **16**, RAM **43**, non-volatile memory **45**, power manager **44** and a battery **46**. The microcontroller controls the overall operation of the control module and communicates with the transducers via wireless communications device **26**. By way of example only, the microcontroller is implemented by an Atmega **103** processor manufactured by Atmel. The communications device is substantially similar to the device described above for the transducers, while the microcontroller implements the wireless protocol. Communicator interface **16** provides communication between the transducer control module and WAN **18** for communication with monitoring system **20**. The interface may be internal or external (e.g., as shown in FIG. **2**) of control module **14** and may be a separate or integral component. The microcontroller includes internal storage for software and typically utilizes RAM **43** for working storage. Non-volatile memory **45** typically stores configuration information for the transducer control module. Power manager **44** is coupled to an object, such as battery **46**, to monitor the battery and a power charging system for a host environment (e.g., boat or vehicle battery, shore power, etc.). Local interface **47** provides an end-user with direct access to the transducer control module from a computer system or other device to query the control module or set parameters. The various components (i.e., interface, power manager, memories, microcontroller) of the control module are typically implemented by conventional or commercially available components.

The transducer control module is generally local to the object being monitored and has two-way communications with the monitoring system and transducers. The control module further makes decisions based on user-defined rules, and may monitor parameters of the object (e.g., temperature or power source). The use of local decision making capability reduces message traffic between the monitoring system and monitored asset.

The transducer control module may communicate with the monitoring system via any conventional or commercially available communications system, such as cellular modems, wireless Ethernet, wired Ethernet, satellite modems, telephone line modems, routers and interface cards. By way of example only, a satellite modem is utilized as interface **16** to communicate with a satellite network, such as Orbcomm, serving as WAN **18** between the control module and monitoring system. The satellite network generates an e-mail message that is sent to the monitoring system for storage and processing. The transducer control module may collect data from each transducer at predetermined intervals corresponding to a default sample rate or a user-defined sample rate. Preferably, the module will gather the current absolute level from the transducer and keep a running average so that the difference between the current level and the long term average level can be determined, for example to identify shock loading conditions and other transient conditions. Root mean square (RMS) levels can also be calculated and stored by the module, e.g., to evaluate vibrations. The module is preferably programmed to generate and send messages to monitoring system **20** when measured levels exceed user-defined or default thresholds. Message-generating events can also be defined by combinations of thresholds which are exceeded so that, for example, if the level on channel one exceeds some first number and the level on channel two exceeds some second number, an event message is generated by the transducer control module and sent to the monitoring system. The module memory may be partitioned and detailed information on an event may be stored in one of the partitions for later analysis. The message preferably includes a summary which quantifies the event so that the monitoring system can decide whether or not to send an alarm as described below.

In addition, the connection between transducer control module **14** and monitoring system WAN **18** can be either wired or wireless, or a combination of both. Representative wired WANs include Ethernet, telephone dial-up connections, and the complex communications network commonly referred to as the Internet. Representative wireless WANs include wireless Ethernet (IEEE 802.11), cellular telephones, radio-telephone systems, and commercially-available satellite-based communications systems. The data transmitted over the WAN can be encrypted to prevent unauthorized access.

The transducer control module performs several tasks including identifying newly installed sensors, determining the type of sensor and storing its data and acting on stored data based on conditions from the monitoring system (e.g., event detection). The event detection logic basically monitors transducer data for reportable events, prepares event and status reports described below in the appropriate format for interface **16**, controls interface **16** to conserve bandwidth and battery power and sends the event and status messages or reports to the monitoring system. Event reports notify the monitoring system of a change in the monitored asset that requires action, while status reports are periodically transmitted to update status information about the system.

Events are defined as changes in a monitored input (of a transducer) that result in performance of an action. An event report is sent to the monitoring system when the transducer control module detects a valid event. The transducer control module, based on transducer TEDS information, knows the parameters being measured and can link measurement data to defined events to detect occurrence thereof. The monitoring system may be notified of the time, date and Global Positioning System (GPS) location of the event. Event reports typically do not include identification information in order to reduce communications overhead, but rather indicate that a particular event has occurred. The monitoring system determines the meaning of the event report based on the control module serial number in a message header (e.g., e-mail header) and account information in the monitoring system database.

By way of example only, event reports include sixteen formats, while the transducer control module may store a maximum of sixteen event reports. In addition, a single event may include many different monitored inputs or outputs, each referred to as a term. The terms may be weighted, while events may be added, deleted or modified by users via the end-user terminals connected to the monitoring system. When an end-user modifies an event, the monitoring system sends an event definition to the transducer control module that includes information describing the event including the number of terms, input channels and type of event report. The message is typically transmitted through the satellite network to the transducer control module that stores the message for processing. The transducer control module typically receives the message via e-mail as described above and periodically checks for e-mail messages, preferably every fifteen minutes, to update event definitions.

Status reports are periodically transmitted at scheduled intervals and may contain any information available to the transducer control module. By way of example only, a status report may be transmitted daily (e.g., at midnight) and report various object characteristics. Generally, sixteen formats are available for status reports, while the transducer control module may store a maximum of sixteen status reports. Status reports are configurable by an end-user, where the monitoring system generates a report definition for the transducer control module when an end-user modifies a status report. The report definition includes information that describes the status report to the transducer control module. Since the status reports do not include identification information, the monitoring system determines appropriate actions based on information in the monitoring system database.

As described above, the transducer control module is in communication with the transducers and constantly monitors the wireless network for incoming messages. Since the control module is a slave device, it does not initiate communications with the transducers. When a transducer reports the condition of an input, the control module transmits an acknowledge message that may include a request to update an output channel or return additional status information.

The transducer control module uses transducer data as a basis for determining and reporting events. The transducer data is arranged into channels, where each transducer generally has two channels, but may include a maximum of 255 channels. Further, transducers may require a run-time calculation, where run-time refers to the amount of time a transducer reports an on state for a particular input. This calculation is performed by the control module automatically when a run-time transducer is recognized based on TEDS information. The run-time information is incorporated as a new channel for the transducer in the control module and monitoring system. In addition, some transducers require a cycle count channel. The transducer control module further calculates this value and incorporates the channel into the transducer information.

The transducer control module further provides time, date and location stamping for event and status reports. Time stamps, within an approximate one second interval, are provided internally by the transducer control module, while other time and data information is provided by an external GPS receiver. The GPS system further provides the location of events. The transducer control module utilizes UTC (Coordinated Universal Time) or GMT (Greenwich Mean Time) while differences between an end-user time zone and UCT are corrected by the monitoring system at the time of display. In addition, the transducer control module monitors the primary power source of the asset. If the power source fails, the control module includes an internal battery backup to transmit a power fail report to the monitoring system. The power backup enables the control module to operate for several days in the event primary power is not promptly restored.

Monitoring system **20** includes computer hardware and software which receives, stores, and analyzes event and status information from the item or facilities being monitored. The monitoring system watches for, detects, and reports trends in the monitored data, as well as detecting when the alarm conditions have been met. The monitoring system is the principal interface between the overall system and the end-user. It is the sub-system with which they interact to receive status reports, program event and alarm conditions, and issue control commands to actuators. The monitoring system provides for multiple users and multiple levels of access to the reports and information for the monitored facilities. Preferably, each end-user is provided access to the information for their monitored facilities and none other. End-users are able to designate multiple levels of access for themselves and in turn their staff or clients. For example, a trucking company can authorize their customers to receive simple location and shipment status reports, but not reports on equipment condition or driver performance. Similarly, the maintenance facility can receive the equipment reports, but not information on shipments or the driver. These security provisions and access levels are selectable by the end-user through their interface with the monitoring system.

A preferred embodiment of monitoring system **20** is illustrated in FIG. **8**. Specifically, monitoring system **20** includes monitor application **21**, a database **25** and a web server **23** allowing the end-user to interact with the monitoring system over the WAN, such as the Internet, using commercially available software known as web browsers. This enables end-users to receive event reports and check the status of the monitored facilities from anywhere in the world without requiring special communications facilities or having to install special software on their local computer. Standard capabilities of web servers and browsers, such as secure sockets layer (SSL) service, can be used to provide the required security and data access controls. The monitor application and web server each access database **25**.

The monitoring system is typically implemented by a conventional personal or other computer system. The computer system may include any of the major platforms or operating systems. By way of example only, monitoring system **20** includes a Microsoft Windows NT Server 4.0 operating system, and Microsoft Internet Information Server version 4.0 in web server **23**. Database **25** is typically implemented by Microsoft Access 2000, but may utilize any conventional database. The web server further utilizes Microsoft Active Server Pages Scripting to send SQL queries to the database. Connection to the database is accomplished by the web server and monitor application via open database connectivity (ODBC).

Monitoring system **20** basically coordinates communications between a system web site, database and transducer control module. Communication between monitor application **21** and the transducer control module is preferably via e-mail as described above. Web server **23** and database **25** transfer information via ODBC and Active Server Pages scripting. Monitor application **21** periodically checks for e-mail messages from transducer control modules, or may retrieve messages from a server. When messages are received, they are processed and stored in the database based on user accounts by monitor application **21**. When a message includes measurement data, the transducer data is arranged by the transducer control module into channels, where the monitoring application knows the data represented in the channels for proper storage in the database. If the message defines an alarm condition, a notification (e.g., e-mail, fax, pager, etc.) is sent to each person residing on a notification list for that event stored in the database as described below. When a user creates or modifies report and event definitions via the web site, new definitions are sent to the transducer control module. Monitor application **21** periodically checks database **25** for new definitions and transmits e-mail messages to the appropriate transducer control modules.

Monitor application **21** maintains an event log, an alarm notification log and an e-mail log. The application records into the event log each event that occurs along with time stamps indicating the time the event occurred (UTC), the time the event report was received by the monitoring system and the time the event processing and logging was completed. When alarm notifications are sent, the monitor application records into the alarm notification log the time of notification. Further, alarm messages may be displayed at the web site so that a user may receive them immediately upon entering the system. The time at which a user acknowledges receipt of the message is further recorded into the alarm notification log for each alarm. In addition, monitor application **21** records in the e-mail log each e-mail message that is received and processed. Report and event definition messages that are sent to transducer control modules are also recorded in the e-mail log.

Database **25** typically includes several tables to store system information as illustrated, by way of example only, in FIG. **9**. Initially, hardware information is entered into the database during manufacturing and assembly phases. Specifically, communicators table **110** is a master index of satellite communicators used in the system. This includes information relating to a unit serial number, registration date and e-mail address assigned. TCM table **112** is similarly a master index table of transducer control modules and includes information relating to the manufacturing date, firmware version, unit serial number and unit serial number of corresponding satellite communicator with which that control module is packaged. The communicator serial number is entered in the database for each control module at the time the control module and communicator are assembled. The communicator serial number is the primary key for linking an e-mail address to a communicator and for linking the communicator to a transducer control module. The transducer control module serial number is used by a user to register a monitored asset and is the primary key for linking the hardware to an asset. An asset identification number (Asset ID) is the primary key for linking an asset to a user account number.

Sensor module types table **122** is a master index of transducers and includes the sensor module ID (e.g., serial number), manufacture date and type of sensor module. The type is a primary key linking a sensor module to sensor modules table **124** and channel definitions table **126** collectively containing information about the hardware configuration for that type of sensor including the quantity of channels and a description of each channel. The sensor module ID is the primary key for linking each transducer to calibration data in calibration TEDS table **128**. The combination of the sensor module ID and channel number links a transducer to channel TEDS table **129** including the range of possible values and physical units of measurement for the transducer data.

Customer information table **148** stores customer information including a unique customer account number. Login table **150** is utilized to link a customer's name and password with the account number. An account may have several assets, each of which is identified by a unique asset identification number (Asset ID). An asset is registered by a user entering a name and asset description at the web site. The asset is assigned a unique Asset ID and the information is stored in registered assets table **152**. The account number is the primary key that links customer information table **148** to registered assets table **152**. Once an asset is registered to an account, a user registers the control module serial number for that asset via the web site. Registering basically creates an association between the asset and a physical, e-mail addressable, control module. The asset is considered a monitored asset and is stored in monitored asset table **114**. This table includes information relating to the asset monitoring system hardware, such as Asset ID, control module serial number, system status, quantity of transducers installed for the control module and quantity of events and reports defined for the control module.

The Asset ID is the primary key for linking a registered asset to control module serial numbers stored in monitored asset table **114**. An asset may have plural control modules registered to it, each having a corresponding group of transducers. Thus, the combination of the Asset ID and control module are primary keys for linking to tables containing configuration settings and data related to the asset and control module pair and corresponding transducers.

After transducers are installed for a control module, information about the transducers including the sensor module ID is stored in installed sensor modules table **116**. The primary keys linking the Asset ID and control module to corresponding installed transducers are the Asset ID and control module serial number. The combination of the Asset ID, control module serial number and sensor module ID are the primary keys linking the Asset ID and control module pair to data table **118** containing actual channel data and module description table **120** containing descriptions of transducers. These keys in further combination with a channel number link to channel description table **121** containing channels customized by the user. The Asset ID and control module serial number are the primary keys for linking to GPS table **138** containing GPS position data for the asset and control module.

The Asset ID and control module serial number are the primary keys linking to user defined events table **130** containing user defined events including the quantity of terms defining the event and whether or not the event should trigger an alarm. The combination of the Asset ID, control module serial number and event number are primary keys linking to event definitions table **134** containing the individual terms comprising the event definitions, while these keys, for events that trigger alarms, link to notification list table **132** containing notification lists for sending messages when an alarm condition is detected.

The Asset ID and control module serial number are the primary keys linking to reports table **142** containing user defined reports to be generated by the monitoring system including the quantity of report items and the schedule on which the reports are to be sent. The combination of the Asset ID, control module serial number, report number and report format are primary keys linking to report items table **144** containing individual items that comprise the report definitions.

The Asset ID and control module serial numbers are the primary keys for accessing e-mail log table **140**. This table contains a log of e-mail messages (e.g., events, reports and configuration messages) sent and received by each control module. These keys may further be utilized and/or combined with an event number to access event log table **136**. The event log table contains a log of event messages and alarm notifications sent by the control module (e.g., whether or not the notifications are acknowledged by the user). System log table **146** records internal information (e.g., program errors, events, etc.) that occur during monitoring system execution.

Referring back to FIG. **8**, end-user terminals **22** are generally standard personal computers with web browser software and are connected to the monitoring system through a WAN, such as the Internet. This permits access to the monitored information form anywhere in the world that has Internet access, without having to install special software on each computer used for access to the monitoring information. Alternatively, the end-user terminals can be personal computers running special software developed for the above purpose, dumb terminals connected to a network or a mainframe, personal information managers and digital assistants, pagers, cellular phones, etc. End-user terminals **22** typically interact with web server **23** to provide information to an end-user. Monitor application **21** generally executes in the background to store transducer information in the database and correspond with the transducer control modules to provide event definitions and receive the transducer reports and information as described above. Web server **23** utilizes Active Server Pages with Visual Basic scripts that execute within the web server to build web pages containing the information for display to a user. In response to entered information, the scripts essentially retrieve the desired monitoring information from database **25**. The monitor application and web server each access (e.g., read and write), and indirectly communicate information to each other through, the database. The resulting web pages are transferred to end-user terminal **22** for display. The database further maintains the format of the web pages desired or specified by the user for display.

The user may specify various characteristics or parameters for system operation via the web site. For example, the user may specify: names for monitored data, particular notifications for alarm conditions (e.g., when to notify, manner of notification, events triggering notification, etc.), devices to be turned on or off, layout of web page, and the particular transducers from which information is to be displayed. This information is stored in database **25**. When events are entered, the terms are stored in the database, and monitor application **21** periodically checks for new or modified events to transmit the appropriate messages to corresponding control modules as described above.

The manner in which web server **23** processes user requests and displays monitored information is illustrated in FIG. **10**. Specifically, a user logs onto the web site by entering a username and password at step **160**. The username and password are utilized to retrieve an account number from the database and validate the account at step **162**. If invalid information is entered, the user is prompted to repeat the login process. When a valid account is determined at step **162**, the account number is utilized to query the database for registered assets of that account at step **164**. A list of assets having user specified names (e.g., specified by the user during asset registration) is displayed to the user at step **166**. The user selects a displayed asset at step **168**, and the selected asset name is used to query the database at step **170** to retrieve an Asset ID and a list of transducer control modules that are registered for the selected asset. A list of control modules having user specified names (e.g., specified by the user during control module registration) is displayed to the user at step **172**.

The user subsequently selects a displayed control module at step **174** and measurements from the selected control module are determined at step **176**. This is accomplished by using the selected control module serial number and Asset ID to query the database to retrieve the quantity of transducers installed for the selected control module, the unique sensor module ID and the current status of each transducer (e.g., active or inactive). Active transducers are reporting data, while inactive transducers are transducers that have been installed, but are either removed or not responding at the time of the most recent sensor report. The sensor module ID is used to query the database to retrieve information relating to transducer type (e.g., temperature, voltage, etc.), the quantity of channels and description of each channel. The sensor module ID and channel number are subsequently used to query the database for the channel TEDS and calibration TEDS information. This provides calibration coefficients and physical units of measurement to facilitate determination of the actual data value for a channel.

Once channel data is determined for each transducer of the selected control module at step **176**, a table is displayed including the transducer and channel descriptions (e.g., user-specified descriptions) and corresponding measurements at step **178**. In addition, the user may, via the web site, define events to be reported by each transducer by selecting the transducer and specifying the conditions. Custom reports may further be defined by the user and request data for one or more transducers at certain intervals. Newly defined or modified events and reports are stored in the database and indicated accordingly. The monitor application periodically polls the database for new or modified definitions for transmission to the control module as described above.

Operation of the remote monitoring system is described with reference to FIGS. **1–2**. Initially, the end-user obtains (purchases, leases, etc.) a smart remote monitoring kit. The kit includes a basic suite of transducers **10** for the selected application, a transducer control module **14**, a communicator **16** for interfacing the transducer control module to the WAN of choice, and complete instructions for installation and activation. A default user name and password can also be supplied for use in activating the monitoring account. Alternatively, the transducers and control module may be available separately or in any combination. The end-user installs (or has installed) the monitoring kit by placing the transducers at appropriate locations and/or connecting them to corresponding components, and disposing the control module locally with respect to the transducers. As part of this installation, the communicator is connected to (for wired systems) or makes contact with (for wireless systems) the WAN.

Monitoring system **20** recognizes and validates the unique identifier of the transducer control module and starts receiving and processing event reports and status information. The end-user contacts the monitoring system through an end-user terminal **22** using, for example, the Internet and a web browser. The end-user activates the monitoring account, makes arrangements for payment of monitoring fees (e.g., by deposit account, credit card or applying for a corporate account), defines the desired alarms and status reports, and defines the distribution list (e.g., names, telephone numbers, e-mail addresses, etc.) for messages as described above. The monitoring system continues to receive event reports and status information from the transducer control module, and processes them according to the options selected by the end-user when the account was activated. The end-user may purchase additional transducers for use with the smart remote monitoring system. When installed and connected to the transducer control module, these optional transducers identify themselves to the transducer control module and, in turn, to the monitoring system as described above. The monitoring system recognizes the additional transducers, knows what they are, and what data and reports they can provide. It adds the new transducers to the user account. The end-user contacts the monitoring system through end-user **22** terminal as described above and selects the monitoring options appropriate to the additional transducers.

At any time, the end-user can contact the monitoring system through an end-user terminal to view monitored information and update information (e.g., the alarm conditions, status reports, distribution lists, access controls, etc.) as described above.

Some of the advantages of the remote monitoring system and method according to the present invention is that it can be internet based allowing end-users to interact with the system from anywhere in the world without the need for special equipment, communications facilities, or software; that it provides real-time, on-demand status information, not just alarm notifications so that end-users can check on monitored facilities at any time, from anywhere; that the transducers and transducer control modules are self-identifying so that once connected, the monitoring system knows what the sensors are and what to do with the information they provide and end-users can simply install and connect new transducers or control modules, with the monitoring system immediately accepting data reports; that all transmitted messages can be encrypted to control access to event reports and status information; that all features, including event detection thresholds, alarm conditions, alarm notification actions, lists and addresses, information access, etc. are user programmable by direct interaction with the monitoring system; that the system and method provides direct notification to the end-user using the communications media, addresses or telephone numbers, and message format selected by the user so that, for example, in the case of a yacht, messages can be sent to the boat owner, the charter operator, the boat's home marina, and the customary maintenance facility, depending on the content of the message and the options selected by the user; and that any or all of the above can occur automatically, without human intervention on the part of the monitoring service.

It will be appreciated that the embodiments described above and illustrated in the drawings represent only a few of the many ways of implementing a smart remote monitoring system and method.

The transducers may be implemented by analog or digital sensors, and may further include processors and/or circuitry to process measured signals to provide a "smart" transducer. In addition to an actual sensing element, the transducers may include signal conditioning electronics, an analog to digital converter, a digital communication interface and TEDS to provide plug-and-play capability and other features such as temperature compensation and correction, and decision making capability. For example, changes in trends for any of the above sensors, such as a significant change in how long or how often the bilge pump runs, can be cause for an alarm notification. The transducers may include sensors to receive input and/or actuators to control systems or to enable or enhance the sensor measurements. For example, an actuator can be used to disconnect the battery charger in order to measure the true voltage of the battery. The transducers may be positioned at suitable locations to provide corresponding measurements, and may include any conventional or other fastening devices. Further, the transducers may include any conventional or other connectors to facilitate measurement of a desired parameter (e.g., voltage, device status, etc.). The transducers may include any type of sensing element to measure any type of characteristic (e.g., voltage, temperature, device status, etc.), and may receive power from any conventional or other power source (e.g., battery, electrical generator, common wall outlet jack, etc.). The transducer may include any conventional or other microcontroller, processor or circuitry to control transducer operation. The electronic data sheet may include any quantity or type of information relating to a transducer(e.g., type, calibration information, measurement units, etc.). The sensor interface may be any conventional or other device for providing signals from the sensing element compatible with the microcontroller or other circuitry (e.g., digital-to-analog converter, etc.). Any quantity of transducers having any types of sensing elements or intelligence may be utilized to monitor an object.

The transducers may communicate with the transducer control module via any wired or wireless communication medium. The transducer identification (UID) may include any quantity of any type of alphanumeric or other characters or symbols. The transducers may include any quantity of states, and switch between the states in any desired fashion. The transducers may further be arranged to be slave devices and respond to transducer control module requests. The transducer data may be arranged on any channel or quantity of channels in any fashion. The transducer may have any quantity of channels, while the channels may be arranged in any fashion. The transducers may detect or measure any state changes or values of an object (e.g., temperature, on/off condition, operating mode of a device, etc.), and may send status reports at any desired interval having any information. The status messages may be assigned specific intervals to form a time slot arrangement for the transducers. The transducers may store any quantity of messages and/or reports, while the messages and/or reports may have any format or information. In addition, the transducers may include the transducer control module, and may directly communicate with the monitoring system.

The transducer control module may be disposed at any location suitable for communication with the transducers, and may utilize any conventional or other power source (e.g., battery, electrical generator, common wall outlet jack, etc.). The install button may be implemented by any button or other input device, and may be disposed at any location on the control module or control module housing. Alternatively, a similar input device may be disposed on the transducers to initiate or assist in the registration process. The control module may include any quantity of LEDs or other indicators to indicate successful registration of a transducer in any manner (e.g., blink any quantity of times within any desired interval, etc.). The transducers may be registered with a control module at any time and in any desired fashion (e.g., utilize special packets or other identifiers, send any information, any handshaking schemes, etc.), and utilize any techniques to ensure registration of a transducer with a proper control module. The transducer control module may include any conventional microcontroller, processor or other circuitry to control module operation. The communicator, local interface, RAM, non-volatile memory and power manager may be implemented by any conventional or other devices or circuitry performing their functions. The RAM and non-volatile memory may be implemented by any types of memory and store any desired information.

The transducer control module may accommodate any quantity of transducers. The transducers and transducer control modules may communicate via any wired or wireless communication medium (e.g., LAN, WAN, direct connection, etc.) and utilize any protocol. The communications device for the transducers and transducer control module may include any conventional or other receivers, transmitters antenna switches or antennas or other devices performing their functions. The transducers and transducer control module may communicate utilizing any transmission frequency, band or energy medium (e.g., light, RF, ultrasound, etc.). The data may be transmitted at any desired rate and in any desired format (e.g., any quantity of data, stop and parity bits). The data may be transmitted utilizing any technique or protocol.

The wireless protocol may be implemented for any wired or wireless communication scheme. The protocol packet may be of any format or size and have any quantity of fields of any size containing any desired information. The protocol may utilize any data verification techniques (e.g., parity, checksum, etc.). The checksum may be determined based on any conventional or other techniques The protocol may utilize any desired handshaking, while reply intervals or re-transmission attempts may be set to any desired values. The data may be encoded in any desired fashion. The transducer control module may store any quantity of incoming or outgoing messages and/or reports. The protocol may utilize any techniques to facilitate a single transducer of a control module transmitting at a time, and may listen for any desired interval for a carrier signal or other indication of transmission by another transducer.

The events may be defined by any quantity or type of terms, values or other settings. The events may be defined by or triggered based on measurements from any quantity or combinations of any type of transducers. The control module may send messages at any time up to an alarm condition (e.g., warning messages indicating that an alarm condition is approaching). The terms of an event may be weighted in any desired fashion to indicate an alarm or other event condition. The control module may check for communications (e.g., e-mail, messages, reports, etc.) from the monitoring system at any desired intervals for status, event definitions or other information. The transducer control module may determine time stamps or utilize external systems (e.g., GPS) to provide time stamps for various events.

The transducer control module may communicate with the monitoring system via any wired or wireless communications device or network. Messages and/or reports may be sent between the control module and monitoring system via any communications medium (e.g., satellite, e-mail, packets, etc.). The messages and/or reports may be encoded or encrypted in any fashion. The messages and/or reports (e.g., event and status) may have any quantity of formats and include any desired information. The event and status reports may be transmitted to the monitoring system at any desired intervals, while event definition reports may be sent to the control module at any desired interval.

The monitoring system may be implemented by any conventional personal or other type of computer or processing system, and include any conventional, commercially available or custom software. The monitoring system may communicate with end-user systems via any communications devices and/or networks. The web server may be implemented by any commercially available or other web server, and utilize any software package or custom software to generate and display web pages. The monitor application may check for messages and/or reports received via any communications medium (e.g., via e-mail, retrieve information from another server system, etc.) from the control module and store information in the database at any desired interval or specific times. The monitoring system may notify end-users of alarm or other conditions in any desired manner (e.g., pager, web site, facsimile, telephone, etc.). The monitoring system may maintain or record any desired information in any desired logs. The monitor application may check the database for new events or other information and send corresponding messages and/or reports to the control module at any desired intervals. The monitoring system may include any quantity of software modules arranged in any fashion and performing any quantity of the above described functions.

The database may be implemented by any conventional or other database or data storage structure (e.g., files, data structures, etc.). The database may include any quantity of tables associated in any fashion and having any desired keys. The database may be accessed in any desired fashion by any querying techniques. The database may be arranged in any fashion and store any information.

The end-user systems may be implemented by any conventional personal or other computer or processing system or device (e.g., laptop, palm pilot, cellular telephone, etc.), or be implemented by a dumb terminal connected to a mainframe or network type computer. The end-user system may access the monitoring system via nay communications medium (e.g., LAN, WAN, Internet, Intranet, wireless or wired communications, etc.). An end-user may specify any desired parameters for event or other conditions, web page layout, measurement names or any other information to control system operation. The account number and password may have any quantity of any type of alphanumeric or other characters or symbols.

The transducer control module and corresponding transducers may be available in the form of a kit. The kit may include any quantity of control modules, transducers and other devices. Alternatively, these devices may be individually available, or available in any quantities and/or combinations.

The end-user and monitoring computer systems of the present invention may be implemented by any personal or other type of computer system (e.g., IBM-compatible, Apple, Macintosh, laptop, palm pilot, etc.). The computer systems of the present invention may include any commercially available operating system (e.g., Windows, OS/2, Unix, Linux, etc.). The computer systems of the present invention may further include any commercially available or custom software (e.g., server software, browser software, etc.), and any types of input devices (e.g., keyboard, mouse, voice recognition, etc.). It is to be understood that the software for the monitoring system and controllers of the transducers and transducer control module of the present invention may be implemented in any desired computer language and could be developed by one of ordinary skill in the computer arts based on the functional descriptions contained in the specification and flow charts illustrated in the drawings. The computer systems and controllers of the present invention may alternatively be implemented by hardware or other processing circuitry. The various functions of the computer systems and controllers may be distributed in any manner among any quantity of computer or processing systems, processors or circuitry. The software and/or algorithms described above and illustrated in the flow charts may be modified in any manner that accomplishes the functions described herein. The software of the monitoring system and controllers of the present invention may be available on a recorded medium (e.g., floppy diskettes, CD-ROM, memory devices, etc.), or may be downloaded (e.g., in the form of carrier waves, packets, etc.) to the processing devices from a network.

The exact sensors and actuators used will vary with the application. For example, when monitoring private yachts for absentee owners, the sensors might include any or all of the following:

1. Bilge water level sensor (actual depth or high-low detection by float switch).
2. Bilge pump performance sensor (how long it takes to drain the bilge).
3. Leak rate sensor (how often the bilge pump comes on).
4. Battery voltage sensor (with and without charger on).
5. Battery current sensor (indicative of occupancy or electrical problem).
6. Engine starting cycles sensor (may indicate unauthorized use).
7. Engine running time sensor (for maintenance or to detect unauthorized use).

8. Engine oil level sensor.
9. Fuel level sensor.
10. Water level sensor.
11. Pitch and roll of the boat sensor (may indicate problem with mooring lines).
12. Intrusion sensor (unauthorized boarding).
13. Cabin temperature sensor.
14. Engine compartment temperature sensor.
15. Fire or smoke detectors.
16. Hazardous gas detectors.
17. Position/motion sensors for unauthorized use or mooring failure (broken anchor chain, etc.).
18. Galvanic action sensor (to detect excess galvanic action of the hull and/or fittings due to an electrical grounding fault or depletion of the sacrificial anodes).
19. Sensors to monitor operation or status of any other system on board the boat (e.g., air conditioning, food storage temperature, engine room air vents, owner's hot tub, etc.).

As a further example, a vacation home monitoring system can have similar sensors except that the emphasis would be on the basement instead of the bilge, plumbing leaks, and the performance of the heating and air conditioning system. Other sensors, such as intrusion detection, will be very similar.

The present invention is not limited to the specific applications disclosed herein but may be utilized to monitor any types of property, equipment or other objects. For example, the present invention may be utilized in substantially the same manner described above to monitor:

1. Yachts at a dock to prevent yachts from sinking at the dock from small leaks or loose moorings and to detect theft and possibly assist recovery.
2. Yachts underway to prevent incidents or expensive repairs due to malfunction of yacht systems.
3. Vacation homes to prevent costly repairs due to small problems going unnoticed in unoccupied homes (e.g., water, freezing, etc.).
4. Yachts on land to prevent theft (or enable recovery) of expensive boats stored on trailers or in boatyard racks.
5. Recreational vehicle (RV) status to prevent costly repairs due to small problems going unnoticed in RVs while stored.
6. RV security to prevent theft (or enable recovery) of RVs while stored.
7. Aircraft status to prevent costly repairs due to small problems going unnoticed in aircraft while stored (e.g., water, loose tiedowns, etc.).
8. Aircraft security to prevent theft (or enable recovery) of aircraft.
9. Medical refrigeration to prevent loss of irreplaceable medical specimens or pharmaceuticals (e.g., tissue, sperm, embryos, bacteria or virus samples, etc.) due to temperature.
10. Food storage to prevent health problems or expensive recalls due to spoiled food.
11. Poultry incubators to prevent loss of eggs/babies due to improper temperature.
12. Poultry houses to prevent loss of birds due to equipment malfunctions.
13. Livestock barns to prevent loss of animals due to equipment malfunctions.
14. Horse barns to reassure absentee owners of conditions for their expensive horses (e.g., temperature, water, stall door opening, etc.).
15. Swimming pools to alert owners/managers of unauthorized use or equipment failure.
16. Amusement park rides to prevent incidents due to malfunctioning equipment and record operation of equipment for investigation of any that do occur, and to detect changes in ride quality of rides (e.g., coaster-type rides).
17. Rental vehicle status to prevent costly repairs due to small problems going unnoticed in rental vehicles while in operation by customers.
18. Rental vehicle security to prevent theft (or enable recovery) of rental vehicles (and locate late/missing vehicles).
19. Farm equipment status to prevent costly repairs due to small problems going unnoticed in farm equipment.
20. Farm equipment security to prevent theft (or enable recovery) of expensive farm equipment.
21. Hazardous material barges to prevent catastrophic spills of hazardous material due to equipment malfunction and possibly operator error.
22. River barges tracking to solve reported problems of poor cellular coverage and power management of present tracking systems.
23. Truck tracking to find lost trucks and drivers.
24. Trailer tracking to solve reported problems of poor power management of trailer tracking systems.
25. Residential utilities to eliminate need for meter readers (e.g., in homes with full-time Internet connections).
26. Smart home status to prevent costly repairs due to small problems going unnoticed in home systems and provide integrated remote control in a home through a web server (e.g., in homes with full-time Internet connections).
27. HVAC to prevent costly repairs due to small problems going unnoticed in commercial and residential systems and to eliminate need for site visits for systems under maintenance contracts.
28. Title V equipment to eliminate need for site visits to verify operation of emission monitoring equipment, especially systems under maintenance contracts.
29. Bridge structures to detect damage (e.g., from earthquakes, impacts, etc.) to bridges and overpasses by shock or tilt sensing.
30. Tower structures to detect damage to or of deterioration of telecommunications towers by shock or tilt sensing.
31. Clean rooms to prevent (or minimize) production losses due to problems with temperature, humidity, or vibration and to prevent quality audit problems from not having continuous monitoring records.
32. Pipelines to prevent incidents and/or catastrophic spills due to equipment malfunction and possibly operator error.
33. Storage tanks to prevent incidents and/or catastrophic spills due to equipment malfunction and possibly operator error and to prevent interruption of service due to unnoticed depletion of stock.
34. Cranes to reduce chances of incidents or accidents due to improper use of portable cranes (e.g., poor load management, failure to extend outriggers, etc.) or improper maintenance.
35. Mines to detect safety or operational problems with widely-distributed mining equipment.
36. Industrial process temperature to prevent incidents or loss of production due to improper temperature.
37. Room air to detect indoor air quality problems (e.g., temperature, humidity, CO/CO2, etc.).
38. Power quality to prevent damage to sensitive equipment by detecting problems with power quality (e.g., brownouts, phase dropouts, distortion, etc.).
39. Power use to eliminate need for meter readers for large campus-type facilities with multiple sub-meters (e.g., colleges typically have hundreds of on-campus meters, may also apply to apartment complexes).

40. Water level/flow to warn of problems with stream flow (e.g., high or low).
41. Seismic to warn of possible earthquake damage to remote facilities (e.g., power substations, transmission line towers, telecommunications facilities, etc.).
42. Railway crossings to prevent incidents due to malfunctioning equipment and record operation of equipment for investigation of any that do occur.
43. Track gauge to prevent incidents due to improper track gauge (e.g., track tends to open up under use).
44. Power transmission lines to improve repair response time by reporting location (and nature) of failure.
45. Tramways/ski lifts to prevent incidents due to malfunctioning equipment and record operation of equipment for investigation of any that do occur.
46. Elevators/escalators to prevent incidents due to malfunctioning equipment and record operation of equipment for investigation of any that do occur.
47. Well-heads/pumps to reduce loss of production for remote well-head pumping station (e.g., due to equipment malfunction, depletion of fuel, etc.) and to reduce possibility (or extent) of hazardous material spill.
48. Landfills to reduce possibility (or extent) of hazardous waste contamination.
49. Parking garages/lots to improve utilization of large parking facilities by detecting empty spaces and to locate abandoned vehicles by tracking abnormal parking time.
50. Aircraft structure to detect changes in structure before hazardous condition develops (e.g., shock or 'G' loads, landing cycles, change in shape).
51. Aircraft engines to prevent incidents or expensive repairs by enabling condition-based maintenance (CBM) of aircraft engines (especially when engines are leased or under maintenance contracts).
52. High-risk drivers to reduce risk from high-risk drivers by detecting and reporting improper activities (e.g., parental reports for speed, location, hours of operation, etc.).
53. Local traffic speed to enable local communities (e.g., neighborhoods, gated communities, apartment/townhouse complexes, etc.) to detect and identify violators of local speed limits.
54. Railway ride quality to report violations of ride quality standard for railway shipments of expensive goods.
55. Truck/trailer ride quality to report violations of ride quality standard for shipments of expensive goods (e.g., attached to vehicle).
56. Cargo ride quality to report violations of ride quality standard for shipments of expensive goods (e.g., attached to cargo such as large motors, pumps, etc.).
57. Heavy equipment ride quality to prevent injury to operator due to malfunction/deterioration of suspension or seat.
58. Motor sports ride quality to provide on-the-air data on 'G' loads for various motor sports (e.g., automobiles, boats, aircraft, etc.) and provide accident data to improve design of safety systems.
59. Vending machines to detect malfunctions (e.g., including temperature of temperature-controlled unit), to reduce refill trips and/or lost sales by detecting low stock and to enable e-commerce transactions.
60. Billboards to detect equipment malfunctions, including lights and to eliminate need for site visits to read the power meter.
61. Weather to detect local hazardous and favorable weather conditions (e.g., for irrigation, sporting events, boating, etc.)

From the foregoing description, it will be appreciated that the invention makes available a novel smart remote monitoring system and method wherein end-users may remotely monitor an object and access information related to the monitored object via a communications network.

Having described preferred embodiments of a new and improved smart remote monitoring system and method, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A remote monitoring system for measuring conditions of an object at a remote location and providing information relating to said measurements to an end-user, said system comprising:

at least one sensor module to measure said conditions of said remote object, wherein each sensor module is configured for attachment to said remote object by said end-user and includes a notification module to inform said remote monitoring system of the presence ofthat sensor module coupled to said remote object;

a control module local to and in communication with said at least one sensor module to receive and analyze said measured conditions and determine the occurrence of events specified by said end-user; and

a monitoring system remote from and in communication with said control module to facilitate entry of said user-specified events and to receive said measured conditions from said control module and transmit said received measured conditions to a processing system of said end-user in response to a request for said measured conditions from said end-user;

wherein said notification module includes:

a message transmission module to facilitate transmission of a registration message to register said at least one sensor module with said control module;

an information transmission module to facilitate transmission of sensor module information to said control module in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

an indicator module to indicate to said end-user registration of said at least one sensor module in response to receiving said reply message from said control module indicating reception of said sensor module information;

an assignment module to assign a prior corresponding control module to said at least one sensor module in response to the absence of said reply message to transmission of said registration message; and

a sleep module to place said at least one sensor module in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control module.

2. The system of claim **1** further including a wireless communications network to facilitate communications between said at least one sensor module and said control module.

3. The system of claim **2** wherein at least one sensor module includes:

a sensor unit to measure a corresponding condition of said remote object; and a sensor module communications device coupled to said sensor unit to facilitate communications with said control module over said wireless communications network.

4. The system of claim **3** wherein said sensor unit includes:

a transducer to measure said corresponding condition of said remote object and produce transducer signals indicating said measured condition;

a sensor unit controller to process said transducer signals, wherein said sensor unit controller includes:

a conditioning module to condition said transducer signals and produce conditioned signals for transmission to said control module;

a storage unit to store transducer information facilitating transducer identification and processing of transducer signals; and

a communications module to facilitate communications with said control module over said wireless communications network; and

a controller interface disposed between said transducer and said sensor unit controller to receive said transducer signals from said transducer and produce controller signals compatible with said sensor unit controller to facilitate communications between said transducer and said sensor unit controller.

5. The system of claim **4** wherein said sensor unit controller further includes:

a sleep state module to control said sensor module to operate in a low power sleep mode; and

an active state module to facilitate periodic transition from said low power sleep mode to an active mode to facilitate measurement of said corresponding condition and transmission of said measured corresponding condition to said control module.

6. The system of claim **3** wherein said sensor module communications device includes:

a receiver to receive an incoming message from said control module over said wireless communications network;

a transmitter to transmit an outgoing message to said control module over said wireless communications network;

an antenna to receive said incoming message and transmit said outgoing message in the form of radio signals; and

an antenna switch to selectively couple said receiver and transmitter to said antenna to respectively receive said incoming message and transmit said outgoing message.

7. The system of claim **3** wherein said control module includes:

a control module communications device to facilitate communications with each said sensor module via said wireless communications network;

a module controller to process said measured conditions received from said at least one sensor module and facilitate communications with said monitoring system, wherein said module controller includes:

a registration module to register said at least one sensor module with said remote monitoring system in response to receiving notification from said at least one sensor module via said notification module and to receive and store sensor module information corresponding to said at least one sensor module, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

an event module to process said received measured conditions in accordance with said corresponding sensor module information and to determine occurrence of said events specified by said end-user and received from said monitoring system; and

a communications module to facilitate communications with said at least one sensor module over said wireless communications network; and

a module communications unit to facilitate communications with said monitoring system.

8. The system of claim **1** wherein said control module further includes:

a power source;

a power management module to monitor said power source and power facilities at said remote location; and

a local interface to provide a direct connection to said control module to retrieve control module status information and set control module parameters.

9. The system of claim **2** wherein said at least one sensor module and said control module each include:

a transmission module to facilitate on/off keyed transmissions to enable communication between said at least one sensor module and said control module via said wireless communications network; and

a reception module to receive and decode said on/off keyed transmissions.

10. The system of claim **9** wherein said transmission module includes:

an encoding module to encode an outgoing message for transmission over said wireless communications network;

an error checking module to insert message validity information within said outgoing message to facilitate a determination of message validity by said reception module;

a monitor module to determine the presence of an available communication link on said wireless communications network and to facilitate transmission of said encoded message in response to determining the presence of said available communication link;

a storage module to store said encoded message in response to determining the absence of said available communication link;

a re-transmission module to periodically re-transmit said encoded message in response to the absence of a reply message to an initial transmission of said encoded message; and

a discard module to discard said encoded message in response to expiration of a prescribed time interval prior to receiving said reply message.

11. The system of claim **10** wherein said encoding module includes:

a bit conversion module to translate each bit within said outgoing message into a bit pair, wherein each bit within said bit pair has a different state.

12. The system of claim **11** wherein said error checking module includes:

a checksum module to produce a checksum for said outgoing message to enable determination of message validity by said reception module.

13. The system of claim **10** wherein said reception module includes:

a retrieval module to receive said outgoing message until complete reception of said outgoing message or expiration of a prescribed reception time interval;

a validity module to examine said message validity information of said received message and determine validity of said received message;

a message processor to process said received message in response to said validity module determining that said received message is valid; and

an acknowledgment module to facilitate transmission of a reply message in response to determining that said received message is of a type requiring transmission of said reply message.

14. The system of claim **1** further including a first wide area network to facilitate communications between said control module and said monitoring system.

15. The system of claim **14** wherein said first wide area network includes a satellite network.

16. The system of claim **14** wherein said monitoring system includes:

a monitor interface module to facilitate communications with said control module over said first wide area network, wherein said monitor interface module includes:

a message processor to receive incoming messages including information relating to said measured conditions and occurrence of said user-specified events from said control module; and

a message transmission module to facilitate transmission of outgoing messages including information relating to said user-specified events to said control module via said first wide area network;

a monitor storage unit to store information relating to said end-user, said user-specified events and said measured conditions; and

an end-user module to facilitate communications with said end-user processing system to transmit information to and receive information from said end-user.

17. The system of claim **16** wherein said end-user module includes:

a request processor to process an information request received from said end-user and to transmit information indicated in said information request and relating to said measured conditions to said end-user processing system via a second wide area network; and

an event definition module to receive and process an event definition from said end-user specifying an event and facilitate transmission of said event definition to said control module via said monitor interface module.

18. The system of claim **16** wherein said monitor interface module further includes:

an alarm notification module to transmit a notification to persons designated by said end-user in response to receiving an incoming message from said control module indicating occurrence of a corresponding user-specified event.

19. The system of claim **17** further including plural sensor modules, wherein at least one event definition is based on measurements from at least two different sensor modules.

20. The system of claim **2** wherein said monitoring system facilitates entry of commands to control said remote object and transmits said commands to said control module, and at least one sensor module includes:

an actuator unit to control said remote object in response to said commands received from said control module; and

a control module communications device coupled to said actuator unit to facilitate communications with said control module over said wireless communications network.

21. In a remote monitoring system, a method of measuring conditions of an object at a remote location and providing information relating to said measurements to an end-user, said method comprising the steps of:

(a) measuring said conditions of said remote object via at least one sensor module, wherein said at least one sensor module is configured for attachment to said remote object by said end-user;

(b) receiving and analyzing said measured conditions and determining the occurrence of events specified by said end-user via a control module local to and in communication with said at least one sensor module; and

(c) facilitating entry of said user-specified events and receiving said measured conditions from said control module and transmitting said received measured conditions to a processing system of said end-user in response to a request for said measured conditions from said end-user via a monitoring system remote from and in communication with said control module;

wherein step (a) further includes:

(a.1) informing said remote monitoring system, via said at least one sensor module, of the presence of that sensor module coupled to said remote object, wherein step (a.1) further includes:

(a.1.1) transmitting a registration message to register said at least one sensor module with said control module;

(a.1.2) transmitting sensor module information to said control module in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

(a.1.3) indicating to said end-user registration of said at least one sensor module in response to receiving said reply message from said control module indicating reception of said sensor module information;

(a.1.4) assigning a prior corresponding control module to said at least one sensor module in response to the absence of said reply message to transmission of said registration message; and

(a.1.5) placing said at least one sensor module in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control module.

22. The method of claim **21** wherein step (b) further includes:

(b.1) receiving said measured conditions via a wireless communications network facilitating communications between said at least one sensor module and said control module.

23. The method of claim **22** wherein step (a) further includes:

(a.2) measuring a corresponding condition of said remote object via at least one sensor module; and

(a.3) facilitating communications between said at least one sensor module and said control module over said wireless communications network.

24. The method of claim **23** wherein said step (a.2) includes:

(a.2.1) measuring said corresponding condition of said remote object via a transducer and producing transducer signals indicating said measured condition;

(a.2.2) conditioning said transducer signals and producing conditioned signals for transmission to said control module via a sensor controller;

(a.2.3) storing transducer information facilitating transducer identification and processing of said transducer signals in a storage unit of said sensor controller; and

(a.2.4) processing said transducer signals from said transducer to produce controller signals compatible with said sensor controller to facilitate communications between said transducer and said sensor controller.

25. The method of claim **24** wherein step (a.2.1) further includes:

(a.2.1.1) controlling said at least one sensor module to operate in a low power sleep mode; and

(a.2.1.2) facilitating periodic transition from said low power sleep mode to an active mode to facilitate measurement of said corresponding condition and transmission of said measured corresponding condition to said control module.

26. The method of claim **23** wherein step (a.3) includes:

(a.3.1) receiving an incoming message at said at least one sensor module from said control module over said wireless communications network via a receiver;

(a.3.2) transmitting an outgoing message from said at least one sensor module to said control module over said wireless communications network via a transmitter;

(a.3.3) receiving said incoming message and transmitting said outgoing message in the form of radio signals via an antenna; and

(a.3.4) selectively coupling said receiver and transmitter to said antenna to respectively receive said incoming message and transmit said outgoing message.

27. The method of claim **23** wherein step (b) further includes:

(b.2) processing said measured conditions received from said at least one sensor module and facilitating communications with said monitoring system;

(b.3) registering said at least one sensor module with said remote monitoring system in response to receiving notification from said at least one sensor module and receiving and storing sensor module information corresponding to said at least one sensor module, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions; and

(b.4) processing said received measured conditions in accordance with said corresponding sensor module information and determining occurrence of said events specified by said end-user and received from said monitoring system.

28. The method of claim **27** wherein step (b) further includes:

(b.5) monitoring a power source and power facilities at said remote location; and

(b.6) providing a direct connection to said control module to retrieve control module status information and set control module parameters.

29. The method of claim **23** wherein step (a.3) includes:

(a.3.1) facilitating on/off keyed transmissions by said at least one sensor module and said control module to enable communication between said at least one sensor module and said control module via said wireless communications network; and

(a.3.2) receiving and decoding said on/off keyed transmissions at said at least one sensor module and said control module.

30. The method of claim **29** wherein step (a.3.1) includes:

(a.3.1.1) encoding an outgoing message for transmission over said wireless communications network;

(a.3.1.2) inserting message validity information within said outgoing message to facilitate a determination of message validity at step (a.3.2);

(a.3.1.3) determining the presence of an available communication link on said wireless communications network and transmitting said encoded message in response to determining the presence of said available communication link;

(a.3.1.4) storing said encoded message in response to determining the absence of said available communication link;

(a.3.1.5) periodically re-transmitting said encoded message in response to the absence of a reply message to an initial transmission of said encoded message; and

(a.3.1.6) discarding said encoded message in response to expiration of a prescribed time interval prior to receiving said reply message.

31. The method of claim **30** wherein step (a.3.1.1) includes:

(a.3.1.1.1) encoding said outgoing message by translating each bit within said outgoing message into a bit pair, wherein each bit within said bit pair has a different state.

32. The method of claim **30** wherein step (a.3.1.2) includes: (a.3.1.2.1) producing a checksum for said outgoing message to enable determination of message validity at step (a.3.2).

33. The method of claim **30** wherein step (a.3.2) includes:

(a.3.2.1) receiving said outgoing message until complete reception of said outgoing message or expiration of a prescribed reception time interval;

(a.3.2.2) examining said message validity information of said received message and determining validity of said received message;

(a.3.2.3) processing said received message in response to step (a.3.2.2) determining that said received message is valid; and

(a.3.2.4) transmitting a reply message in response to determining that said received message is of a type requiring transmission of said reply message.

34. The method of claim **21** wherein step (b) further includes:

(b.1) facilitating communications between said control module and said monitoring system via a first wide area network.

35. The method of claim **21** wherein step (b) further includes:

(b.1) facilitating communications between said control module and said monitoring system via a satellite network.

36. The method of claim **34** wherein step (c) includes:

(c.1) facilitating communications with said control module over said first wide area network;

(c.2) receiving incoming messages including information relating to said measured conditions and occurrence of said user-specified events from said control module;

(c.3) transmitting outgoing messages including information relating to said user-specified events to said control module via said first wide area network;

(c.4) storing information relating to said end-user, said user-specified events and said measured conditions; and (c.5) facilitating communications with said end-user processing system to transmit information to and receive information from said end-user.

37. The method of claim **36** wherein step (c.5) includes:

(c.5.1) processing an information request received from said end-user and transmitting information indicated in said information request and relating to said measured conditions to said end-user processing system via a second wide area network; and

(c.5.2) receiving and processing an event definition from said end-user specifying an event and transmitting said event definition to said control module to facilitate determination of occurrence of said event.

38. The method of claim **36** wherein step (c) further includes:

(c.6) transmitting a notification to persons designated by said end-user in response to receiving an incoming message from said control module indicating occurrence of a corresponding user-specified event.

39. The method of claim **37** wherein plural sensor modules measure said conditions of said remote object, and step (c.5.2) further includes:

(c.5.2.1) receiving and processing at least one event definition based on measurements from at least two different sensor modules.

40. The method of claim **22** wherein step (c) further includes:

(c.1) facilitating entry of commands to control said remote object and transmitting said commands to said control module.

41. The method of claim **40** wherein step (a) further includes:

(a.2) controlling said remote object via at least one sensor module in response to said commands received from said control module.

42. A remote monitoring kit for measuring conditions of an object at a remote location and providing information relating to said measurements to a remote monitoring system for display to an end-user, wherein said remote monitoring system facilitates entry of user-specified events and receives said measured conditions from said kit and transmits said received measured conditions to a processing system of said end-user, said kit comprising:

at least one sensor module to measure said conditions of said remote object, wherein each sensor module is configured for attachment to said remote object by said end-user and includes a notification module to inform said remote monitoring system of the presence of that sensor module coupled to said remote object; and

a control module local to and in communication with said at least one sensor module to receive and analyze said measured conditions and determine the occurrence of said user-specified events received from said remote monitoring system, wherein said control module is remote from and in communication with said remote monitoring system;

wherein said notification module includes:

a message transmission module to facilitate transmission of a registration message to register said at least one sensor module with said control module;

an information transmission module to facilitate transmission of sensor module information to said control module in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

an indicator module to indicate to said end-user registration of said at least one sensor module in response to receiving said reply message from said control module indicating reception of said sensor module information;

an assignment module to assign a prior corresponding control module to said at least one sensor module in response to the absence of said reply message to transmission of said registration message; and

a sleep module to place said at least one sensor module in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control module.

43. The kit of claim **42** wherein communications between said at least one sensor module and said control module are facilitated via a wireless communications network.

44. The kit of claim **43** wherein at least one sensor module includes:

a sensor unit to measure a corresponding condition of said remote object; and

a sensor module communications device coupled to said sensor unit to facilitate communications with said control module over said wireless communications network.

45. The kit of claim **43** wherein said remote monitoring system facilitates entry of commands to control said remote object and transmits said commands to said control module, and at least one sensor module includes:

an actuator unit to control said remote object in response to said commands received from said control module; and

a control module communications device coupled to said actuator unit to facilitate communications with said control module over said wireless communications network.

46. The kit of claim **43** wherein said control module includes:

a control module communications device to facilitate communications with each said sensor module via said wireless communications network;

a module controller to process said measured conditions received from said at least one sensor module and facilitate communications with said remote monitoring system, wherein said module controller includes:

a registration module to register said at least one sensor module with said remote monitoring system in response to receiving notification from said at least one sensor module via said notification module and to receive and store sensor module information corresponding to said at least one sensor module, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

an event module to process said received measured conditions in accordance with said corresponding sensor module information and to determine occurrence of said events specified by said end-user and received from said remote monitoring system; and

a communications module to facilitate communications with said at least one sensor module over said wireless communications network; and

a module communications unit to facilitate communications with said remote monitoring system.

47. The kit of claim **43** wherein said at least one sensor module and said control module each include:

a transmission module to facilitate on/off keyed transmissions to enable communication between said at least one sensor module and said control module via said wireless communications network; and

a reception module to receive and decode said on/off keyed transmissions.

48. A method of measuring conditions of an object at a remote location via a remote monitoring kit that measures said conditions and provides information relating to said measurements to a remote monitoring system for display to an end-user, wherein said remote monitoring system facilitates entry of user-specified events and receives said measured conditions from said kit and transmits said received measured conditions to a processing system of said end-user, said method comprising the steps of:

(a) connecting at least one sensor module of said kit to said remote object to measure said conditions of said remote object, wherein each sensor module is configured for attachment to said remote object by said end-user;

(b) informing a control module of said kit of the presence of said at least one sensor module, wherein said control module is local to and in communication with said at least one sensor module to receive notification from said at least one sensor module indicating said presence of said at least one sensor module, and step (b) further includes:

(b.1) transmitting a registration message to register said at least one sensor module with said control module;

(b.2) transmitting sensor module information to said control module in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

(b.3) indicating to said end-user registration of said at least one sensor module in response to receiving said reply message from said control module indicating reception of said sensor module information;

(b.4) assigning a prior corresponding control module to said at least one sensor module in response to the absence of said reply message to transmission of said registration message; and

(b.5) placing said at least one sensor module in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control module;

(c) entering said user-specified events into said remote monitoring system;

(d) measuring said conditions of said remote object via said at least one sensor module;

(e) receiving and analyzing said measured conditions at said control module and determining the occurrence of said user-specified events received from said remote monitoring system, wherein said control module is remote from and in communication with said remote monitoring system; and

(f) accessing said remote monitoring system via said processing system to retrieve said measured conditions.

49. The method of claim **48** wherein step (e) includes:

(e.1) facilitating communications between said at least one sensor module and said control module via a wireless communications network.

50. The method of claim **48** wherein at least one sensor module includes an actuator unit, and step (c) includes:

(c.1) entering commands into said remote monitoring system to control said remote object and transmitting said commands to said control module; and

step (d) includes:

(d.1) controlling said remote object via said actuator unit of said at least one sensor module in response to said commands received from said control module.

51. The method of claim **49** wherein step (e) further includes:

(e.2) facilitating on/offkeyed transmissions from said at least one sensor module and said control module to enable communications via said wireless communications network; and

(e.3) receiving and decoding at said at least one sensor module and said control module said on/off keyed transmissions.

52. The method of claim **48** wherein plural sensor modules measure said conditions of said remote object, and step (c) further includes:

(c.1) entering at least one event based on measurements from at least two different sensor modules.

53. A remote monitoring system for measuring conditions of an object at a remote location and providing information relating to said measurements to an end-user, said system comprising:

a plurality of sensor modules to measure said conditions of said remote object;

a control module local to and in communication with each said sensor module to receive and analyze said measured conditions and determine the occurrence of events specified by said end-user, wherein said events are based on measurements from at least two different sensor modules; and

a monitoring system remote from and in communication with said control module to facilitate entry of said user-specified events and to receive said measured conditions from said control module and transmit said received measured conditions to a processing system of said end-user in response to a request for said measured conditions from said end-user;

wherein each sensor module includes a notification module to inform said remote monitoring system of the presence of that sensor module, said notification module including:

a message transmission module to facilitate transmission of a registration message to register that sensor module with said control module;

an information transmission module to facilitate transmission of sensor module information to said control module in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

an indicator module to indicate to said end-user registration of that sensor module in response to receiving said reply message from said control module indicating reception of said sensor module information;

an assignment module to assign a prior corresponding control module to that sensor module in response to the absence of said reply message to transmission of said registration message; and

a sleep module to place that sensor module in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control module.

54. The system of claim **53** wherein communications between said sensor modules and said control module are facilitated via a wireless communications network.

55. The system of claim **54** wherein at least one sensor module includes:

a sensor unit to measure a corresponding condition of said remote object; and

a sensor module communications device coupled to said sensor unit to facilitate communications with said control module over said wireless communications network.

56. The system of claim **54** wherein said monitoring system facilitates entry of commands to control said remote object and transmits said commands to said control module, and at least one sensor module includes:

an actuator unit to control said remote object in response to said commands received from said control module; and

a control module communications device coupled to said actuator unit to facilitate communications with said control module over said wireless communications network.

57. The system of claim **54** wherein said control module includes:

a control module communications device to facilitate communications with each said sensor module via said wireless communications network;

a module controller to process said measured conditions received from said sensor modules and facilitate communications with said monitoring system, wherein said module controller includes:

a registration module to register each said sensor module with said remote monitoring system in response to receiving notification from that sensor module and to receive and store sensor module information corresponding to that sensor module, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

an event module to process said received measured conditions in accordance with said corresponding sensor module information and to determine occurrence of said events specified by said end-user and received from said monitoring system; and

a communications module to facilitate communications with said sensor modules over said wireless communications network; and

a module communications unit to facilitate communications with said monitoring system.

58. The system of claim **54** wherein said sensor modules and said control module each include:

a transmission module to facilitate on/off keyed transmissions to enable communication between said sensor modules and said control module via said wireless communications network; and

a reception module to receive and decode said on/off keyed transmissions.

59. The system of claim **53** wherein said monitoring system includes an alarm notification module to transmit a notification to persons designated by said end-user in response to receiving an incoming message from said control module indicating occurrence of a corresponding user-specified event.

60. In a remote monitoring system, a method of measuring conditions of an object at a remote location and providing information relating to said measurements to an end-user, said method comprising the steps of:

(a) measuring said conditions of said remote object via a plurality of sensor modules;

(b) receiving and analyzing said measured conditions and determining the occurrence of events specified by said end-user via a control module local to and in communication with said sensor modules, wherein said events are based on measurements from at least two different sensor modules; and

(c) facilitating entry of said user-specified events and receiving said measured conditions from said control module and transmitting said received measured conditions to a processing system of said end-user in response to a request for said measured conditions from said end-user via a monitoring system remote from and in communication with said control module;

wherein step (a) further includes:

(a.1) informing said remote monitoring system, via each sensor module, of the presence of that sensor module, wherein step (a.1) further includes:

(a.1.1) transmitting a registration message to register that sensor module with said control module;

(a.1.2) transmitting sensor module information to said control module in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions;

(a.1.3) indicating to said end-user registration of that sensor module in response to receiving said reply message from said control module indicating reception of said sensor module information;

(a.1.4) assigning a prior corresponding control module to that sensor module in response to the absence of said reply message to transmission of said registration message; and

(a.1.5) placing that sensor module in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control module.

61. The method of claim **60** wherein step (b) further includes:

(b.1) receiving said measured conditions via a wireless communications, network facilitating communications between said sensor modules and said control module.

62. The method of claim **61** wherein step (c) further includes:

(c.1) facilitating entry of commands to control said remote object and transmitting said commands to said control module.

63. The method of claim **62** wherein step (a) further includes:

(a.2) controlling said remote object via at least one sensor module in response to said commands received from said control module.

64. The method of claim **61** wherein step (b) further includes:

(b.2) processing said measured conditions received from said sensor modules and facilitating communications with said monitoring system;

(b.3) registering each said sensor module with said remote monitoring system in response to receiving notification from that sensor module and receiving and storing sensor module information corresponding to that sensor module, wherein said sensor module information includes a sensor module identification and information for processing said measured conditions; and

(b.4) processing said received measured conditions in accordance with said corresponding sensor module information and determining occurrence of said events specified by said end-user and received from said monitoring system.

65. The method of claim **61** wherein step (b.1) includes:

(b.1.1) facilitating on/off keyed transmissions by said sensor modules and said control module to enable communication between said sensor modules and said control module via said wireless communications network; and

(b.1.2) receiving and decoding said on/off keyed transmissions at said sensor modules and said control module.

66. The method of claim **60** wherein step (c) further includes:

(c.1) transmitting a notification to persons designated by said end-user in response to receiving an incoming message from said control module indicating occurrence of a corresponding user-specified event.

67. The system of claim **1** wherein said control module includes:

a clock module to maintain an indication of current time; and

an event time module to provide a time stamp corresponding to said current time indication for said determined occurrence of end-user specified events for transmission with event information to said monitoring system.

68. The system of claim **1** wherein said control module includes:

a receiver module to receive location information associated with said remote object from a Global Positioning System for transmission of object position information to said monitoring system.

69. The system of claim **68** wherein said control module further includes:

a report module to periodically generate a report including a location of said remote object indicated by said received location information for transmission to said monitoring system.

70. The system of claim **68** wherein said control module further includes:

an event location module to provide a location associated with said determined occurrence of end-user specified events and indicated by said received location information for transmission to said monitoring system.

71. The system of claim **1** wherein said control module includes:

a receiver module to receive time information from a Global Positioning System; and

a clock module to maintain an indication of current time in accordance with said received time information to facilitate determination of time indications associated with said remote object for transmission to said monitoring system.

72. The method of claim **21** wherein step (b) further includes:

(b.1) maintaining an indication of current time; and

(b.2) generating a time stamp corresponding to said current time indication for said determined occurrence of end-user specified events for transmission with event information to said monitoring system.

73. The method of claim **21** wherein step (b) further includes:

(b.1) receiving location information associated with said remote object from a Global Positioning System for transmission of object position information to said monitoring system.

74. The method of claim **73** wherein step (b) further includes:

(b.2) periodically generating a report including a location of said remote object indicated by said received location information for transmission to said monitoring system.

75. The method of claim **73** wherein step (b) further includes:

(b.2) determining a location associated with said determined occurrence of end-user specified events in accordance with said received location information for transmission to said monitoring system.

76. The method of claim **21** wherein step (b) further includes:

(b.1) receiving time information from a Global Positioning System; and

(b.2) maintaining an -indication of current time in accordance with said received time information to facilitate determination of time indications associated with said remote object for transmission to said monitoring system.

77. The kit of claim **42** wherein said control module includes:

a clock module to maintain an indication of current time; and

an event time module to provide a time stamp corresponding to said current time indication for said determined occurrence of end-user specified events for transmission with event information to said remote monitoring system.

78. The kit of claim **42** wherein said control module includes:

a receiver module to receive location information associated with said remote object from a Global Positioning System for transmission of object position information to said remote monitoring system.

79. The kit of claim **78** wherein said control module further includes:

a report module to periodically generate-a report including a location of said remote object indicated by said received location information for transmission to said remote monitoring system.

80. The kit of claim **78** wherein said control module further includes:

an event location module to provide a location associated with said determined occurrence of end-user specified events and indicated by said received location information for transmission to said remote monitoring system.

81. The kit of claim **42** wherein said control module includes:

a receiver module to receive time information from a Global Positioning System; and

a clock module to maintain an indication of current time in accordance with said received time information to facilitate determination of time indications associated with said remote object for transmission to said remote monitoring system.

82. The method of claim **48** wherein step (e) further includes:

(e.1) maintaining an indication of current time; and

(e.2) generating a time stamp corresponding to said current time indication for said determined occurrence of end-user specified events for transmission with event information to said remote monitoring system.

83. The method of claim **48** wherein step (e) further includes:

(e.1) receiving location information associated with said remote object from a Global Positioning System for transmission of object position information to said remote monitoring system.

84. The method of claim **83** wherein step (e) further includes:

(e.2) periodically generating a report including a location of said remote object indicated by said received location information for transmission to said remote monitoring system.

85. The method of claim **83** wherein step (e) further includes:

(e.2) determining a location associated with said determined occurrence of end-user specified events in accordance with said received location information for transmission to said remote monitoring system.

86. The method of claim **48** wherein step (e) further includes:

(e.1) receiving time information from a Global Positioning System; and

(e.2) maintaining an indication of current time in accordance with said received time information to facilitate determination of time indications associated with said remote object for transmission to said remote monitoring system.

87. The system of claim **53** wherein said control module includes:

a clock module to maintain an indication of current time; and

an event time module to provide a time stamp corresponding to said current time indication for said determined occurrence of end-user specified events for transmission with event information to said monitoring system.

88. The system of claim **53** wherein said control module includes:

a receiver module to receive location information associated with said remote object from a Global Positioning System for transmission of object position information to said monitoring system.

89. The system of claim **88** wherein said control module further includes:

a report module to periodically generate a report including a location of said remote object indicated by said received location information for transmission to said monitoring system.

90. The system of claim **88** wherein said control module further includes:

an event location module to provide a location associated with said determined occurrence of end-user specified events and indicated by said received location information for transmission to said monitoring system.

91. The system of claim **53** wherein said control module includes:

a receiver module to receive time information from a Global Positioning System; and

a clock module to maintain an indication of current time in accordance with said received time information to facilitate determination of time indications associated with said remote object for transmission to said monitoring system.

92. The method of claim **60** wherein step (b) further includes:

(b.1) maintaining an indication of current time; and

(b.2) generating a time stamp corresponding to said current time indication for said determined occurrence of end-user specified events for transmission with event information to said monitoring system.

93. The method of claim **60** wherein step (b) further includes:

(b.1) receiving location information associated with said remote object from a Global Positioning System for transmission of object position information to said monitoring system.

94. The method of claim **93** wherein step (b) further includes:

(b.2) periodically generating a report including a location of said remote object indicated by said received location information for transmission to said monitoring system.

95. The method of claim **93** wherein step (b) further includes:

(b.2) determining a location associated with said determined occurrence of end-user specified events in accordance with said received location information for transmission to said monitoring system.

96. The method of claim **73** wherein step (b) further includes:

(b.1) receiving time information from a Global Positioning System; and

(b.2) maintaining an indication of current time in accordance with said received time information to facilitate determination of time indications associated with said remote object for transmission to said monitoring system.

97. A remote monitoring system for measuring conditions of an object at a remote location and providing information relating to said measurements to an end-user, said system comprising:

at least one sensor means for measuring said conditions of said remote object, wherein each sensor means is configured for attachment to said remote object by said end-user and includes notification means for informing said remote monitoring system of the presence ofthat sensor means coupled to said remote object;

control means local to and in communication with said at least one sensor means for receiving and analyzing said measured conditions and determining the occurrence of events specified by said end-user; and

monitoring means remote from and in communication with said control means for facilitating entry of said user-specified events and receiving said measured conditions from said control means and transmitting said received measured conditions to a processing system of said end-user in response to a request for said measured conditions from said end-user;

wherein said notification means includes:

message transmission means for facilitating transmission of a registration message to register said at least one sensor means with said control means;

information transmission means for facilitating transmission of sensor means information to said control means in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor means information includes a sensor means identification and information for processing said measured conditions;

indicator means for indicating to said end-user registration of said at least one sensor means in response to receiving said reply message from said control means indicating reception of said sensor means information;

assignment means for assigning a prior corresponding control means to said at least one sensor means in response to the absence of said reply message to transmission of said registration message; and

sleep means for placing said at least one sensor means in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control means.

98. A remote monitoring kit for measuring conditions of an object at a remote location and providing information relating to said measurements to a remote monitoring system for display to an end-user, wherein said remote monitoring system facilitates entry of user-specified events and receives said measured conditions from said kit and transmits said received measured conditions to a processing system of said end-user, said kit comprising:

at least one sensor means for measuring said conditions of said remote object, wherein each sensor means is configured for attachment to said remote object by said end-user and includes notification means for informing said remote monitoring system of the presence ofthat sensor means coupled to said remote object; and

control means local to and in communication with said at least one sensor means for receiving and analyzing said measured conditions and determining the occurrence of said user-specified events received from said remote monitoring system, wherein said control means is remote from and in communication with said remote monitoring system;

wherein said notification means includes:

message transmission means for facilitating transmission of a registration message to register said at least one sensor means with said control means;

information transmission means for facilitating transmission of sensor means information to said control means in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor means information includes a sensor means identification and information for processing said measured conditions;

indicator means for indicating to said end-user registration of said at least one sensor means in response to receiving said reply message from said control means indicating reception of said sensor means information;

assignment means for assigning a prior corresponding control means to said at least one sensor means in response to the absence of said reply message to transmission of said registration message; and

sleep means for placing said at least one sensor means in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control means.

99. A remote monitoring system for measuring conditions of an object at a remote location and providing information relating to said measurements to an end-user, said system comprising:

a plurality of sensor means for measuring said conditions of said remote object;

control means local to and in communication with each said sensor means for receiving and analyzing said measured conditions and determining the occurrence of events specified by said end-user, wherein said events are based on measurements from at least two different sensor means; and

monitoring means remote from and in communication with said control means for facilitating entry of said user-specified events and receiving said measured conditions from said control means and transmitting said received measured conditions to a processing system of said end-user in response to a request for said measured conditions from said end-user;

wherein each sensor means includes notification means for informing said remote monitoring system of the presence of that sensor means, said notification means including:

message transmission means for facilitating transmission of a registration message to register that sensor means with said control means;

information transmission means for facilitating transmission of sensor means information to said control means in response to receiving a reply message within a predetermined quantity of registration message transmissions, wherein said sensor means information includes a sensor means identification and information for processing said measured conditions;

indicator means for indicating to said end-user registration of that sensor means in response to receiving said reply message from said control means indicating reception of said sensor means information;

assignment means for assigning a prior corresponding control means to that sensor means in response to the absence of said reply message to transmission of said registration message; and

sleep means for placing that sensor means in a low power sleep mode in response to the absence of said reply message to transmission of said registration message and the absence of a prior corresponding control means.

* * * * *

US006600971B1

(12) United States Patent
Smith et al.

(10) Patent No.: US 6,600,971 B1
(45) Date of Patent: Jul. 29, 2003

(54) **DISTRIBUTED CONTROL NETWORK FOR IRRIGATION MANAGEMENT**

(75) Inventors: **Brian J. Smith**, Laguna Niguel, CA (US); **Eric Schafer**, Carlsbad, CA (US)

(73) Assignee: **Signature Control Systems, Inc.**, Chino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/537,093**

(22) Filed: **Mar. 29, 2000**

(51) **Int. Cl.**^{7} **G05B 11/01**; G05B 23/02

(52) **U.S. Cl.** **700/284**; 700/17; 700/20; 709/201

(58) **Field of Search** 700/14, 15, 16, 700/17, 19, 20, 284; 709/201, 243; 137/624.11, 624.12

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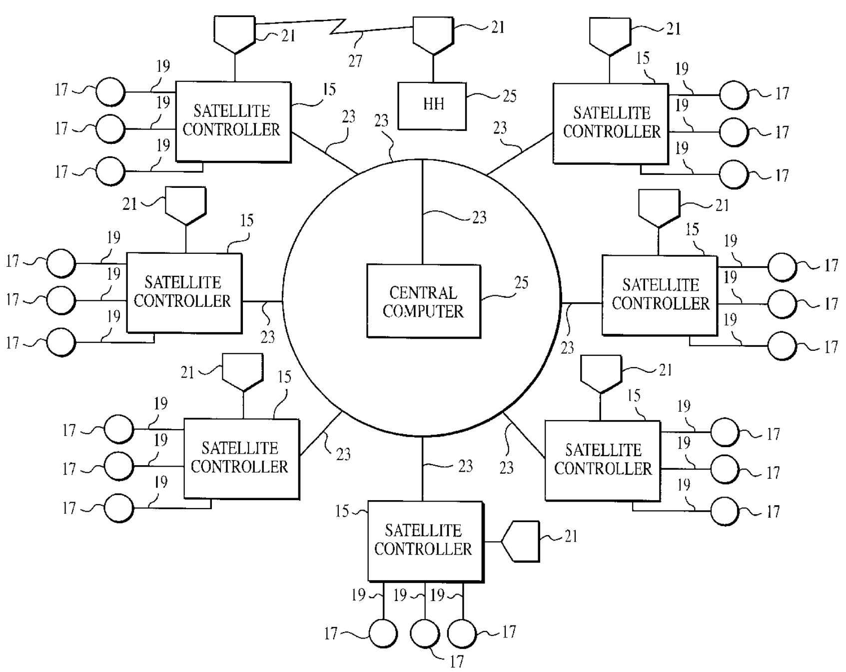
Primary Examiner—Paul P. Gordon
(74) *Attorney, Agent, or Firm*—Hale and Dorr LLP; Cynthia K. Nicholson

(57) **ABSTRACT**

A system and method for operating a distributed control network for irrigation management. The system incorporates several irrigation controllers wherein each of the controllers can transmit, receive and respond to commands initiated by any device or satellite controller on the network, a communication bus that is connected to the controllers, a central computer that is connected to the bus, several sensing devices that are connected to each controller, and several sprinkler valves that are connected to each controller. The controllers can be operated in local mode via a user interface and in a remote mode via a wireless connection. The controllers are capable of monitoring and acknowledging the commands that are transmitted on the bus.

28 Claims, 5 Drawing Sheets



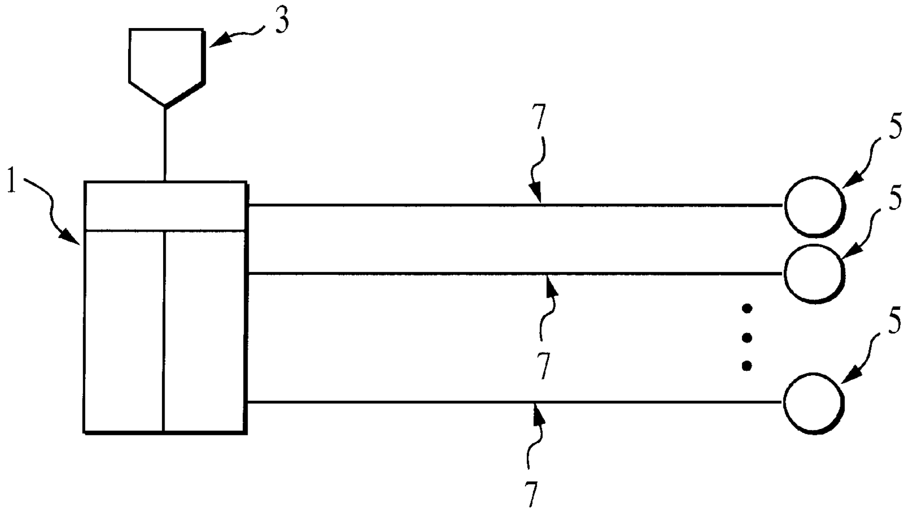


FIG. 1
(PRIOR ART)

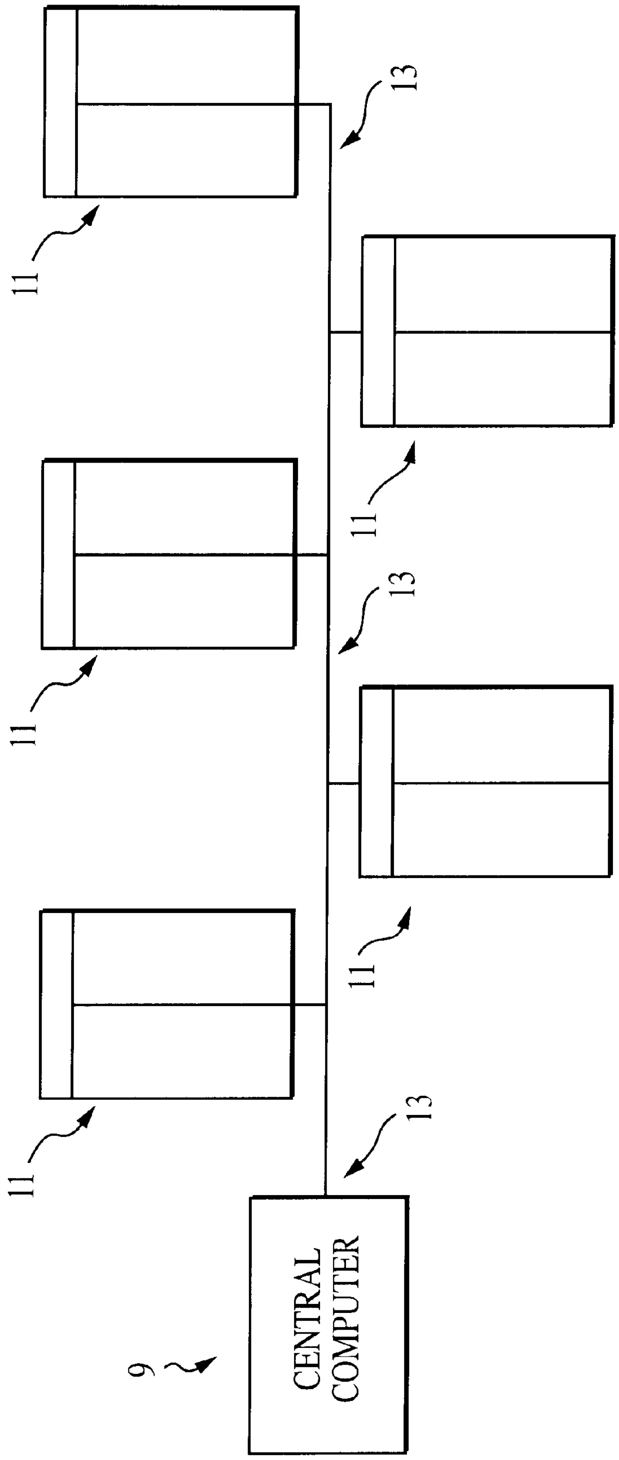


FIG. 2
(PRIOR ART)

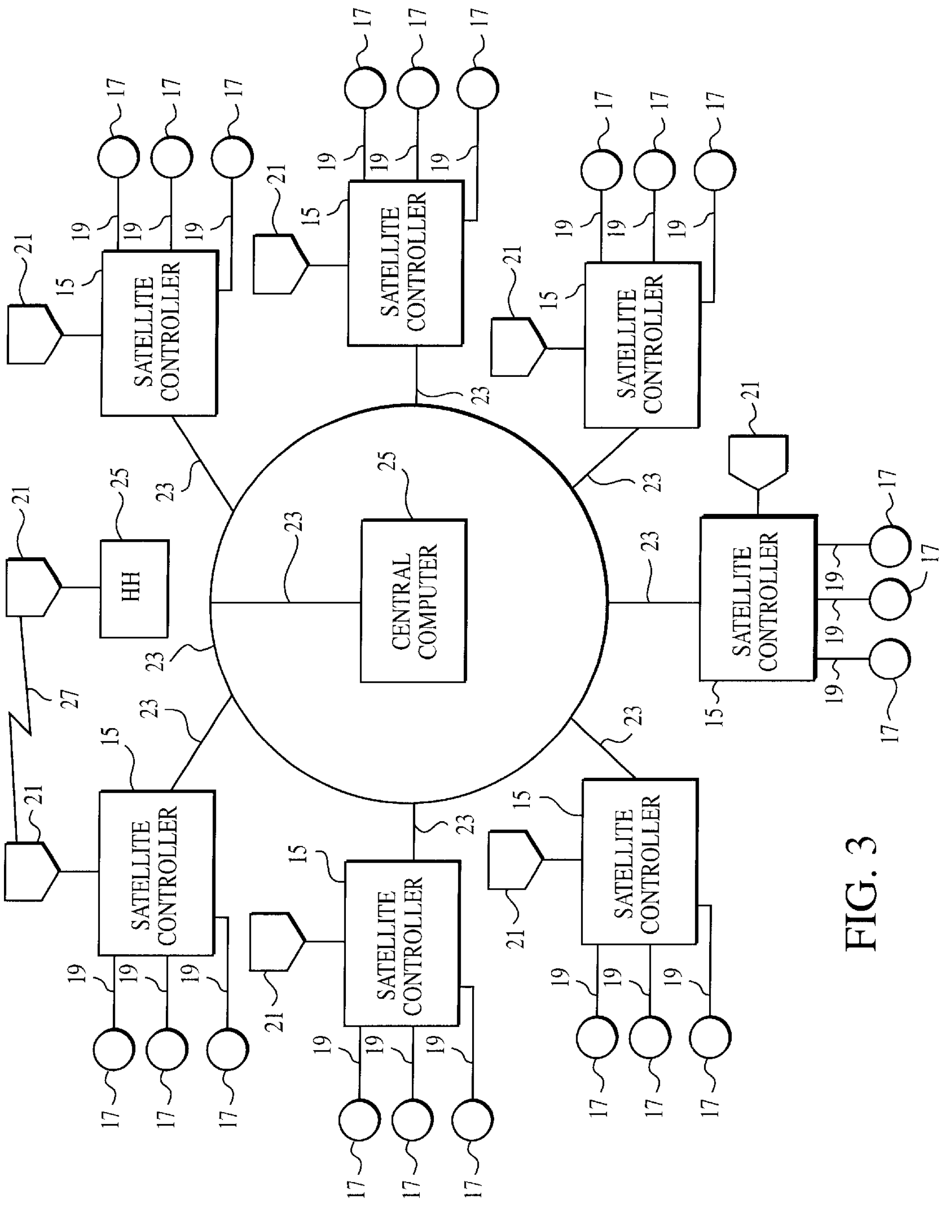

CENTRAL COMPUTER
SATELLITE CONTROLLER
SATELLITE CONTROLLER
SATELLITE CONTROLLER
SATELLITE CONTROLLER
SATELLITE CONTROLLER
SATELLITE CONTROLLER
SATELLITE CONTROLLER
HH
15
17
19
21
23
25
27

FIG. 3

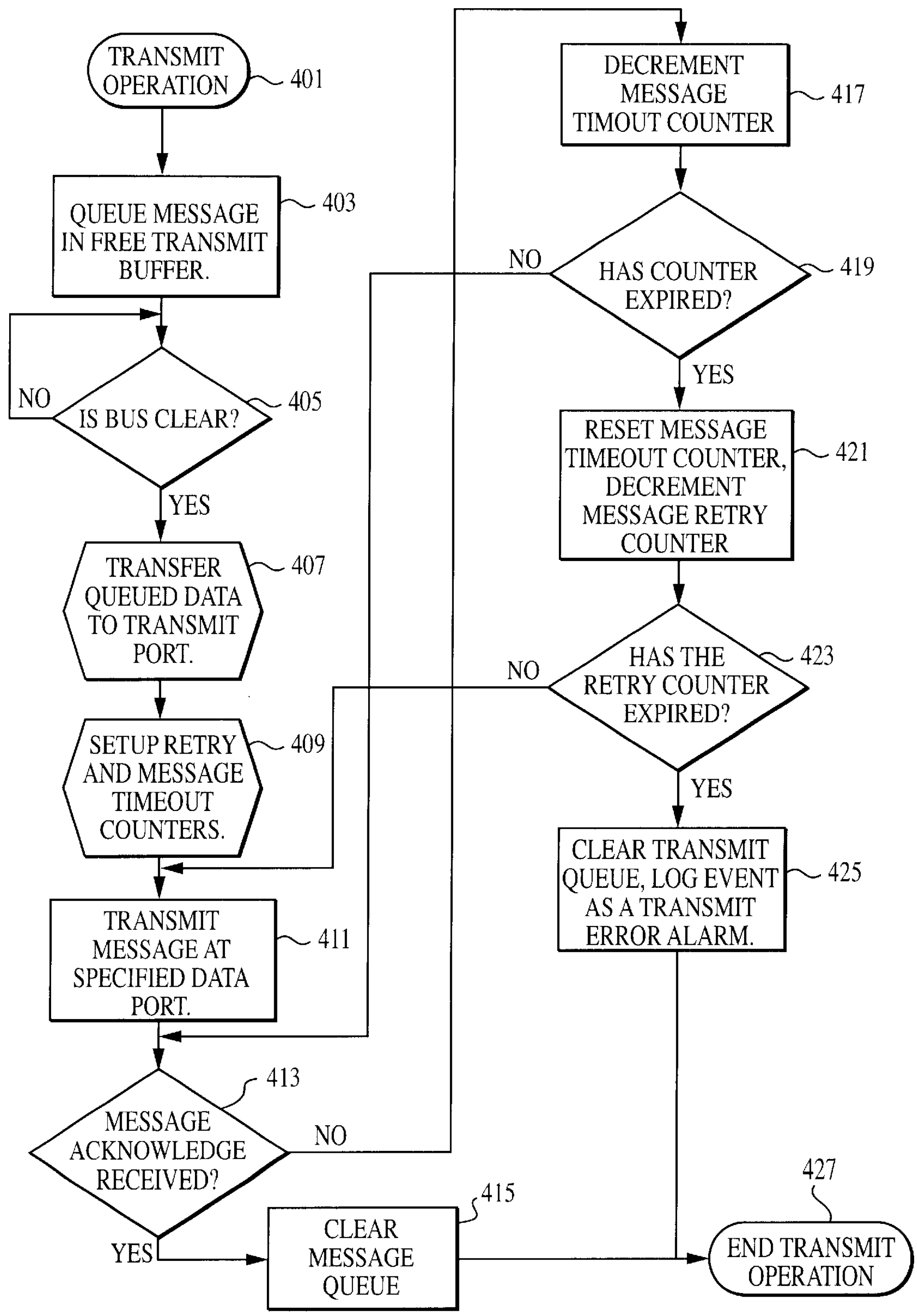

TRANSMIT OPERATION
401
QUEUE MESSAGE IN FREE TRANSMIT BUFFER.
403
NO
IS BUS CLEAR?
405
YES
TRANSFER QUEUED DATA TO TRANSMIT PORT.
407
SETUP RETRY AND MESSAGE TIMEOUT COUNTERS.
409
TRANSMIT MESSAGE AT SPECIFIED DATA PORT.
411
MESSAGE ACKNOWLEDGE RECEIVED?
413
NO
YES
CLEAR MESSAGE QUEUE
415
DECREMENT MESSAGE TIMOUT COUNTER
417
HAS COUNTER EXPIRED?
419
NO
YES
RESET MESSAGE TIMEOUT COUNTER, DECREMENT MESSAGE RETRY COUNTER
421
HAS THE RETRY COUNTER EXPIRED?
423
NO
YES
CLEAR TRANSMIT QUEUE, LOG EVENT AS A TRANSMIT ERROR ALARM.
425
END TRANSMIT OPERATION
427

FIG. 4

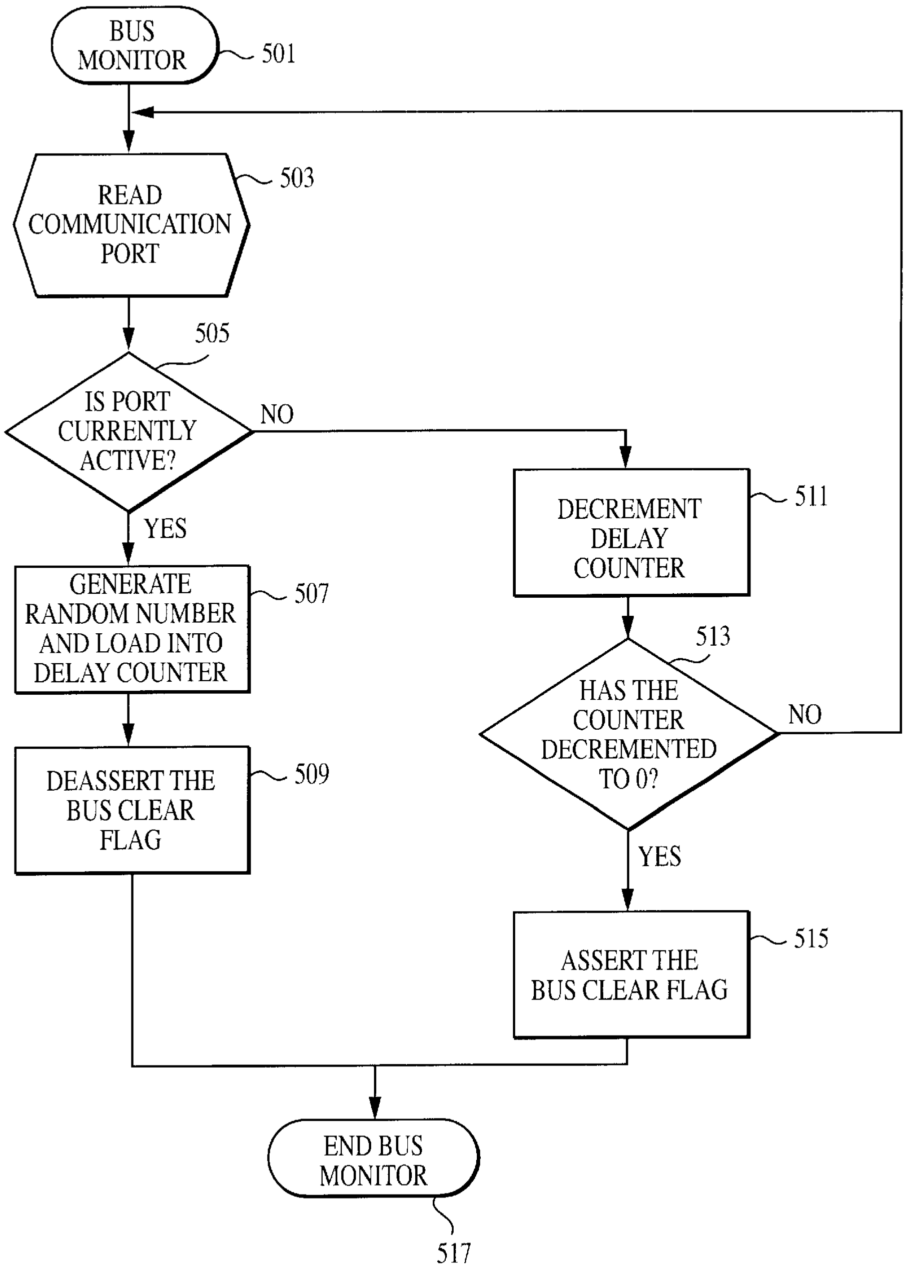

BUS MONITOR
501
READ COMMUNICATION PORT
503
505
IS PORT CURRENTLY ACTIVE?
NO
YES
GENERATE RANDOM NUMBER AND LOAD INTO DELAY COUNTER
507
DEASSERT THE BUS CLEAR FLAG
509
DECREMENT DELAY COUNTER
511
513
HAS THE COUNTER DECREMENTED TO 0?
NO
YES
ASSERT THE BUS CLEAR FLAG
515
END BUS MONITOR
517

FIG. 5

DISTRIBUTED CONTROL NETWORK FOR IRRIGATION MANAGEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an irrigation control system. More particularly, the invention relates to a peer-to-peer irrigation sprinkler control system with the ability to monitor and control the entire system from any satellite controller.

2. Description of the Related Art

In the area of irrigation management and control, there are two significant types of control systems that are used: the stand-alone controller and the central-satellite system. FIG. **1** shows a traditional stand-alone controller **1**, which is typically used for smaller irrigation sites, with outputs varying from four (4) to approximately forty eight (48) outputs. The stand-alone controller **1** is a device that is usually wall mounted, and offers a user interface such as a keypad and a liquid crystal display. With the user interface, a user can set up automatic watering programs, perform manual watering, as well as perform some additional functions for irrigation control.

Connected to the stand-alone controllers **1** are sensors **3** and irrigation solenoid valves **5**. The sensors **3** monitor multiple variables that typically include the amount of rainfall, water flow and power consumption. Then, the sensors **3** provide this data to the stand-alone controller **1**. Also connected to the stand-alone controller **1** are a plurality of valves **5**. The valves **5** are typically 24 VAC solenoid operated valves. The valves **5** are connected to the stand-alone controller **1** with field wiring **7** that delivers the 24 VAC to the valve solenoid.

The stand-alone controller **1** provides valve control and records sensor data as input to various programmable features. The controllers **1** are set-up and programmed via a graphical user interface on the controller. It is known in the art that typical irrigation controllers contain microprocessors as disclosed in U.S. Pat. No. 5,956,248, by Williams et al.

In larger installations, multiple stand-alone controllers must be used because the distance between the controller and valve stations is limited by a maximum amount of tolerable wiring impedance. However, sites that utilize multiple stand-alone controllers are difficult to maintain because they must be managed independently at the location of the installation.

An alternative to the multiple stand-alone controllers solution for large installations is a conventional central-satellite control system shown for example in FIG. **2**. U.S. Pat. No. 4,244,022 entitled "Irrigation Control System " by Kendall, discloses a master-slave type control system for large-scale irrigation that incorporates a central computer **9** connected to a plurality of satellite controllers **11** which are in turn connected to control irrigation solenoid valves. Central-satellite control systems generally consist of various sense and/or control devices linked together via a communication bus **13**. This distributed control methodology allows the management of large sites from a single location. A typical installation will contain multiple field controllers, or satellites **11**, and a single central control center **9**. The central control center is managed by a personal computer **9**.

The satellite controller **11** is a field device, similar to a stand-alone controller, that offers both valve solenoid control and various sensor interfaces. More sophisticated satellites also have a user interface for local programming.

A major difference between the satellite controller **11** and the stand-alone controller **1** is the communication bus **13** interface. The communication bus **13** interface allows the satellites **11** to communicate with the remote central computer **9**. The type of communication bus **13** varies depending on the requirements of each individual site. Typical central-satellite systems use twisted pair wire, radio modems, analog telephone modems, wireless communication (RF VHF, UHF, microwave frequencies), fiber optics, power lines, telephone cables, cellular telephones, infrared, wireless pager systems, or television cables for the communication bus.

In managing large installations, the central-satellite system has some advantages over using multiple stand-alone controllers. The central-satellite system significantly reduces the manpower and level of effort required to maintain a large installation. For example, problems at a satellite location can be instantly reported to the central computer. Also, complex watering schedules can be realized, such as those based on evapotranspiration, by utilizing the computer's graphical user interface and processor capabilities. U.S. Pat. No. 5,208,855 by Marian, discloses one such method and apparatus for irrigation control using evapotranspiration. U.S. Pat. No. 5,870,302 by Oliver discloses a system and method for using evapotranspiration in controlling automated and semi-automated irrigation systems.

Despite the advantages of the central-satellite system, problems still exist with this system. The cost of a central-satellite system can be very high. For example in a smaller site consisting of 5–10 satellite controllers, the costs associated with operating and maintaining a central computer are not feasible, even though a networked solution is preferred. Additionally, there is a large and difficult learning curve for a system operator to fully understand and utilize the capabilities of the system. Moreover, the satellites are mostly simple receivers that can only communicate on the bus when specifically addressed by the central computer.

The Oliver patent discloses that satellite controllers may communicate with other satellite controllers but only to pass data along from a communications and electronic control device. The Oliver patent does not disclose satellite controllers that are capable of monitoring and controlling the entire irrigation control system. Similarly, U.S. Pat. No. 5,740,031 by Gagnon, discloses irrigation controllers that can transmit and receive communications with other irrigation controllers and computer interfaces but in the capacity of a repeater when the central computer can not communicate directly with a controller due to signal attenuation and/or reflection. Again, Gangon does not disclose an irrigation controller capable of monitoring and controlling the entire system. If the central computer fails, then the entire system must operate as individual stand-alone controllers. The present invention provides a system, method and apparatus to meet these needs and address these deficiencies.

BRIEF SUMMARY OF THE INVENTION

The present invention is a system, method and apparatus for managing and controlling irrigation by forming an irrigation control system. The irrigation control system forms a peer-to-peer network of satellite irrigation controllers, as opposed to known master-slave or client-server type systems. The present invention may be monitored and operated from a central computer or at any one of the satellite controllers. The use of peer-to-peer architecture allows any satellite controller to address any other satellite controller. Thus, the user can monitor and control the entire system from any satellite controller, or node in the network. The invention provides peer-to-peer control of the entire system at each satellite controller through the use of a high speed micro-controller.

The present invention can be used to meet any type of irrigation needs. For example, the irrigation control system can be used to irrigate both large and small areas. When the system is used to irrigate large areas, a central computer is connected to the communication bus and becomes part of the peer-to-peer network. The central computer provides the additional computing power needed to manage large irrigation sites. The central computer provides a convenient centralized site, for example, for collecting, downloading and programming information. After two or three controllers, the central computer is a desirable feature. For other smaller irrigation sites, the central computer is not needed. The central computer could be any computer, such as a personal computer.

As mentioned above, each satellite controller utilizes a high-speed micro-controller to accomplish its functions. A flash memory micro-controller is acceptable. A primary responsibility of the micro-controller is to monitor and control the communication bus. The bus is a half-duplex communication bus that allows only one device to transmit at any one time. In order for the peer-to-peer architecture to function, proper bus management is imperative to ensure reliable communication between the devices.

The present invention includes a software algorithm used by the micro-controller to monitor and control the communication bus. The software algorithm minimizes bus collisions and provides a message acknowledgement scheme to the transmitting device providing feedback of a successful transmission. If acknowledgements are not received within a prescribed amount of time, a number of transmit retries can be used until the acknowledgement is detected or the operation is aborted. If the operation is aborted, then an alarm condition is recorded. Furthermore, the messages are packaged into small packets of data, allowing all devices an opportunity to take control of the bus.

In the present invention, the communication bus can take a variety of conventional forms.

One example of flexibility of the peer-to-peer architecture is realized by using a DTMF radio receiver, which receives and decodes tones from handheld radios for remote system control. The DTMF radio receiver is optimally placed at any node in the network. A DTMF message is sent to the receiver and the message is prefaced with a specific satellite controller address. The receiver then forwards the message onto the communication bus and the message is received at the specified satellite controller. (Other conventional systems require a central computer for satellite to satellite communications.)

According to the invention, there is provided a system for operating a distributed control network for irrigation management. There are irrigation controllers, each of the controllers being responsive to a command from an other controller, wherein the controllers are capable of transmitting, receiving and responding to a command, and wherein the controllers can be operated in a local mode via a graphical user interface and in a remote mode via a wireless connection. There is a communication bus, connected to the controllers, wherein the controllers are capable of monitoring commands and the controllers are capable of acknowledging the commands. Also provided is a central computer, connected to the bus, communicating with the controllers via the bus. There are sensing devices connected to each of the controllers. Sprinkler valves are connected to the controllers.

Further in accordance with the invention, there is provided a method for operating a distributed control network for irrigation management. There is a step if initiating a command at one of several irrigation controllers, wherein said controllers are connected to sensing devices and sprinkler valves. There is a step of transmitting the command from the controller to an other controller via a communication bus. There is also a step of monitoring the command on the communication bus by the controller. There is a step of receiving the command at the other controller, acknowledging said command by the other controller, acting on said command by the other controller; and providing a connection from a central computer to the controllers on the communication bus.

These and other objects, features and advantages of the present invention are readily apparent from the following drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a prior art stand alone controller.

FIG. **2** is a block diagram of a prior art Central-Satellite (master-slave or client-server) irrigation control system.

FIG. **3** is a block diagram of a peer-to-peer irrigation control system.

FIG. **4** is a flowchart of a software algorithm used by a micro-controller in satellite controllers to provide a message acknowledgment scheme and to give the transmitter feedback for a successful message transmission.

FIG. **5** is a flowchart of the software algorithm used by the micro-controller to monitor a communication bus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is made to FIG. **3**, which depicts the block diagram of the distributed control network for irrigation management. The control network is a peer-to-peer network wherein the entire system, or any portion thereof, can be monitored and operated from any node in the network. Several satellite controllers **15** are connected to one another, and further connected to a central computer **25**, all via a communication bus **23**. FIG. **3** is not meant to limit the number of satellite controllers **15** that can be connected to the communication bus **23**. The satellite controllers **15** operate as nodes in the peer-to-peer network wherein the entire control system can be monitored and operated.

In the system depicted in FIG. **3**, the satellite controllers **15** perform a variety of functions. The satellite controllers **15** control the solenoid operated valves **17** and interface with various sensors **21**. Any standard solenoid is acceptable. Preferably, the satellite controller can operate up to 96 valves.

The satellite controllers **15** can be operated both locally at the satellite controller and remotely from other devices on the bus **23**. When the satellite controller is in local mode, the satellite controller **15** can operate the valves that feed directly off of that controller. For example, one might operate the satellite controller **15** in local mode, for example, to do maintenance. One might operate the controller in local mode, for example, to do maintenance. Preferably, operating in local mode has no effect on programmed watering schedules. The satellite controllers **15** are operated in local mode advantageously via a graphical user interface attached to the satellite controller **15**. The satellite controller preferably includes an LCD user interface.

In addition to operating in local mode, the satellite controller **15** can be operated in remote mode. When operated remotely, the satellite controller **15** can be monitored and controlled from any node in the network, such as the central computer **25** or any other satellite controller **15**. The satellite controller **15** is typically operated remotely to recognize complex watering schedules such as evapotranspiration. The user can remotely control a satellite controller **15** which in turn can control some or all of the other satellite controllers **15**. Thus, a significant advantage, the ability to share system resources, is realized by utilizing the peer-to-peer architecture. All controllers **15** can be repeaters, and can maintain links to all other controllers. All controllers **15** can read or sense data on any other controller on the bus.

In one variation of the invention, a DTMF radio receiver, which receives and decodes tones from handheld radios for remote systems, can be optimally placed at one of the satellite controllers **15**. The user can send a DTMF message to the receiver that can be addressed to any satellite controller **15**. The DTMF message is prefaced with a satellite address and is forwarded on the bus from the satellite controller **15** with the receiver to the controller that was addressed in the message. Thus, the message is received and forwarded on the bus to the specified satellite controller **15**.

The satellite controllers **15** can perform a variety of functions, whether in local or remote mode. From the controller **15**, the user can manually initiate watering of an irrigation site which overrides any automatic watering schedule. At front controller **15** or another controller on the network, the user can also adjust/review manual operation, sensor review, and watering schedules, at any other controller on the network. Additionally, the satellite controllers **15** can be programmed to realize complex watering schedules based on the input received from its sensors **21** such as evapotranspiration. Additional functions performed by the satellite controllers **15** include, for example, that sensors, programs, control functions can be transmitted onto the network for review, action from, and by any other satellite, central computer, or remote handheld devices.

An appropriate satellite controller is commercially available under the trademark Tora LTD Plus™ or Rainbird Par™, for example. However, other controllers are also adequate and available.

Connected to each satellite controller **15** is a plurality of sprinkler valves **17**. The sprinkler valves **17** are solenoid operated and are connected to the satellite controller **15** via field wiring **19**. The field wiring **19** delivers 24 VAC to the valve solenoids.

Also connected to each satellite controller **15** are various sensors **21** that provide input to the controller **15**. The sensors **21** typically measure rainfall, water flow, water pressure, temperature, wind speed, wind direction, relative humidity, solar radiation, and power consumption.

As shown in FIG. **3**, the satellite controllers **15** are connected indirectly to one another via a communication bus **23**. The type of communication bus **23** can vary depending on the requirements of each individual site. Typical systems will be implemented with twisted pair wire, radio modems, analog telephone modems and so forth. The communication bus **23** is preferably a half-duplex communication bus that allows only one device to transmit at any one time, to avoid data collisions on the bus. Full duplex is an option.

Also shown in FIG. **3** is the central computer **25** that is connected to the communication bus **23**. The central computer **25** can be remotely located from the satellite controllers **15** and has the capability to monitor and operate the entire system. The central computer **25** is typically used for management of large irrigation sites. One advantage of the present invention, is that the central computer **25** is not always necessary. In prior art inventions, the central computer **9** was necessary in order to monitor and control all of the satellite controllers **11** because the satellite controllers **11** were not capable of monitoring and controlling the entire system. However, in the present invention, the monitoring and control functions can be performed at any satellite controller **15**. Thus, the central computer **25** is not necessary for all applications. Typically, the central computer **25** will be present for large irrigation site management and will not be present for smaller irrigation site management. Central computers may poll satellite controllers and then react by adjusting schedules, etc., and to download new schedules. A general purpose computer, such as the IBM™ PC, is appropriate.

FIG. **3** also illustrates a remote device **25**, here a hand held unit. If the central computer **25** becomes disconnected from the bus **23**, or if communications are disrupted, communications can occur via bus **23** and the remote device **25**, via a remote connection **27**.

Referenced in FIG. **4** is a flowchart of an appropriate software algorithm used by the micro-controller in a satellite controller **15** to provide a message acknowledgment scheme and to give the transmitter feedback for a successful message transmission. The algorithm is designed to ensure proper bus management by the micro-controller. Other appropriate algorithms will work, and, indeed, one of skill in the art will appreciate similar algorithms.

Reference is made to FIGS. **3** and **4**. Step **401** is the transmit operation. At step **403**, a message is queued in a free transmit buffer. Step **405** queries whether the communication bus **23** is clear. If the bus **23** is not clear, then step **405** is repeated. If the bus **23** is clear, then the message is transferred from the transmit buffer to a transmit port at step **407**. Next at step **409**, a retry counter and a message timeout counter are set-up. After the counters have been set-up, then step **411** transmits the message from the transmit port to the specified data port. Step **413** queries whether a message acknowledge is has been received. If the message has been acknowledged, then the message queue is cleared at step **415** and the transmit operation ends at step **427**. The bus **23** is then available for other transmissions.

However, if the message has not been acknowledged at step **413**, then it proceeds to step **417** where the message timeout counter is decremented. Step **419** queries whether the timeout counter has expired. If the counter has not expired, then the process goes back to step **411**. If the timeout counter has expired, then step **421** resets the message timeout counter and decrements the message retry counter. Step **423** queries whether the message retry counter has expired. If the retry counter has not expired at step **423**, the process returns to step **411**. If the message retry counter has expired, then step **425** clears the transmit queue and the event is logged as a transmit error alarm. The end transmit operation then occurs at step **427**.

Referenced in FIG. **5** is a flowchart of the software algorithm used by the micro-controller in each satellite controller **15** to monitor the communication bus **23**. Step **501** signals the bus monitor operation. At step **503**, a communication port is read. Step **505** queries whether the port is currently active. If the communication port is currently active, then step **507** generates a random number is loads the number into a delay counter. Step **509** deasserts the bus clear flag. The bus monitor process is ended at step **517**.

However, if the communication port is not active at step **505**, then step **511** decrements the delay counter. Then, step **513** queries whether the delay counter has decremented to zero. If the delay counter is not at zero, then the process goes back to step **503** and repeats the process. If the delay counter is at zero, then step **515** asserts the bus clear flag. Then, the bus monitor process is ended at step **517**.

While the preferred mode and best mode for carrying out the invention have been described, those familiar with the art to which this invention relates will appreciate that various alternative designs and embodiments for practicing the invention are possible, and will fall within the scope of the following claims.

What is claimed is:

1. A peer-to-peer distributed network system for management and/or control of irrigation, comprising:

(A) a plurality of irrigation controllers, each of said irrigation controllers transmitting at least one command to at least one other of said irrigation controllers, and each being responsive to at least one command received from said at least one other controller;

(B) a communication bus connecting each of said irrigation controllers, wherein said at least one command is transmitted from one of said irrigation controllers to said at least one other irrigation controller on said communication bus; and

(C) wherein said at least one transmitted command includes at least one command initiated at said irrigation controller and not repeating said at least one received command.

2. The system claimed in claim **1**, wherein each of said irrigation controllers initiates and transmits a plurality of commands, including said at least one command, on said communication bus.

3. The system claimed in claim **1**, wherein at least one of said irrigation controllers is operated from a remote location via a wireless connection communicating therewith.

4. The system claimed in claim **1**, wherein at least one of said irrigation controllers is operated locally via a user interface connected thereto.

5. The system claimed in claim **1**, wherein at least one of said irrigation controllers monitors said at least one command on said communication bus.

6. The system claimed in claim **1**, wherein at least one of said irrigation controllers, responsive to a receipt of said at least one command from said at least one other irrigation controller, transmits an acknowledgement of said at least one received command to said at least one other irrigation controller on said communication bus.

7. The system claimed in claim **1**, wherein a plurality of commands are transmitted on said communication bus from at least one of said controllers to said at least one other controller, further comprising a bus management scheme to prevent collision of said plurality of commands on said communication bus.

8. The system claimed in claim **1**, further comprising a central computer, wherein said central computer is connected to said irrigation controllers on said communication bus; and said central computer monitors and/or controls at least one of said irrigation controllers.

9. The system claimed in claim **1**, wherein said commands are selected from a group comprising: adjust operation, review operation, sensor review, water schedule, and initiate watering.

10. A method for a peer-to-peer distributed network for management and/or control of irrigation, comprising the steps of:

(A) providing a plurality of irrigation controllers connected via a communication bus, each of said irrigation controllers being responsive to commands received and capable of initiating and transmitting at least one command to at least one other of said irrigation controllers;

(B) transmitting at least one command, from at least one of said irrigation controllers, to said at least one other irrigation controller via the communication bus; and

(C) transmitting a response, responsive to said at least one transmitted command from said at least one irrigation controller and received by said at least one other irrigation controller, from said at least one other irrigation controller to said at least one irrigation controller.

11. The method claimed in claim **10**, further comprising the step of initiating said at least one transmitted command from said at least one irrigation controller to said at least one other irrigation controller.

12. The method claimed in claim **10**, further comprising the step of operating said plurality of irrigation controllers from a remote location via a wireless connection communicating therewith.

13. The method claimed in claim **10**, further comprising the step of operating said plurality of irrigation controllers locally via a graphical user interface connected thereto.

14. The method claimed in claim **10**, further comprising the step of monitoring, in at least one of said irrigation controllers, a plurality of commands including said at least one command on said communication bus.

15. The method claimed in claim **10**, further comprising the step of transmitting an acknowledgement from one of said irrigation controllers, responsive to a receipt of said at least one command from said at least one other controller, from said at least one irrigation controller to said at least one other irrigation controller on said communication bus.

16. The method claimed in claim **10**, further comprising the step of transmitting a plurality of commands including said at least one command on said communication bus from at least one of said irrigation controllers to at least one other of said irrigation controllers; further comprising the step of preventing collision of said plurality of commands on said communication bus.

17. The method claimed in claim **10**, further comprising the step of providing a connection from a central computer to said plurality of irrigation controllers on said communication bus, wherein said central computer monitors and/or controls at least one of said irrigation controllers.

18. The method claimed in claim **10**, wherein said commands are selected from a group comprising: adjust operation, review operation, sensor review, water schedule, and initiate watering.

19. A system for operating a distributed control network for irrigation management, comprising:

(A) a plurality of irrigation controllers, each of said controllers being responsive to a command from an other controller; wherein said controllers are capable of transmitting, receiving and responding to a plurality of commands, and wherein said controllers can be operated in a local mode via a graphical user interface and in a remote mode via a wireless connection;

(B) a communication bus, connected to said controllers, wherein said controllers are capable of monitoring said commands and said controllers are capable of acknowledging said commands;

(C) a central computer, connected to said bus, communicating with said controllers via said bus;

(D) a plurality of sensing devices connected to each of said controllers; and

(E) a plurality of sprinkler valves connected to each of said controllers.

20. A method for operating a distributed control network for irrigation management, comprising the steps of:

(A) initiating a command at one of a plurality of irrigation controllers, wherein said controllers are connected to a plurality of sensing devices, wherein said controllers are connected to a plurality of sprinkler valves, and wherein said command can be a plurality of commands;

(B) transmitting said command from said controller to an other controller via a communication bus;

(C) monitoring said command on said communication bus by said controller;

(D) receiving said command at said other controller;

(E) acknowledging said command by said other controller;

(F) acting on said command by said other controller; and

(G) providing a connection from a central computer to said controllers on said communication bus.

21. A method for providing a peer-to-peer network-enabled irrigation controller, comprising the steps of:

providing an irrigation controller, wherein said irrigation controller is configured to initiate and transmit at least one command to an other irrigation controller; and said irrigation controller is configured to receive a transmission including a command from said other irrigation controller, and to transmit an acknowledgement to said other irrigation controller responsive to the command from said other irrigation controller.

22. A method as claimed in claim **21**, further comprising the step of connecting said irrigation controller to at least one sprinkler valve.

23. A method as claimed in claim **21**, further comprising the step of connecting said irrigation controller to at least one sensing device.

24. A method as claimed in claim **21**, further comprising the step of connecting said irrigation controller to said other irrigation controller via a communication bus.

25. A peer-to-peer network-enabled irrigation controller, comprising:

(A) a plurality of satellite irrigation controllers; and

(B) a communications controller, communicating with each satellite irrigation controller of the plurality of satellite irrigation controllers; wherein the communications controller is a micro-controller in one of said satellite irrigation controllers, and is configured to initiate and transmit at least one command to an other of said irrigation controllers, and said irrigation controller is configured to receive and respond to a transmission including a command from said other irrigation controller.

26. The device as claimed in claim **25**, further comprising a port in said communications controller for communication with a communication bus; wherein the communications controller, responsive to a transmission of an event on the bus, initiates a transmission on the communication bus.

27. The device as claimed in claim **26**, wherein said event is a watering schedule.

28. The device as claimed in claim **26**, further comprising at least one sensor input connected to said satellite irrigation controller, wherein said event is based on an input from said at least one sensor input.

* * * * *

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Majors et al.

(10) Patent No.: US 6,633,786 B1
(45) Date of Patent: Oct. 14, 2003

(54) **IRRIGATION SAFETY CONTROL SYSTEM**

(75) Inventors: **Mark M. Majors**, 4818 Marlborough Dr., Albany, GA (US) 31707; **Anthony B. Deese**, Oakfield, GA (US)

(73) Assignee: **Mark M. Majors**, Albany, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/565,996**

(22) Filed: **May 6, 2000**

Related U.S. Application Data

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(51) **Int. Cl.**[7] **G05B 9/02**

(52) **U.S. Cl.** **700/79**; 700/284; 239/70

(58) **Field of Search** 700/14, 284, 21, 700/79, 282–283; 239/63–64, 67, 69, 70

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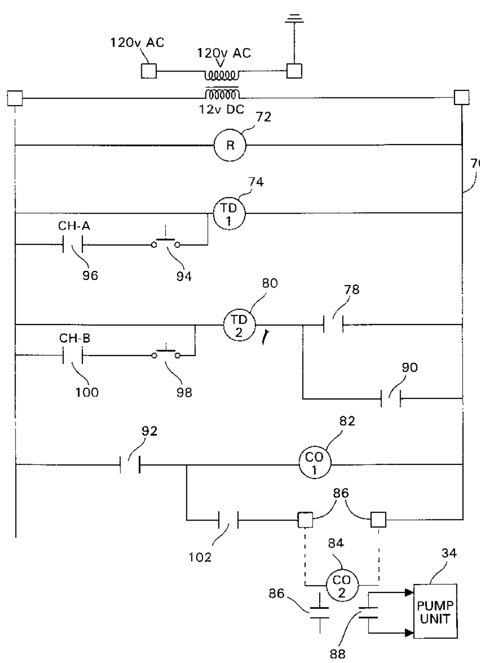
Primary Examiner—John Follansbee
Assistant Examiner—Ronald D Hartman, Jr.
(74) *Attorney, Agent, or Firm*—Brian D. Bellamy

(57) **ABSTRACT**

An safety control system especially useful for controlling the irrigation of crops. The system includes a transmitter having an extended range over two miles. A repeat cycle timer provides a repetitive time delayed input signal to the transmitter which transmits a signal while an irrigation system is operational. A receiver for receives the signal from the transmitter, and a time delay relay latches upon receipt of the signal by the receiver to close a circuit and provide power to a pump unit for a fixed amount of time. If the time delay relay times out without receiving a signal from the transmitter, the irrigation pump unit is shut off.

9 Claims, 4 Drawing Sheets



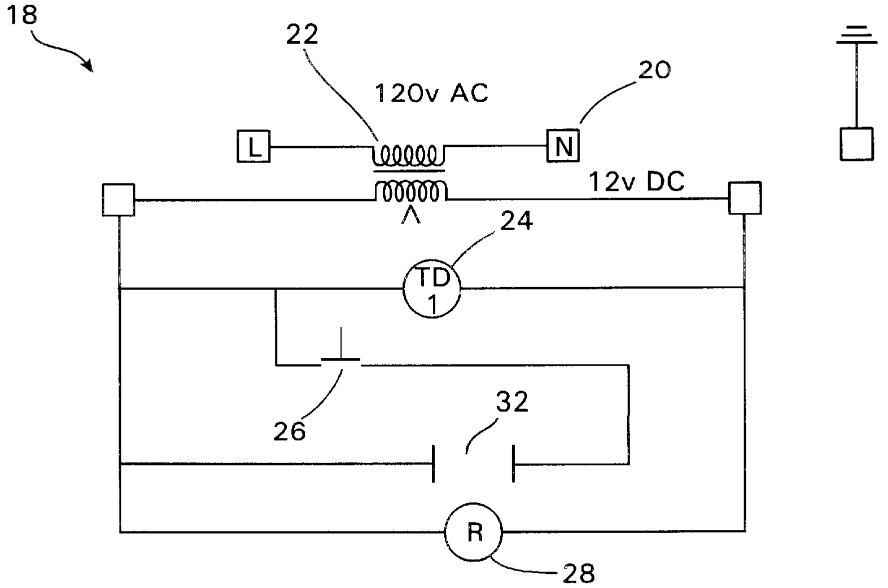


Fig. 1

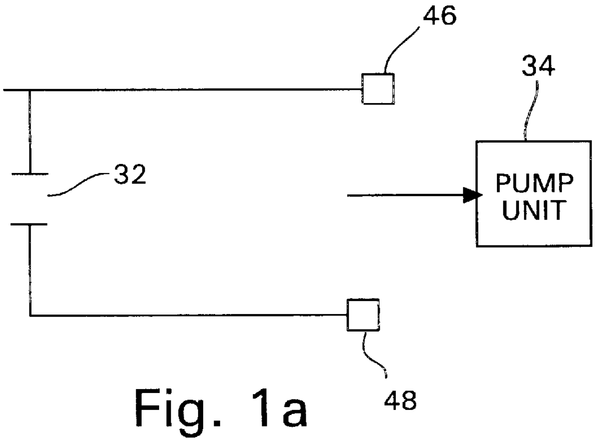


Fig. 1a

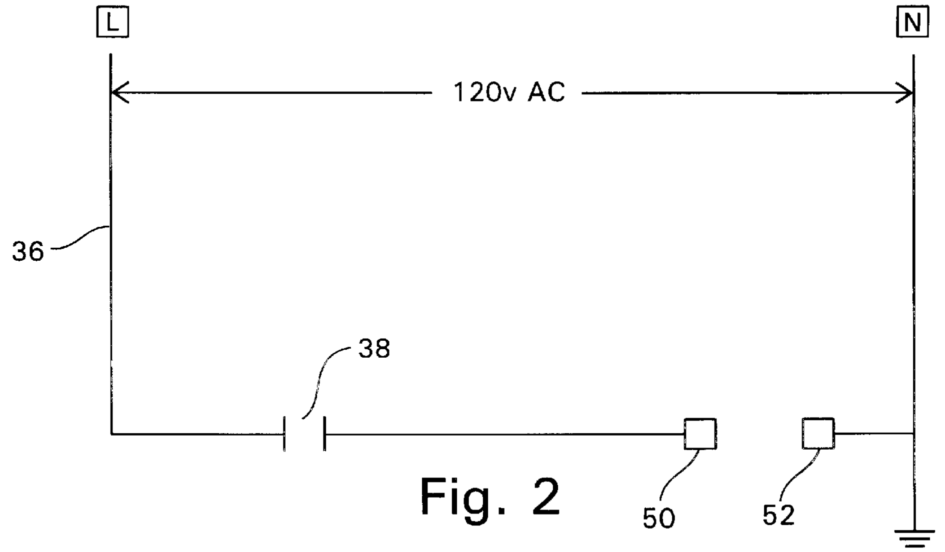


Fig. 2

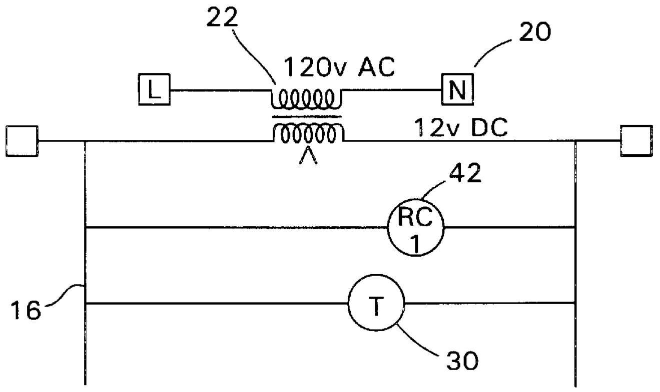


Fig. 3

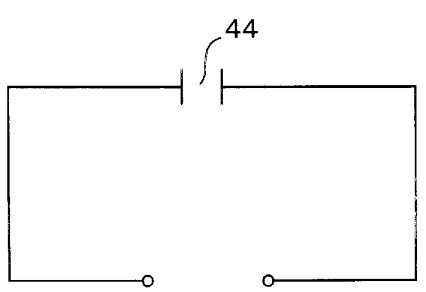


Fig. 3a

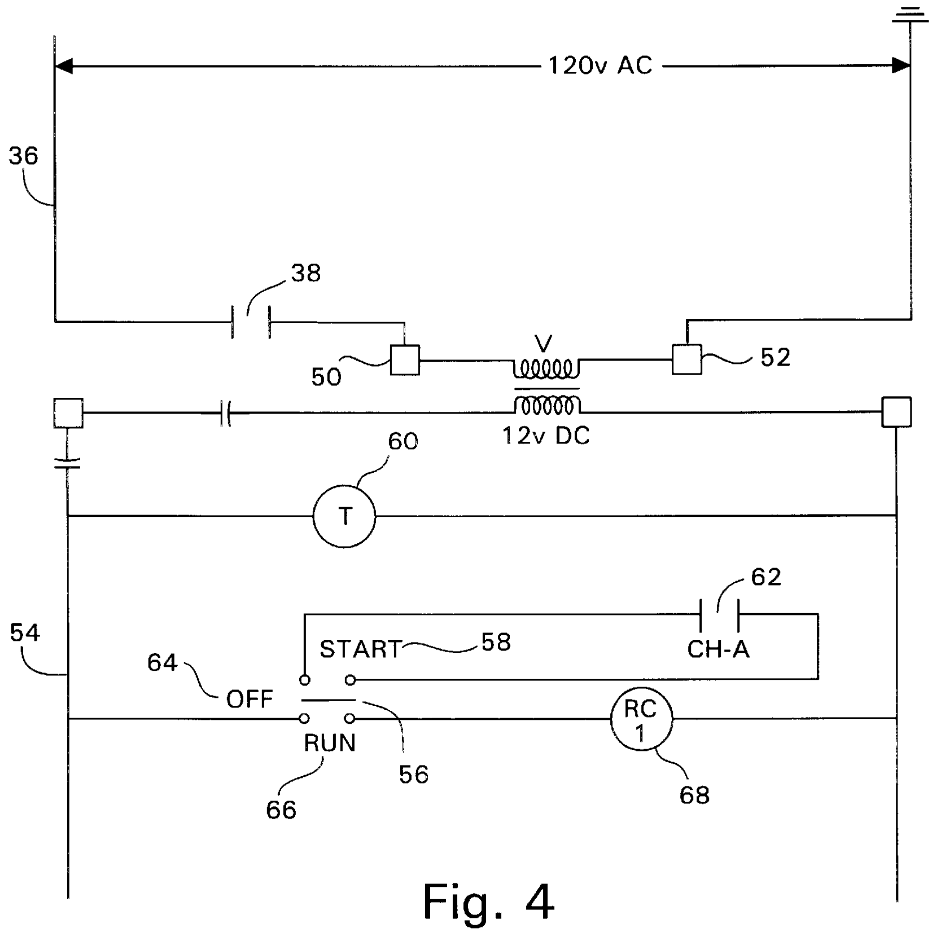

120v AC
36
38
50
V
52
12v DC
60
T
62
54
START
58
CH-A
64
OFF
RC
1
RUN
56
66
68

Fig. 4

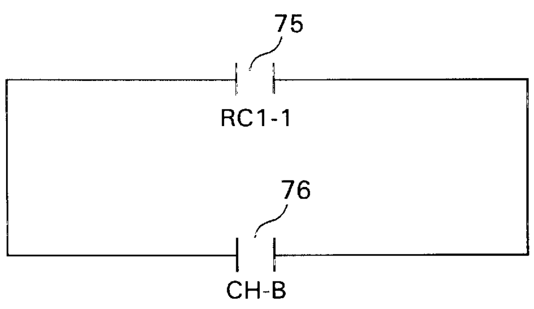

75
RC1-1
76
CH-B

Fig. 4a

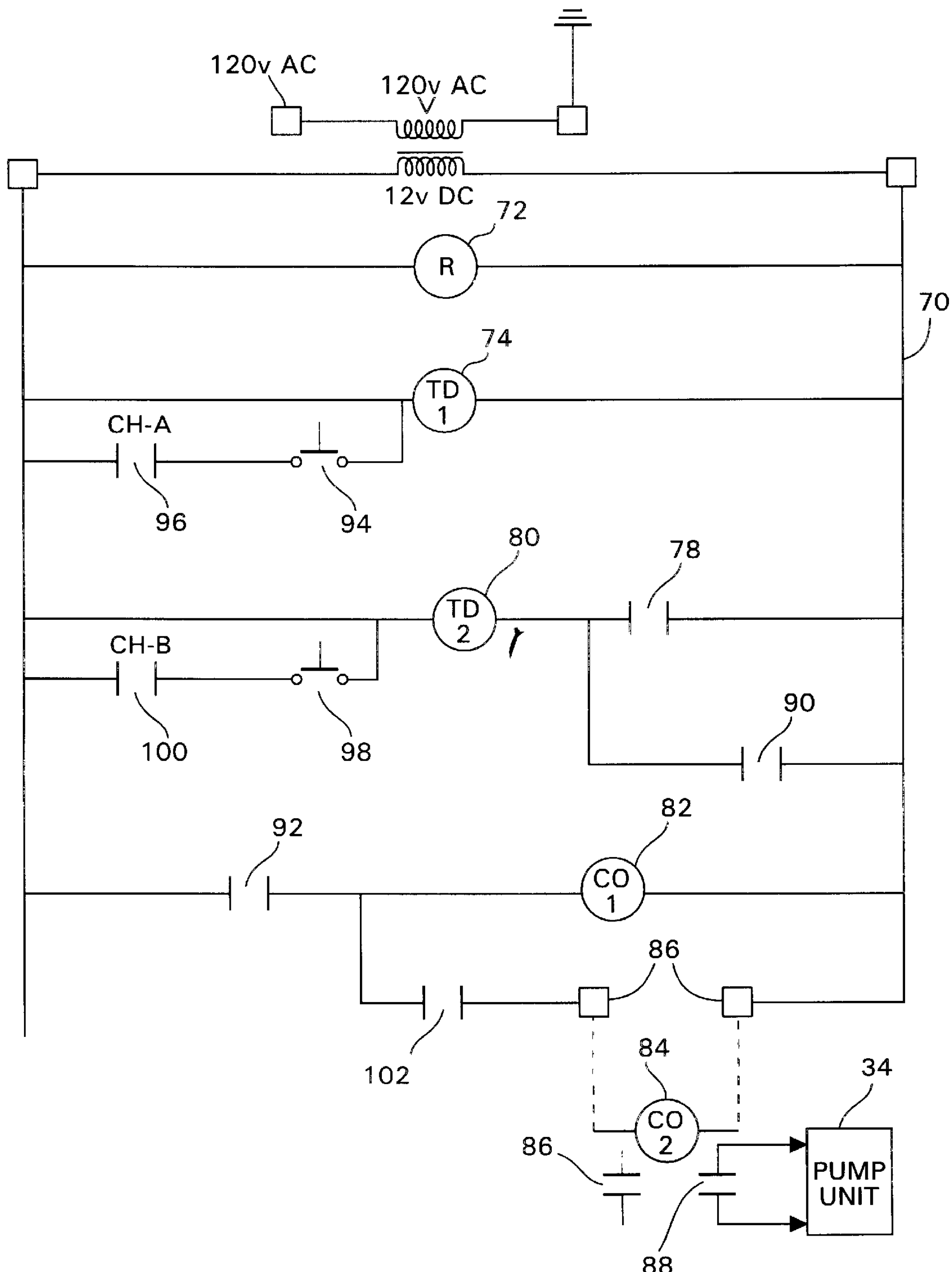

120v AC
120v AC
12v DC
72
R
70
74
TD 1
CH-A
96
94
80
78
TD 2
CH-B
100
98
90
92
82
CO 1
86
102
84
34
CO 2
86
PUMP UNIT
88

Fig. 5

IRRIGATION SAFETY CONTROL SYSTEM

This application claims benefit of provisional application No. 60/133,215 filed May 7, 1999.

BACKGROUND OF THE INVENTION

This invention relates to safety shut-off systems for agricultural irrigation systems, and, more particularly, to an improved wireless safety shut-off system that is reliably operable over an extended range of several miles.

In irrigation systems used in agricultural applications, a typical irrigation system consists of an electrically powered pivot system that circles a field comprising an agricultural crop. The irrigation system further includes a pumping unit that is usually a distance of several thousand feet or even a few miles from the pivot system. To avoid costly damage and wasted resources, the pivot system and pump unit has an automatic shut-off that is triggered by a loss in water pressure, a burn out of underground electrical lines, or a pipe breakage between the pump unit and the pivot system. Malfunctions of the drive motor on the pivot system tower or misalignment of the pivot system could also trigger an automatic shut-off of the pivot system and the pump unit.

In the conditions described, the result could be costly if the pivot system and the pump unit did not shut down properly. For instance, water could run in one place which would result in the system not restarting and could cause the field to erode and damage the crop and hamper harvesting. If an underground pipe broke, a large hole could form in the field that would require costly repairs. If the system was being used to spray nitrogen and the system kept watering, but the system stopped in one place, the nitrogen could harm the crop. Further, a stalled system could cause wastefulness in the use of water, fuel, and chemicals.

In practice, if a farmer does not have an operational safety on his irrigation system, he must operate his system manually with human supervision of the system's operating condition, or he risks severe damage to his crops. Electricity rates are generally cheaper during off-peak hours. Therefore, the farmer must stay awake and supervise the irrigation system at night to reduce costs by taking advantage of the lowest electricity rates.

In the prior art there are wireless type safety systems that are generally being used for water system control and sewage pump stations. However, these wireless systems are generally expensive because of the cost of materials to provide a reliable safety control system. For example, the cost of materials for a safety control system for one irrigation pivot system and one pumping unit would be a minimum of $4000 using known wireless systems. A system this expensive is generally cost prohibitive to farmers.

Other systems have been proposed that use radio waves for switching loads on and off. The systems include a radio transmitter and receiver and work well, except for two major faults. These prior radio wave wireless systems operated by having a transmitter and receiver in the line of sight of each other only. Further, these prior radio wave systems had a range of less than a mile. These disadvantages or faults cause the known methods of using radio waves for irrigation safety control systems to be impracticable because of the distance between a pivot system and a pumping unit in an irrigation system. Other known wireless systems such as cellular communications systems carry costly periodic charges.

The present invention overcomes the above-mentioned and other disadvantages of the prior art systems with a novel and improved wireless safety shut-off system that is reliably operable over an extended range of several miles.

SUMMARY OF THE INVENTION

The present invention provides a wireless irrigation control safety system having a range of two to four miles by using a transmitter operating at 10 watts and providing a 27.255 MHz frequency digital signal. A receiver is provided for receiving said digital signal. The extended range transmitter product used by the present invention is also used in the home security industry. However, this product and receiver did not prove to be very dependable for use in an irrigation control safety system without further improvement. In the known applications using the extended range transmitter and receiver disclosed herein, the transmitter sends one signal to the receiver. If the receiver does not recognize or receive the signal, nothing happens. Experiments found the receiver would fail to receive a signal about 10% of the time, which is an unacceptable fault rate for a critical function such as irrigation system safety control.

In the present invention, a signal is sent every 30 seconds from the transmitter to the receiver. The signal received from the transmitter causes the system to continue running. The signal is used at the receiver to latch a relay in the made position (pump on). This relay starts timing off at an adjustable rate, for example 100 seconds, when a signal is received from the transmitter by the receiver. Every time a signal is sent from the transmitter, the latch relay starts back at timing off at 100 seconds. This latch relay with time delay allows the receiver to miss three signals from the transmitter before the system will safety-off.

Therefore, it is an object of the invention to provide an inexpensive and simple wireless safety shut-off system for agricultural crop irrigation systems.

It is another object of the invention to provide a wireless safety shut-off system that is very reliable.

It is yet another object of the invention is to provide a wireless safety shut-off system having a range of at least two miles.

Still a further object of the invention is to provide a wireless safety shut-off system for agricultural crop irrigation systems that may be packaged and marketed for others to install in the quantity required by the user.

And another object of the invention is to provide a means to replace old safety wiring in agricultural irrigation systems with a reliable wireless safety shut-off system.

The above and other objects, features and advantages of this invention will become more apparent from the following detailed description, when considered in connection with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of the receiver panel of the present invention.

FIG. **1***a* is a schematic view of the relay output of the receiver contained within the receiver panel of FIG. **1**.

FIG. **2** is a schematic view of a typical irrigation system safety circuit.

FIG. **3** is a schematic view of the transmitter switch panel of the present invention.

FIG. **3***a* is a schematic view of the transmitter trigger device contained within the transmitter switch panel of the present invention.

FIGS. **4** and **4***a* are schematic views of a variation of the wireless safety control system of the present invention.

FIG. **5** is a schematic view of a variation of the wireless safety control system of the present invention.

DETAILED DESCRIPTION

FIG. **1** is a receiver panel unit **18** for the wireless safety control system. The receiver panel unit includes a multi-tap hook up terminal **20** for connecting a 120-volt AC power source or a 12-volt DC power source. All of the relays connected to the panel operate on 12-volt DC. Thus, a 120-volt AC to 12-volt DC transformer **22** is installed in each switch or panel to convert power provided at 120-volt AC to 12-volt DC so that the user can hook up to either power source without further action. The above features and others make the safety shut-off system herein one that may be packaged and marketed for others to install.

A time delay off relay **24** is connected to the 12-volt DC source and a switch **26** is provided to initiate contact with the relay **24**. The signal received by a receiver **28** causes the time delay relay **24** to latch an internal solid state latching relay in the made position which causes the pump unit **34** to become and remain activated. Upon latching, the time delay relay **24** starts timing off at an adjustable rate. One-hundred seconds would be a suitable time delay for the relay **24** to time off if a signal is not received by the time delay relay start switch **26**. When a subsequent signal is received from a transmitter **30** by the switch **26**, the relay **24** resets and begins timing again for one-hundred seconds. The one-hundred second time delay permits the system to miss receiving three consecutive signals from the transmitter **30** before the relay **24** will safety-off. The delay process and requirement for the system to miss three consecutive signals before latching off creates a very reliable safety system that does not incur false safety-off occurrences. The preferred embodiment of the invention uses a solid state device **24** that includes a latching relay and a time delay relay in one unit **24**. The solid state time delay relay **24** operates on 12 volts DC and provides a reliable and cost-effective relay. The time delay relay **24** receives its input from an output relay **32** on the radio frequency receiver **28** that receives a signal from the remote transmitter **30**.

The receiver panel unit **18** further includes terminals **46** and **48** that connect to a starter of a pump unit **34** for automatic operation of the pump unit **34** or shut down circuitry of a diesel pump unit **34**. Should the receiver **28** not receive a signal from the transmitter **30** in the one-hundred seconds allotted by the time delay relay **24**, the receiver panel **18** will provide an output and trigger the shut down of the pump unit **34**.

Typically, an irrigation system will include an irrigation control panel **36** located on the pivot system tower near the pivot axis of the pivot system. As shown, the irrigation control panel **36** has a safety circuit **38** with terminals **50** and **52** located on the irrigation control panel **36**.

In the present invention, a transmitter switch panel **16** is connected to the irrigation control panel circuitry **36** and is powered by a 120-volt AC current that is converted to 12-volt DC. The transmitter switch panel **16** includes a repeat cycle solid state timer **42**, labeled RC**1** in FIG. **3**, that operates on the 12-volt DC current and repeats its clock cycle at an interval of time. In the preferred embodiment, the repeat cycle timer **42** provides an on input cycle for two seconds and then times for a thirty second delay before it sends another two second on input cycle signal. These time delays may be set according to the desired application settings. The inventor has found that setting the time delay for fifteen seconds rather than thirty may cause transmitter **30** to overheat because of the transmission frequency. As long as the transmitter switch panel **16** is receiving power from the irrigation system control panel **36**, the on input signal will be generated periodically by the timer **42** and will be carried by the transmitter switch panel circuitry **16** to triggering relay contacts **44** on the transmitter **30** that is connected to the timer **42**. The transmitter triggering contacts **44** are set to the normally open position. Thus, when the on input signal is received by the transmitter **30**, the transmitter contacts **44** close and send a latching signal to the receiver **28**.

FIGS. **4** and **5** represent a variation of the wireless safety control system of the present invention. The system depicted in FIGS. **4** and **5** provide additional improvements to the basic control system unit shown in FIGS. **1** and **3**. In particular, the design illustrated in FIGS. **4** and **5** provides safeguards against false activation signals and isolates the wireless safety system controls from the existing controls on the irrigation system.

The transmitter panel **54** of the irrigation safety control system shown in FIG. **4** includes a three position switch **56**. When the switch is turned left to a start position **58**, the circuit causes the transmitter **60** to transmit a signal at a first channel selection, channel A, by closing the relay **62**, labeled CH-A, on the circuit. In the preferred embodiment of the invention, channel A is set as channel one on the transmitter **60** and receiver **72**. The receiver panel circuitry **70** of FIG. **5** is configured such that a signal on channel A must be received for further operation. The switch **56** may be spring loaded when turned to the left start position **58** so that the switch **56** will automatically return to a middle or off position **64** when released. Transmitting the signal on the first channel, channel A, to the receiver **72** latches a twenty (20) second time delay off relay **74**, labeled TD**1**, located in the receiver panel **70** as shown in FIG. **5**. This gives the user twenty (20) seconds to turn the three position switch **56** to the right to a third position, which is the run position **66**. The time delay of the time delay off relay **74** may be changed according to the users desired specifications.

When the switch **56** is turned to the run position **66** a repeat cycle relay **68**, labeled RC**1** in FIG. **4**, is activated on the transmitter panel **54** causing the auxiliary contacts **75** to close. The repeat cycle relay **68** causes the transmitter **60** to transmit a signal at a second channel selection, channel B, by closing the channel B transmitter contacts **76**, labeled as CH-B, on the transmitter panel circuit **54** of FIG. **4**. In the preferred embodiment of the invention, channel B is set as channel four on the transmitter **60** and receiver **72**. The channel B signal is activated by the repeat cycle relay **68** for two (2) seconds every thirty (30) seconds. The channel B signal cycle is repeated until the irrigation safety control system is turned off or until the safety circuit **38** on the irrigation system pivot control box is kicked out.

As shown in FIG. **5**, when the receiver **72** receives a channel A signal and contacts **96** are closed, the internal switch **94** of time delay off relay **74** is activated and gives the user twenty seconds to turn the switch **56** to the run position **66** and cause the channel B signal to be transmitted to the receiver **72**. During the twenty seconds that the time delay off relay **74** is energized and latched, the contacts **78** of the time delay relay **74** will be closed. If the channel B signal is not received by the receiver **72**, the receiver panel **70** will not provide activation of the irrigation pump unit **34**. However, if the channel B signal is received by the receiver **72**, then the channel B contacts **100** are closed and an internal switch **98** is activated and latches a one-hundred second time delay off relay **80**, labeled as TD**2**. The time delay of the second time delay off relay **80** may be varied according to the users desired settings and the timing of the repeat cycle relay **68** that causes the transmitter **60** to send a signal to the receiver **72**.

Latching the time delay relay **80** activates the control relay **82**, labeled as CO**1**, and closes the contacts **102**. As the time delay off relay **80** is timing off for one-hundred seconds, the transmitter **60** is sending channel B signals to the receiver **72** every thirty (30) seconds as regulated by the repeat cycle relay **68**. Every time the receiver **72** receives the channel B signal time delay off relay **80** resets at one-hundred seconds and begins timing off again. Time delay off relay **74** will time out at the end of 20 seconds, but time delay relay **80** will stay energized because relay **82** is latching the time delay off relay **80** at contacts **90**. Therefore, the receiver **72** will continue to operate until channel B signals are no longer received. The receiver **72** may miss a two signals before the time delay off relay **80** will time out and cause the system shut off. While energized, the relay **82** holds closed a remotely mounted control relay **84**, labeled as CO**2**, through isolated contacts **86** on the control relay **82**. Dry contacts **88** on the control relay **84** are used to operate the pump unit **34**. When channel B signals stop, the time delay off relay **80** will time out and relays **82** and **84** will de-energize causing the isolated contacts **86** and contacts **88** on the control relays **82** and **84** to open and cause the pumping unit **34** to stop.

In the embodiment disclosed, the receiver **28** is the model XR-1 receiver and receiver **72** is the model XR-4 receiver. Both preferred receivers are manufactured by Linear Corporation. The companion transmitters **30** or **60** are the models XT-1 and XT-4, respectively, also manufactured by Linear Corporation. The XR-1 and XR-4 receivers are known for use in various applications where the receiver receives a signal and performs an operation, but is unique in its present application for an irrigation safety control system that is reliable and uses repetitive latching circuitry. The receiver **28** or **72** is used for the present irrigation safety control system because it provides a means for receiving a digital signal from a companion transmitter **30** or **60** over a distance of two to five miles. Further, the transmitters and receivers described may operate without being within the line of sight of each other. The receiver units include two 8-position switches used to set the units' system codes. More than 65,536 codes are possible for the unit. The code set in the receiver is matched to the code of the companion transmitter. These codes may be preset to match the location as not to interfere with other like safety control systems that are nearby. These codes can be easily changed if there is any conflict.

The XT-1 and XT-4 transmitters are extended range FM frequency transmitters that send a 10 watts, 27.255 MHz, digital encoded, FSK modulated, signal to a companion receiver. The transmitters include switches to set one of more than 65,536 codes to coincide with the code set on the receiver described previously.

The component transmitting panels **16** and **54** and receiver panels **18** and **70** of the present invention are enclosed in weatherproof enclosures. Back plates of aluminum or similar heat conductive material may be provided, especially for the transmitter panel **16** or **54**, to act as a heat sink to help cool the panels. Usually the safety system of the present invention will consist of one transmitter panel **16** or **54**, which is located at the irrigation system location (i.e., the pivot system tower), and one receiver panel **18** or **70**, which is located at the pump unit **34** location. Antennas are provided at each location for transmitting and receiving signals generated by the system. The safety system is expandable to accommodate combinations of multiple pivot systems or pump units, according to the farmer's needs. The safety system can include additional receivers assigned complementary tasks such as activating an alarm in the farmer's home, if it is within range of the transmitter, should the pump units shut down.

From the preceding description of the preferred embodiment of this invention, it will be apparent to those skilled in the art that modifications or alterations may be made therein within the scope and spirit of the invention.

We claim:

1. A safety control system comprising:

a transmitter;

a power source for providing power to the transmitter;

a repeat cycle timer that provides a repetitive input cycle separated by a repetitive time delay, the input cycle causes a circuit to close and cause the transmitter that is powered by the power source to transmit a signal during the input cycle;

a receiver for receiving the signal from the transmitter;

a power source for providing power to the receiver;

a time delay relay that latches upon receipt of the signal by the receiver to close a circuit and provide power to a pump unit for a fixed amount of time, and the time delay relay continues to remain latched upon repetitive receipt of the signal by the receiver thereby continuing to close a circuit and continuing to provide power to the pump unit for a subsequent fixed amount of time.

2. The safety control system of claim **1** in which said transmitter can transmit said signal a range of more than one mile.

3. The safety control system of claim **2** in which said transmitter is not required to be in the line of sight of said receiver.

4. The safety control system of claim **1** in which said transmitter can transmit said signal a range of two to five miles.

5. The safety control system of claim **1** in which said repeat cycle timer provides said repetitive input cycle for about two seconds and said repetitive time delay for about thirty seconds.

6. The safety control system of claim **5** in which said fixed amount of time is about one-hundred seconds.

7. The safety control system of claim **1** in which said fixed amount of time is about one-hundred seconds.

8. A safety control system comprising:

a transmitter that can transmit a signal a range of more than two miles;

a power source for providing power to the transmitter;

a repeat cycle timer that provides a repetitive input cycle for two seconds separated by a repetitive time delay of thirty seconds, the input cycle causes a circuit to close and cause the transmitter that is powered by the power source to transmit the signal during the input cycle;

a receiver for receiving the signal from the transmitter;

a power source for providing power to the receiver;

a time delay relay that latches for one-hundred seconds upon receipt of the signal by the receiver to close a circuit and provide power to a pump unit;

whereby the time delay relay will time out after one-hundred seconds if the signal is not received by the receiver and power to the pump unit will be removed.

9. A safety control system comprising:

a transmitter;

a power source for providing power to the transmitter;

a three position switch having a start position, an off position, and a run position in which engaging the switch in the start position causes the transmitter to transmit a signal on a first channel and engaging the switch in the run position causes the transmitter to transmit a signal on a second channel;

a repeat cycle timer that provides a repetitive input cycle separated by a repetitive time delay, the input cycle causes a circuit to close and cause the transmitter that is powered by the power source to transmit the signal on the second channel only during the input cycle;

a receiver for receiving the signal on the first channel and the signal on the second channel from the transmitter;

a power source for providing power to the receiver;

a first time delay relay that latches upon receipt of the signal on the first channel by the receiver to close a circuit and provide a first fixed amount of time for the receipt of the signal on the second channel;

a second time delay relay that initially latches only upon receipt of the signal on the second channel by the receiver within the first fixed amount of time and continues to latch upon the additional receipt of the signal on the second channel by the receiver to close a circuit and provide power to a pump unit for a second fixed amount of time.

* * * * *

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Ton et al.

(10) **Patent No.: US 6,701,665 B1**
(45) **Date of Patent: Mar. 9, 2004**

(54) **REMOTE PHYTOMONITORING**

(75) Inventors: **Yuri Ton**, Ashkelon (IL); **Zohar Ben-Ner**, Doar Na Hof Aza (IL)

(73) Assignee: **Phytech Ltd.**, Kibbutz Yad Mordechai (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 20 days.

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(52) **U.S. Cl.** **47/58.1**; 47/17
(58) **Field of Search** 47/17; 395/800; 364/130, 550, 132, 555.01; 374/135; 709/203

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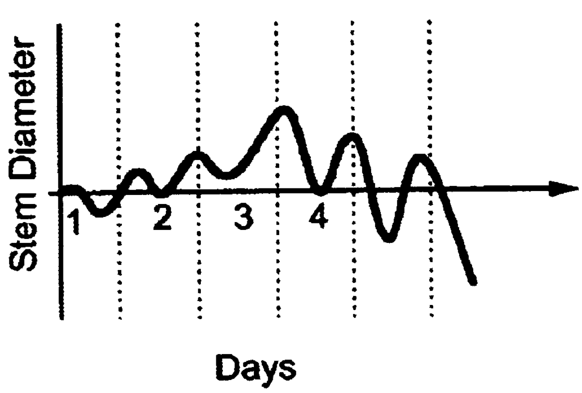
Primary Examiner—Peter M. Poon
Assistant Examiner—Bethany L Griles
(74) *Attorney, Agent, or Firm*—G. E. Ehrlich (1995) Ltd.

(57) **ABSTRACT**

A system for remote monitoring of plants is provided. The system includes (a) at least one sensor positioned on, or in proximity to, a plant, the at least one sensor being for collecting data pertaining to at least one plant related parameter; (b) at least one user client being for receiving and optionally processing the data from the at least one sensor to thereby determine a state of the plant; and (c) a communication network being for communicating the data from the at least one sensor to the at least one user client.

10 Claims, 4 Drawing Sheets



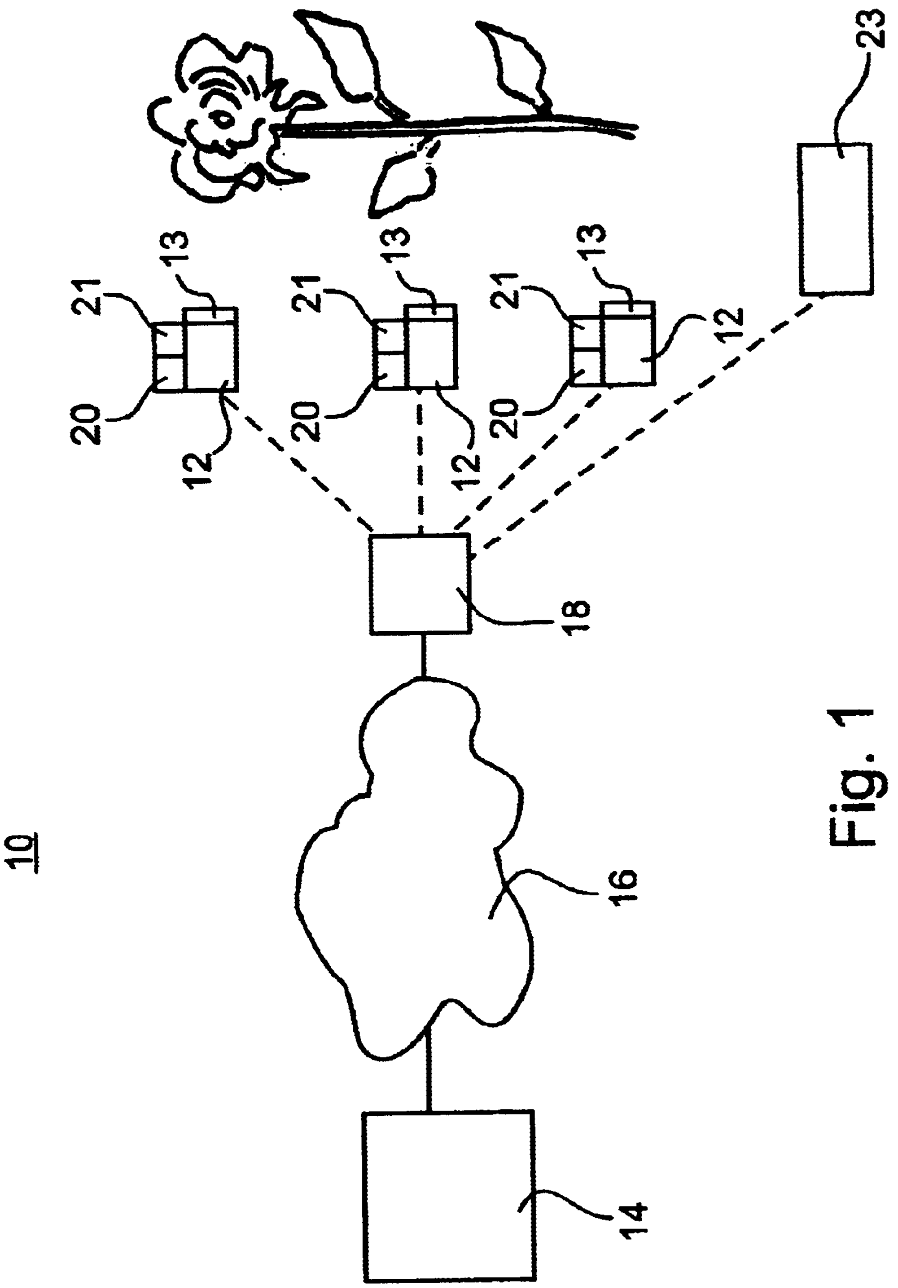


Fig. 1

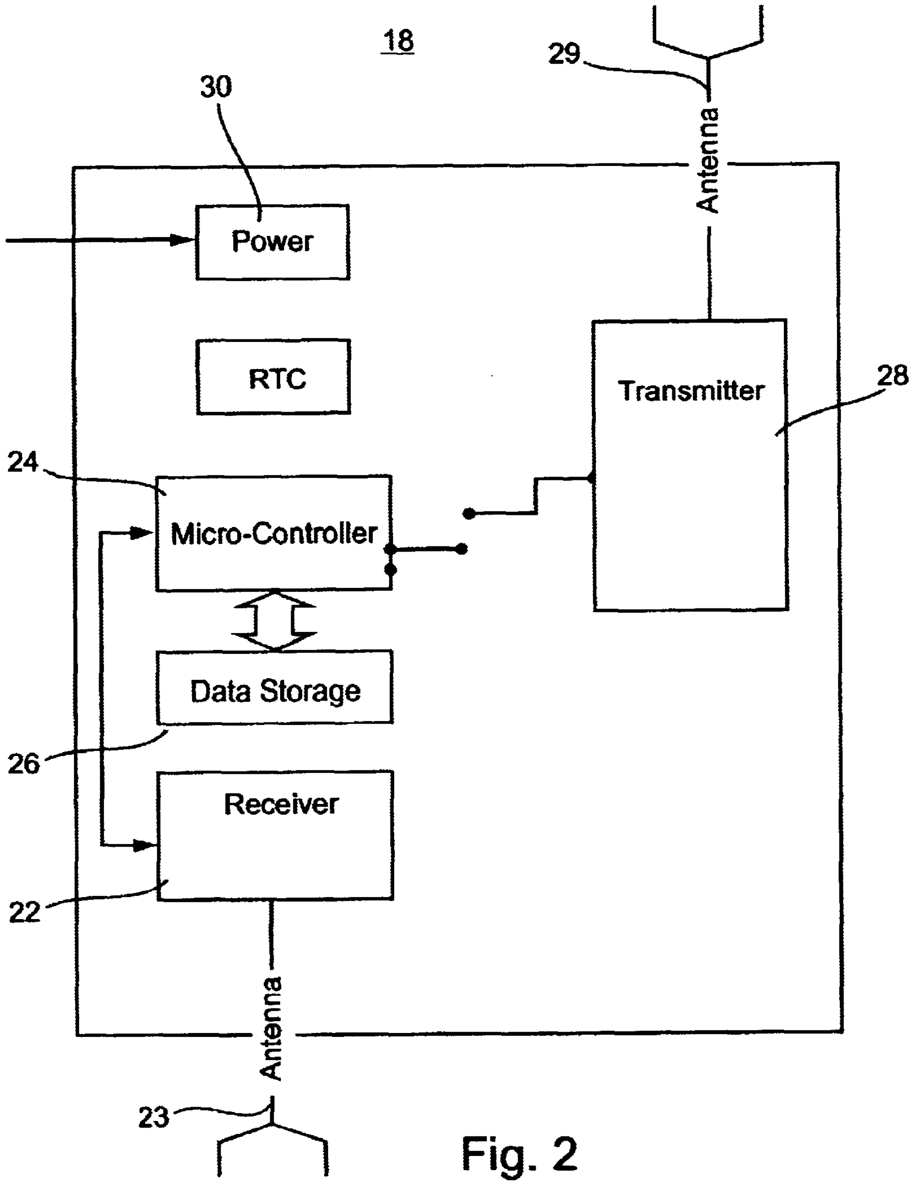

18
29
30
Antenna
Power
RTC
Transmitter
28
24
Micro-Controller
Data Storage
26
Receiver
22
Antenna
23

Fig. 2

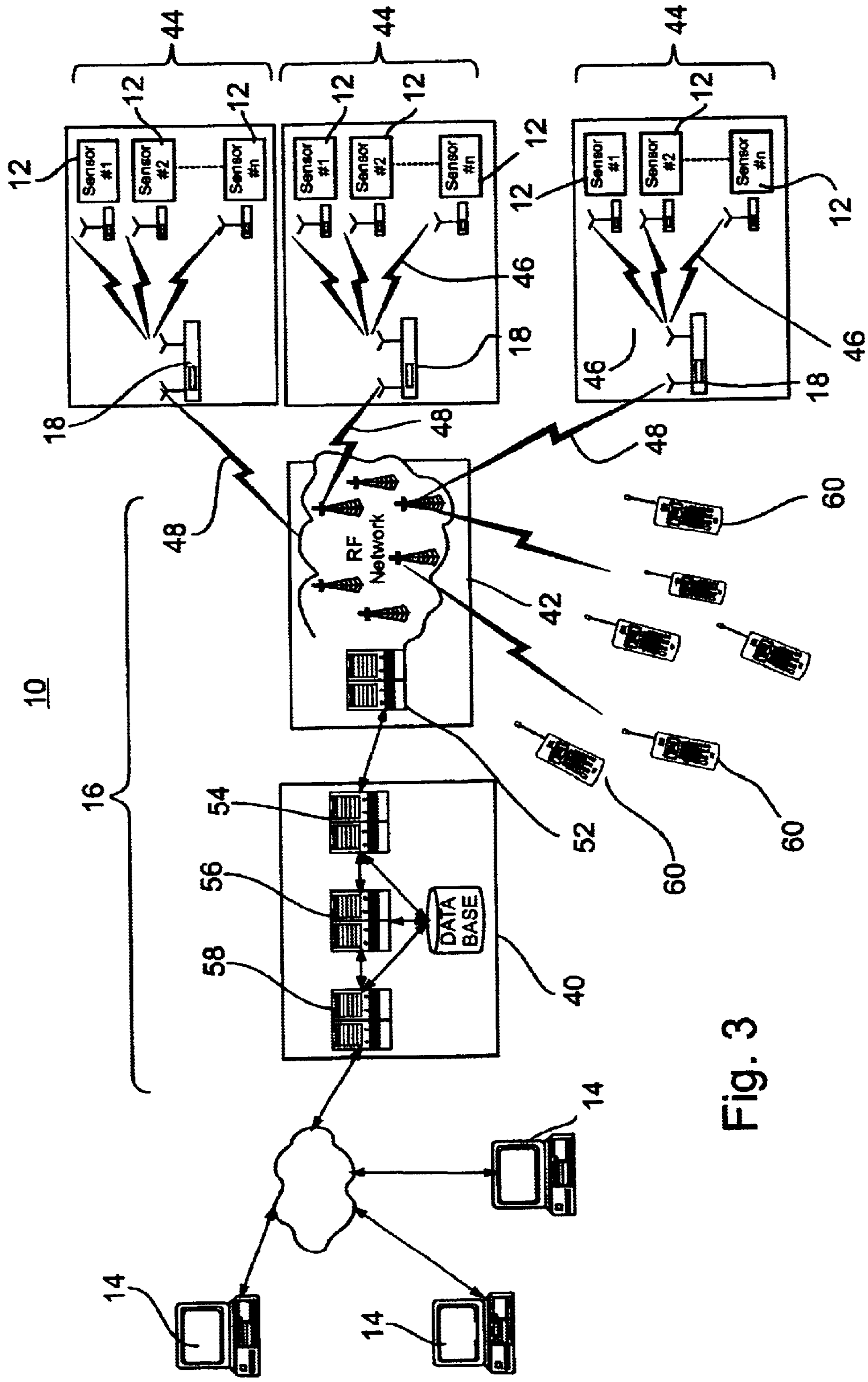

10
16
44
12
Sensor #1
Sensor #2
Sensor #n
18
46
48
RF Network
42
52
54
56
58
DATA BASE
40
60
14

Fig. 3

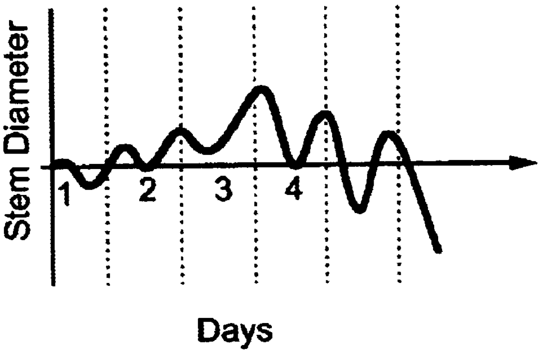


Fig. 4

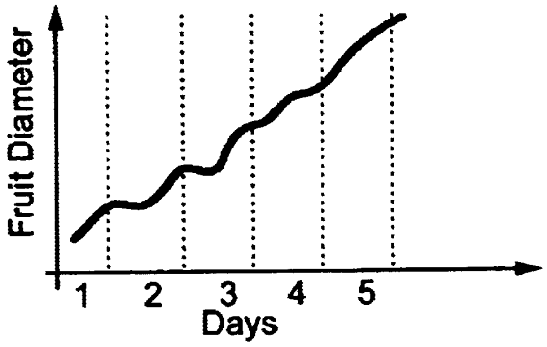


Fig. 5

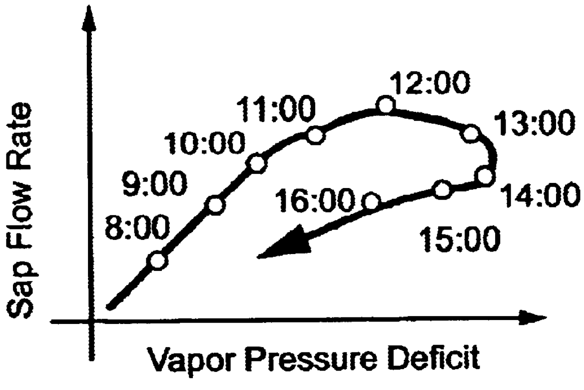


Fig. 6

REMOTE PHYTOMONITORING

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a system and method for remote phytomonitoring and, more particularly, to a system and method which enable a grower to monitor and optionally control plant growth from a remote location.

Cultivation of commercial crops depends on the monitoring of various parameters of a plant or field. For example, maintaining the correct hydration, which is dependent on several factors including irrigation, scheduling and the like is crucial for the proper development of plants and as such, precise monitoring of the hydration, at any given stage of development is advantageous.

In the past growers have mainly relied on their intuition and expertise in assessing crop conditions. This expertise relied mainly on crop and soil inspection and observing the environmental conditions in which the crop was cultivated.

In recent years, growers have increasingly utilized systems and devices which include arrays of precise sensors for measuring the temperature and humidity and other related parameters of the environment and/or soil proximal to the cultivated plants.

The advent of such precise monitoring technologies and methodologies enabled growers to track and record changes in a field or greenhouse enabling close monitoring, in some cases, of a single plant.

For example, recorded sensor data can be analyzed and the resultant data incorporated into a plant hydration profile, such a profile can then be used to assess crop condition and development through daily and seasonal changes. For further details see, for example, Wolf, B. Diagnostic Technique for Improving Crop Production, Haworth Press, P. 185–187.

Although such methodology has substantially enhanced phytomonitoring, it is still difficult to use since it requires periodical on-site collection of the data recorded by the sensors, a task which can be difficult to achieve in cases of large and remote crops.

In addition, the data provided to a grower utilizing present day systems and methods is presented as numerical data. Such presentation can often be difficult to perceive and analyze and as such requires an experienced operator to decipher.

There is thus a widely recognized need for, and it would be highly advantageous to have, a remote phytomonitoring system and method devoid of the above limitation.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a system for remote monitoring of plants comprising: (a) at least one sensor positioned on, or in proximity to, a plant, the at least one sensor being for collecting data pertaining to at least one plant related parameter; (b) at least one user client being for receiving and optionally processing the data from the at least one sensor to thereby determine a state of the plant; and (c) a communication network being for communicating the data from the at least one sensor to the at least one user client.

According to further features in preferred embodiments of the invention described below, the at least one sensor is selected from the group consisting of an air humidity detector, an air temperature detector, a boundary diffusion layer resistance detector, a solar radiation detector, a soil moisture detector and a soil temperature detector.

According to still further features in the described preferred embodiments the at least one sensor is selected from the group consisting of a leaf temperature detector, a flower temperature detector, a fruit surface temperature detector, a stem flux relative rate detector, a stem diameter variation detector, a fruit growth rate detector and a leaf CO_2 exchange detector.

According to still further features in the described preferred embodiments the at least one sensor includes at least one environmental sensor selected from the group consisting of an air humidity detector, an air temperature detector, a boundary diffusion layer resistance detector, a solar radiation detector, a soil moisture detector and a soil temperature detector, and at least one plant sensor selected from the group consisting of a leaf temperature detector, a flower temperature detector, a fruit surface temperature detector, a stem flux relative rate detector, a stem diameter variation detector, a fruit growth rate detector and a leaf CO_2 exchange detector.

According to still further features in the described preferred embodiments the at least one sensor includes a transmitter being for transmitting a signal including the data.

According to still further features in the described preferred embodiments the at least one sensor includes a receiver being for receiving a command signal.

According to still further features in the described preferred embodiments the at least one sensor includes a data storage device being for storing the collected data.

According to still further features in the described preferred embodiments the communication network is selected from the group consisting of a telephone network, a cellular telephone network, a computer network and a satellite network.

According to still further features in the described preferred embodiments the communication network integrates wire and wireless communication.

According to still further features in the described preferred embodiments the at least one sensor includes a plurality of sensors each being in communication with the at least one user client.

According to still further features in the described preferred embodiments the system further comprising a data concentrator being in communication with each of the plurality of sensors and being for relaying the data collected thereby to the at least one user client.

According to still further features in the described preferred embodiments the communication between the data concentrator and each of the plurality of sensors is effected via wire or wireless communication.

According to still further features in the described preferred embodiments the wireless communication is selected from the group consisting of infrared communication, and radiofrequency communication.

According to still further features in the described preferred embodiments the at least one user client is selected from the group consisting of a PDA and a computer.

According to still further features in the described preferred embodiments the system further comprising at least one device being in communication with the at least one user client via the communication network, the device being for modifying the state of the plant or crop including the plant.

According to still further features in the described preferred embodiments the device is selected from the group consisting of an irrigation device and a climate controller.

According to another aspect of the present invention there is provided a method of remote monitoring of plants comprising the steps of: (a) collecting on-site data pertaining to at least one plant related parameter; (b) relaying the data to a remote user client via a communication network; and (c) processing the data to thereby determine a state of the plants.

According to still further features in the described preferred embodiments step (a) is effected by at least one sensor positioned on, or in proximity to, a plant.

According to still further features in the described preferred embodiments the communication network is selected from the group consisting of a telephone network, a cellular telephone network, a computer network and a satellite network.

According to still further features in the described preferred embodiments the communication network integrates wire and wireless communication.

According to yet another aspect of the present invention there is provided a phytosensor comprising: (a) a sensing unit being for collecting data pertaining to a plant related parameter; and (b) a transmitter being for generating a signal including the data.

According to still further features in the described preferred embodiments the phytosensor further comprising a data storage device being for storing the data collected by the sensing unit.

According to still further features in the described preferred embodiments the data collected by the sensing unit is selected from the group consisting of air humidity data, air temperature data, wind speed or boundary diffusion layer resistance data, solar radiation data, soil moisture data, soil temperature data, leaf temperature data, flower temperature data, fruit surface temperature data, stem flux relative rate data, stem diameter variation data, fruit growth rate data and leaf CO_2 exchange data.

The present invention successfully addresses the shortcomings of the presently known configurations by providing a phytomonitoring system which enables a grower to monitor and optionally control plant growth from a remote location.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

FIG. **1** illustrates one embodiment of the system for remote monitoring of plants according to the teachings of the present invention;

FIG. **2** is a schematic depiction of the data concentrator utilized by the system of the present invention;

FIG. **3** illustrates another embodiment of the system for remote monitoring of plants according to the teachings of the present invention;

FIG. **4** is a graph illustrating plant stem diameter variation as a function of time;

FIG. **5** is a graph illustrating fruit diameter variation as a function of time; and

FIG. **6** is a graph illustrating sap flow rate as a function of vapor pressure deficit.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a phytomonitoring system and method which can be used to determine a state of a plant or a crop from a remote location.

The principles and operation of the present invention may be better understood with reference to the drawings and accompanying descriptions.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

Referring now to the drawings, FIG. **1** illustrates the system for remote monitoring of plants which is referred to hereinunder as system **10**.

System **10** includes one or preferably a plurality of sensors **12**, each positioned on, or in proximity to, a plant such as a greenhouse grown plant or a field grown plant. Each of sensors **12** is preferably self powered by a power source such as, for example, a battery provided with, for example, a solar panel for recharging.

Each of sensors **12** serves for collecting data pertaining to a specific plant related parameter. Such data is collected by these sensors from the plant environment and/or from the plant itself. Examples of parameter data include but are not limited to, air humidity data, air temperature data, wind speed or boundary diffusion layer resistance data, solar radiation data, soil moisture data, soil temperature data, leaf temperature data, flower temperature data, fruit surface temperature data, stem flux relative rate data, stem diameter variation data, fruit growth rate data and leaf CO_2 exchange data.

Such data is collected either continuously or preferably periodically by sensors **12** and preferably stored in a data storage device **13** thereof. Storage device **13** can be, for example, a magnetic storage device such as a RAM chip.

System **10** further includes at least one user client **14** which serves for receiving and optionally processing the data collected by sensors **12**.

As used herein, the phrase "user client" generally refers to a computer and includes, but is not limited to, personal computers (PC) having an operating system such as DOS, Windows, OS/2™ or Linux, Macintosh™ computers; computers having JAVA™-OS as the operating system; and graphical workstations such as the computers of Sun Microsystems™ and Silicon Graphics™, and other computers having some version of the UNIX operating system such as AIX™ or SOLARIS™ of Sun Microsystems™; or any other known and available operating system; personal digital assistants (PDA), cellular telephones having Internet capabilities (e.g., wireless application protocol, WAP) and Web TVs.

For purposes of this specification, the term "Windows™" includes, but is not limited to, Windows2000™, Windows95™, Windows 3.x™ in which "x" is an integer such as "1", Windows NT™, Windows98™, Windows CE™ and any upgraded versions of these operating systems by Microsoft Corp. (USA).

System **10** also includes a communication network **16** which facilitates the communication of data from sensor **12** to client **14**.

Communication network can be a computer, telephone (e.g. cellular) or satellite network or any combination thereof. For example, communication network **16** can be a combination of a cellular network and a computer network (e.g. the Internet) as specifically shown in FIG. **3** which is described in detail hereinbelow.

Thus, system **10** of the present invention enables communication of sensor data to remote client **14**, to thereby enable an operator of client **14** which is remote from the plant to receive such data. The state of the plant, which can be a disease state, growth state, hydration state and the like or the state of a crop including the plant, can then be determined by data processing or by simply comparing sensor data collected over a period of time.

For example, as is specifically shown in FIG. **4**, data collected over time from a stem diameter variation sensor (e.g., SD-5, Phytech LTD., Israel) can be utilized to construct a hydration and growth state curve.

Since stem diameter variation is affected by the water state of a plant, measurement of stem diameter over time can provide an indication of plant state. Thus, a general positive trend in stem diameter is indicative of normal plant hydration and growth (days 1, 2 and 3), while a negative trend can be indicative of suboptimal plant hydration (following day 4).

Fruit diameter variation can also serve as an indication of plant state. For example, as is specifically shown in FIG. **5**, a tomato fruit growth data obtained over time by a Fruit Growth Sensor (e.g., FI-3EA, Phytech LTD., Israel) can be utilized to construct a plant state curve.

Thus, the fruit diameter shrinkage observed during days 2 and 3 can be indicative of a physiological disorder or water stress, while the normal fruit diameter variation observed during days 4 and 5 indicates normal plant state and ample watering.

A diurnal interrelation between sap flow rate and air vapor pressure deficit (Air VPD) can also be utilized to asses a plant's state. For example, as is specifically shown in FIG. **6**, data obtained from a sap flow sensor (e.g., SF-4, Phytech, LTD., Israel) and an air temperature and humidity sensor (ATII-3, Phytech, LTD., Israel) can be utilized to construct a water state curve.

The linear curve observed from 8:00 till 12:00 is evidence of unlimited transpiration, while the loop-like diurnal curve observed from 12:00 on, is indicative of reduced transpiration which is most likely due to stomatal response.

Sensor provided data and/or analysis results, such as the graphs illustrated by FIGS. **4**–**6**, are preferably communicated to an operator via a display of user client **14**.

Preferably, the numerical, graph, or table presented results are displayed in a manner which is easily comprehended by the operator. For example, various color schemes, or additional audio data can be utilized to enhance results of importance.

According to a preferred embodiment of the present invention, system **10** further includes a data concentrator **18**, which communicates with each of sensors **12**. Data concentrator **18** serves for collecting sensor data and relaying such data to client **14** via communication network **16**. A detailed description of concentrator **18** is given hereinunder with reference to FIG. **2**.

According to another preferred embodiment of the present invention, communication between sensors **12** and concentrator **18** is effected via RF communication although direct wire communication can also be utilized.

To this end, each of sensors **12** include a transmitter **20** which serves for generating an RF signal which includes the sensor collected (and optionally stored) data described above.

Preferably, each of sensors **12** also include a receiver **21** which serves for receiving a command signal from concentrator **18**; receiver **21** can be integrated with transmitter **20** into a single transceiver device. Such a command signal can either originate from client **14** or from concentrator **18** and serves for initiating data collection from a sensor **12**, for verifying sensor integrity and the like.

As is specifically shown in FIG. **2**, to receive sensor data, concentrator **18** includes a receiver **22** provided with an antenna **23**. Upon receipt, the signal is processed by microcontroller **24** and optionally stored in data storage **26**. Following collection of signals from various sensors **12**, concentrator **18** transmits a signal, via transmitter **28** and antenna **29**, which signal includes the sensor collected data. Preferably, transmitter **28** includes a modem capable of communicating with a public wireless network such as a cellular network. Transmitter **28** can also serve for generating the command signal described above.

Concentrator **18** also includes a power source **30** which serves for powering the various functions of concentrator **18**. Power source **30** can be, for example, a Wall-mounted transformer of 120/240 AC 24 VAC or 120/240 AC 12 VDC of 1000 mA. In such a case, concentrator **18** also includes a voltage regulator in order to stabilize logic and transmitter/receiver power. Alternatively, power source **30** can be a battery rechargeable via a solar panel.

The signal produced by concentrator **18** is relayed by communication network **16** to client **14** and utilized for determining a state of a plant as described above. Thus, concentrator **18** serves as a router for routing data collected by any number of sensors **12** to client **14**.

Preferably, concentrator **18** also serves for mapping sensors **12** communicating therewith. This feature of concentrator **18** enables automatic registration and operation of a sensor **12** which is added to a particular plant or sensor set.

According to another preferred embodiment of the present invention, system **10** can also be utilized to modify the state of the plant monitored or the crop including the plant monitored according to the monitored sensor data.

As is specifically shown in FIG. **1**, and according to this preferred embodiment, system **10** further includes a device **23** which communicates with client **14** via communication network **16** and preferably concentrator **18**. Device **23** can be, for example, an irrigation device, a climate controller, a pruning device and/or any other device capable of modifying the state of the plant or crop including same.

FIG. **3** illustrates one specific configuration of system **10**. According to this configuration, system **10** utilizes a computer network **40** and a cellular network **42** for communication between concentrators **18** and clients **14**.

This configuration illustrates data collection from three concentrators **18** each collecting data from a sensor set **44** including three sensors **12**. A signal collected by each sensor **12** of sensor set **44** is relayed to a specific concentrator **18** via an RF signal **46**. Following accumulation of data from sensor set **44** over a predetermined period of time (e.g. a day), concentrator **18** relays a signal **48** including the accumulated sensor data to a receiver **50** of cellular communication network **42**. This signal is routed by a communication server **52** of cellular network **42** to a communication server **54** of computer network **40**.

The data is then processed by an application server **56** and displayed or communicated to client(s) **14** via server **58**.

Preferably, computer network **40** is the World Wide Web and as such, server **58** is a Web server capable of storing and displaying a Web site. In this case, an operator of client **14** can view the data collected from the sensors via a Web browser program operating in client **14**.

Processing of data to enable determination of the plant state can be effected either by application server **56** or by client **14** using client stored software or Web server **58** provided on-line analysis tools.

It will be appreciated that when processing is effected by application server **56**, alerts of plant state (e.g. hydration state) can be issued to portable device **60** (e.g. cell phone or beeper) of an operator either automatically or on demand. This feature of system **10** enables an operator which is away from client **14** to still track and monitor plant state.

It will further be appreciated that automatic processing also enables automatic control over device **23** described hereinabove with reference to FIG. **1**.

As used herein, the term "Web site" is used to refer to at least one Web page, and preferably a plurality of Web pages, virtually connected to form a coherent group of interlinked documents.

As used herein, the term "Web page" refers to any document written in a mark-up language including, but not limited to, HTML (hypertext mark-up language) or VRML (virtual reality modeling language), dynamic HTML, XML (extended mark-up language) or related computer languages thereof, as well as to any collection of such documents reachable through one specific Internet address or at one specific World Wide Web site, or any document obtainable through a particular URL (Uniform Resource Locator).

As used herein, the phrase "Web browser" or the term "browser" refers to any software application which can display text, graphics, or both, from Web pages on World Wide Web sites. Examples of Web browsers include, Netscape navigator, Internet Explorer, Opera, iCab and the like.

Thus, the present invention enables remote monitoring of plants or crops. By carefully selecting plants as crop standards, and by relaying the sensor data collected therefrom to an operator situated anywhere on the globe, the system of the present invention enables a grower to track crops grown in remote location over extended time periods. In addition, the system of the present invention enables a grower to similarly track the state of the crop via a portable communication device, such as a cellular phone.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. All publications, patents, and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention.

What is claimed is:

1. A method of remote monitoring of a field grown crop, the method comprising:

(a) collecting on-site data pertaining to at least one plant derived parameter selected from the group consisting of a leaf temperature, a flower temperature, a fruit surface temperature, a stem flux relative rate, a stem diameter variation, a fruit growth rate and a leaf CO_2 exchange;

(b) relaying said data to a remote user client via a communication network; and

(c) processing said data to thereby determine a state of the crop.

2. The method of claim **1**, wherein step (a) is effected by at least one sensor positioned on a plant of the crop.

3. The method of claim **1**, wherein said communication network is selected from the group consisting of a telephone network, a cellular telephone network, a computer network and a satellite network.

4. The method of claim **1**, wherein said communication network integrates wire and wireless communication.

5. The method of claim **1**, wherein step (a) is effected by at least one sensor positioned in proximity to said plant of the crop.

6. A method of remote monitoring of a greenhouse grown crop, the method comprising:

(a) collecting on-site data pertaining to at least one plant derived parameter selected from the group consisting of a leaf temperature, a flower temperature, a fruit surface temperature, a stem flux relative rate, a stem diameter variation, a fruit growth rate and a leaf CO_2 exchange;

(b) relaying said data to a remote user client via a communication network; and

(c) processing said data to thereby determine a state of the greenhouse grown crop.

7. The method of claim **6**, wherein step (a) is effected by at least one sensor positioned on a plant of the greenhouse grown crop.

8. The method of claim **6**, wherein said communication network is selected from the group consisting of a telephone network, a cellular telephone network, a computer network and a satellite network.

9. The method of claim **6**, wherein said communication network integrates wire and wireless communication.

10. The method of claim **6**, wherein step (a) is effected by at least one sensor positioned in proximity to a plant of the crop.

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