5. The system of Claim 1, wherein the correction data comprises a position correction representing a comparison between a position fix based on the first position signals and the known position coordinates of the reference positioning receiver.

6. The system of Claim 1, wherein:

the first position signals comprise time-of-arrival data received by the reference positioning receiver from a plurality of satellites; and

the correction data comprises pseudorange corrections for each satellite.

7. The system of Claim 1, further comprising:

a memory coupled to the mobile unit, the memory operable to store map data; and

a display coupled to the mobile unit, the display operable to display the location of the mobile unit and the map data.

8. The system of Claim 1, further comprising a central controller coupled to the mobile unit, the central controller operable to receive the location of the mobile unit.

9. The system of Claim 1, wherein the mobile unit is mounted on a vehicle.

10. The system of Claim 1, wherein the mobile unit is housed in a portable, hand-held housing.

11. The system of Claim 1, wherein the mobile unit further comprises:

a mobile communications device in communication with the cellular telephone network, the mobile communications device operable to receive correction data transmitted by the transmitter site;

a mobile positioning receiver coupled to the mobile communications device, the mobile positioning receiver operable to receive second position signals from the positioning system; and

a processor coupled to the mobile communications device and the mobile positioning receiver, the processor operable to determine the location of the mobile unit in response to the second position signals received from the mobile positioning receiver and the correction data received from the mobile communications device.

12. A locating system using a mobile communications network and a positioning system, comprising:

a reference positioning receiver having known position coordinates and operable to receive first position signals from the positioning system, the reference positioning receiver further operable to generate correction data in response to the first position signals and the known position coordinates;

a first transmitter site of the mobile communications network coupled to the reference positioning receiver;

a second transmitter site of the mobile communications network coupled to the first transmitter site, the second transmitter site operable to transmit correction data received from the first transmitter site; and

a mobile unit in communication with the second transmitter site and the positioning system, the mobile unit operable to receive correction data transmitted by the second transmitter site, the mobile unit further operable to receive second position signals from the positioning system and to determine the location of the mobile unit in response to the second position signals and the correction data.

13. The system of Claim 12, further comprising a communications link coupled to the first and second transmitter sites, the communications link operable to receive correction data from the first transmitter site and to transmit the correction data to the second transmitter site.

14. The system of Claim 12, wherein the second transmitter site transmits the correction data in a control channel.

15. The system of Claim 12, wherein the reference positioning receiver is mounted on the first transmitter site.

16. The system of Claim 12, wherein the known position coordinates of the reference positioning receiver are based on data received by the reference positioning receiver over a statistically significant period of time.

17. The system of Claim 12, wherein the correction data comprises a position correction representing a comparison between a position fix based on the first position signals and the known position coordinates of the reference positioning receiver.

18. The system of Claim 12, wherein:

the first position signals comprise time-of-arrival data received by the reference positioning receiver from a plurality of GPS satellites; and

the correction data comprises pseudorange corrections for each GPS satellite.

19. The system of Claim 12, further comprising:

a memory coupled to the mobile unit, the memory operable to store map data; and

a display coupled to the mobile unit, the display operable to display the location of the mobile unit and the map data.

20. The system of Claim 12, further comprising a central controller coupled to the mobile unit, the central controller operable to receive the location of the mobile unit.

21. The system of Claim 12, wherein the mobile unit is mounted on a vehicle.

22. The system of Claim 12, wherein the mobile unit is housed in a portable, hand-held housing.

23. The system of Claim 12, wherein the mobile unit further comprises:

a mobile communications device in communication with the cellular telephone network, the mobile communications device operable to receive correction data transmitted by the second transmitter site;

a mobile positioning receiver coupled to the mobile communications device, the mobile positioning receiver operable to receive second position signals from the positioning system; and

a processor coupled to the mobile communications device and the mobile positioning receiver, the processor operable to determine the location of the mobile unit in response to the second position signals received from the mobile positioning receiver and the correction data received from the mobile communications device.

24. An apparatus for locating a vehicle within the service area of a cellular telephone network and a positioning system, comprising:

a positioning receiver on the vehicle and operable to receive first position signals from the positioning system;

a mobile communications device on the vehicle and coupled to a transmitter site of the cellular telephone network, the mobile communications device operable to receive correction data transmitted by the transmitter site; and

a processor on the vehicle and coupled to the positioning receiver and the mobile communications device, the controller operable to determine the location of the vehicle in response to the first position signals and the correction data.

25. The apparatus of Claim 24, wherein the mobile communications device receives the correction data in a control channel transmitted by the transmitter site of the cellular telephone network.

26. The apparatus of Claim 24, further comprising:

a memory coupled to the processor, the memory operable to store map data; and

a display coupled to the processor, the display operable to display the location of the vehicle and the map data.

27. The apparatus of Claim 24, further comprising a central controller coupled to the mobile communications device, the central controller operable to receive the location of the vehicle.

28. The apparatus of Claim 24, wherein the correction data comprises a position correction.

29. The apparatus of Claim 24, wherein the correction data comprises pseudorange corrections from a plurality of satellites in the positioning system.

30. A method for locating a mobile unit within the service area of a cellular telephone network and a positioning system, comprising:

receiving first position signals from the positioning system at a reference positioning receiver having known position coordinates;

generating correction data in response to the first position signals and the known position coordinates;

receiving correction data at a cellular transceiver in the mobile unit;

receiving second position signals from a positioning system at a mobile positioning receiver in the mobile unit; and

determining the location of the mobile unit in response to the second position signals and the correction data.

31. The method of Claim 30, wherein the correction data is received at the cellular transceiver in a control channel.

32. The method of Claim 30, wherein the correction data comprises a position correction representing a comparison between a position fix based on the first position signals and the known position coordinates of the reference positioning receiver.

33. The method of Claim 30, wherein:

the positioning system comprises a plurality of satellites; and

the correction data comprises pseudorange corrections for each satellite.

34. The method of Claim 30, further comprising the step of displaying the location of the mobile unit on a map.

35. The method of Claim 30, further comprising the step of receiving the location of the mobile unit at a remote location.

36. The method of Claim 30, wherein the positioning system is GPS.

37. A system for locating a mobile unit within the service area of a mobile communications network, comprising:

a plurality of transmitter sites within the mobile communications network, each transmitter site operable to transmit time-of-arrival data, each transmitter site having known position coordinates;

a mobile communications device on the mobile unit and coupled to the transmitter sites, the mobile communications device operable to receive time-of-arrival data transmitted by at least three transmitter sites;

a memory on the mobile unit and operable to store known position coordinates of the transmitter sites; and

a processor on the mobile unit and coupled to the mobile communications device and the memory, the processor operable to receive time-of-arrival data from the mobile communications device, the processor further operable to determine the position of the mobile unit in response to the time-of-arrival data received from the transmitter sites and the known position coordinates of the transmitter sites stored in the memory.

38. The system of Claim 37, wherein the transmitter sites are associated with a cellular telephone system.

39. The system of Claim 37, wherein the transmitter sites simultaneously transmit time-of-arrival data.

40. The system of Claim 37, wherein the controller is operable to determine the position of the mobile unit using triangulation techniques.

41. The system of Claim 37, wherein the transmitter sites furnish time-of-arrival data in response to a request by the mobile unit.

42. The system of Claim 37, wherein time-of-arrival data contains information relating to the time of transmission of the time-of-arrival data from the transmitter sites.

43. The system of Claim 37, further comprising a clock coupled to the transmitter sites, the clock operable to synchronize the transmission of time-of-arrival data from the transmitter sites.

44. A system for locating a mobile unit within the service area of a mobile communications network, comprising:

a plurality of transmitter sites within the mobile communications network, each transmitter site operable to transmit time-of-arrival data and known position coordinates associated with each transmitter site;

a mobile communications device on the mobile unit and coupled to the transmitter sites, the mobile communications device operable to receive time-of-arrival data and known position coordinates transmitted by at least three transmitter sites; and

a processor on the mobile unit and coupled to the mobile communications device, the processor operable to receive time-of-arrival data and known position coordinates from the mobile communications device, the processor further operable to determine the position of the mobile unit in response to the time-of-arrival data and the known position coordinates.

45. The system of Claim 44, wherein the transmitter sites are associated with a cellular telephone system.

46. The system of Claim 44, wherein the transmitter sites simultaneously transmit time-of-arrival data and known position coordinates.

47. The system of Claim 44, wherein the controller is operable to determine the position of the mobile unit using triangulation techniques.

48. The system of Claim 44, wherein the transmitter sites furnish time-of-arrival data and known position coordinates in response to a request by the mobile unit.

49. The system of Claim 44, wherein time-of-arrival data contains information relating to the time of transmission of the time-of-arrival data from the transmitter sites.

50. The system of Claim 44, further comprising a clock coupled to the transmitter sites, the clock operable to synchronize the transmission of time-of-arrival data and known position coordinates from the transmitter sites.

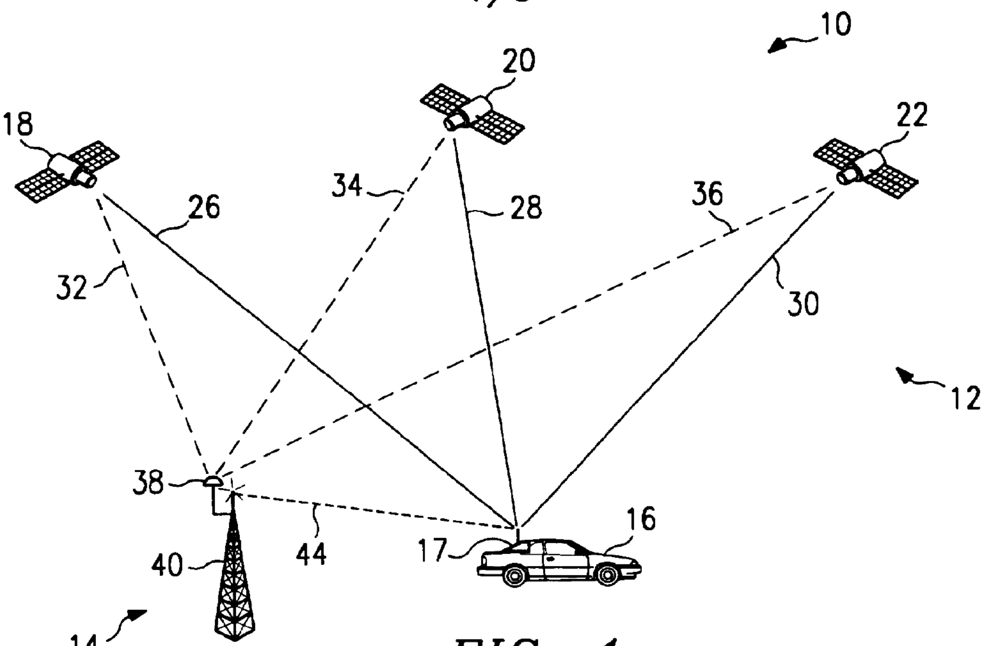
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FIG. 1

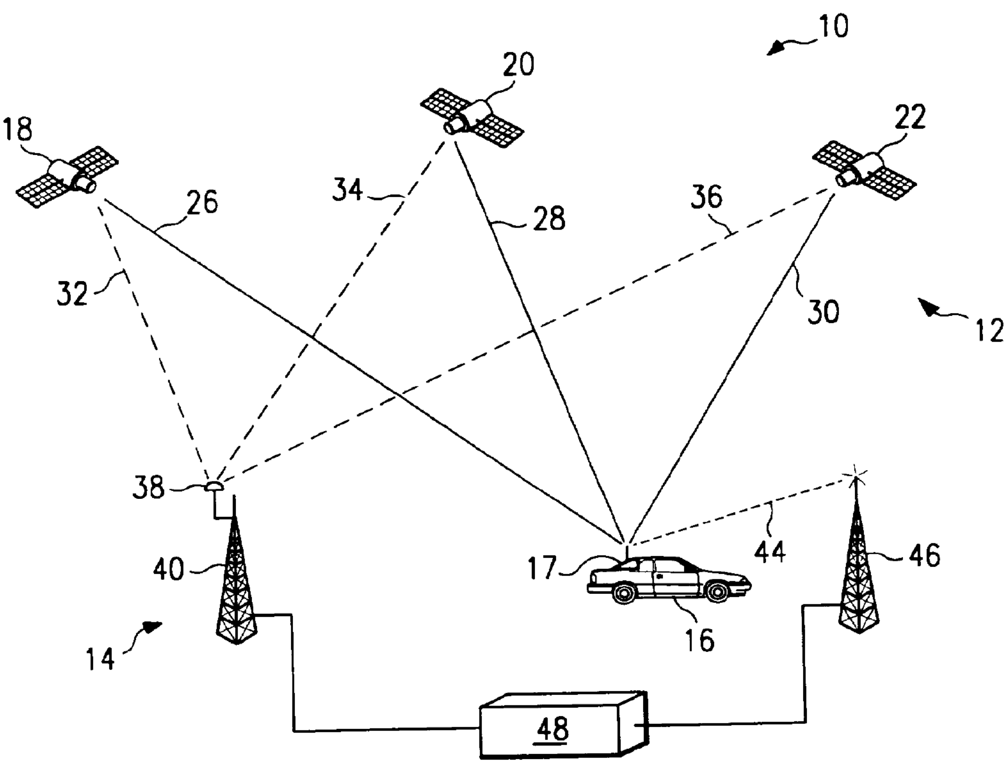
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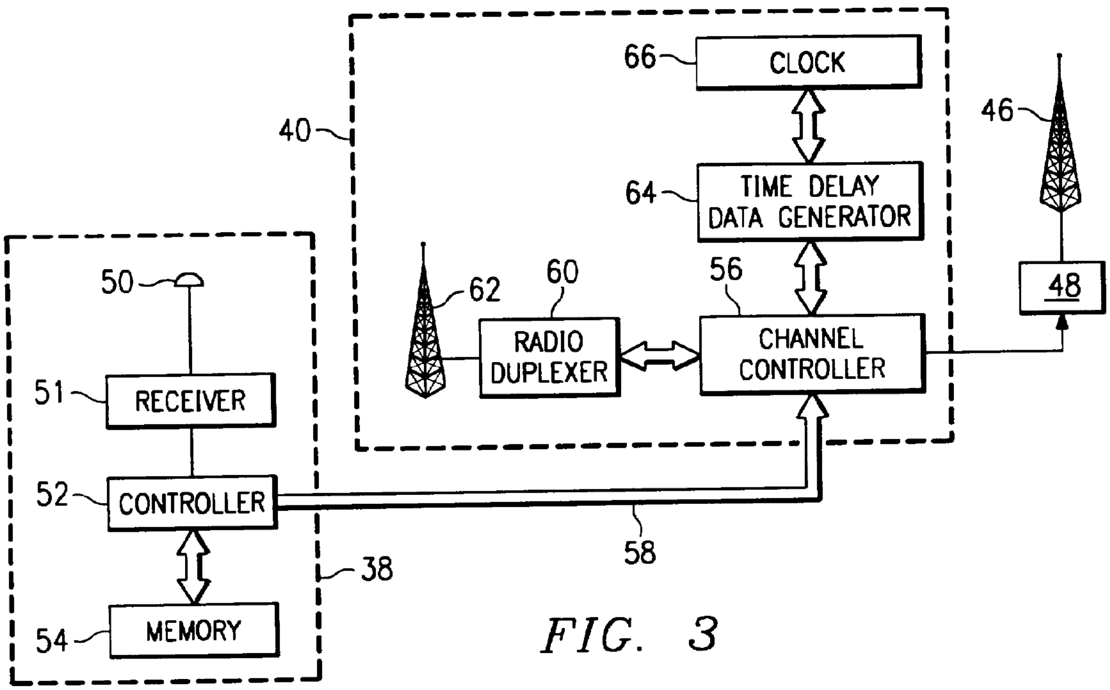
FIG. 2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CLOCK
40
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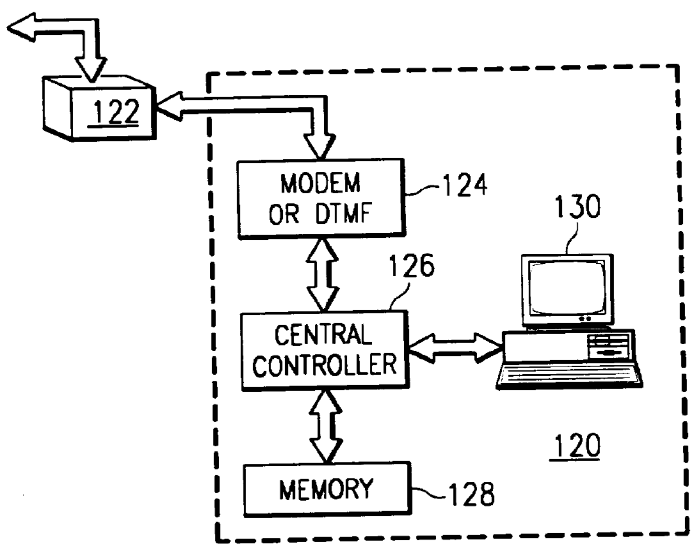
TIME DELAY
DATA GENERATOR
46
50
60
62
56
RADIO
DUPLEXER
CHANNEL
CONTROLLER
48
51
RECEIVER
52
CONTROLLER
58
38
54
MEMORY

FIG. 3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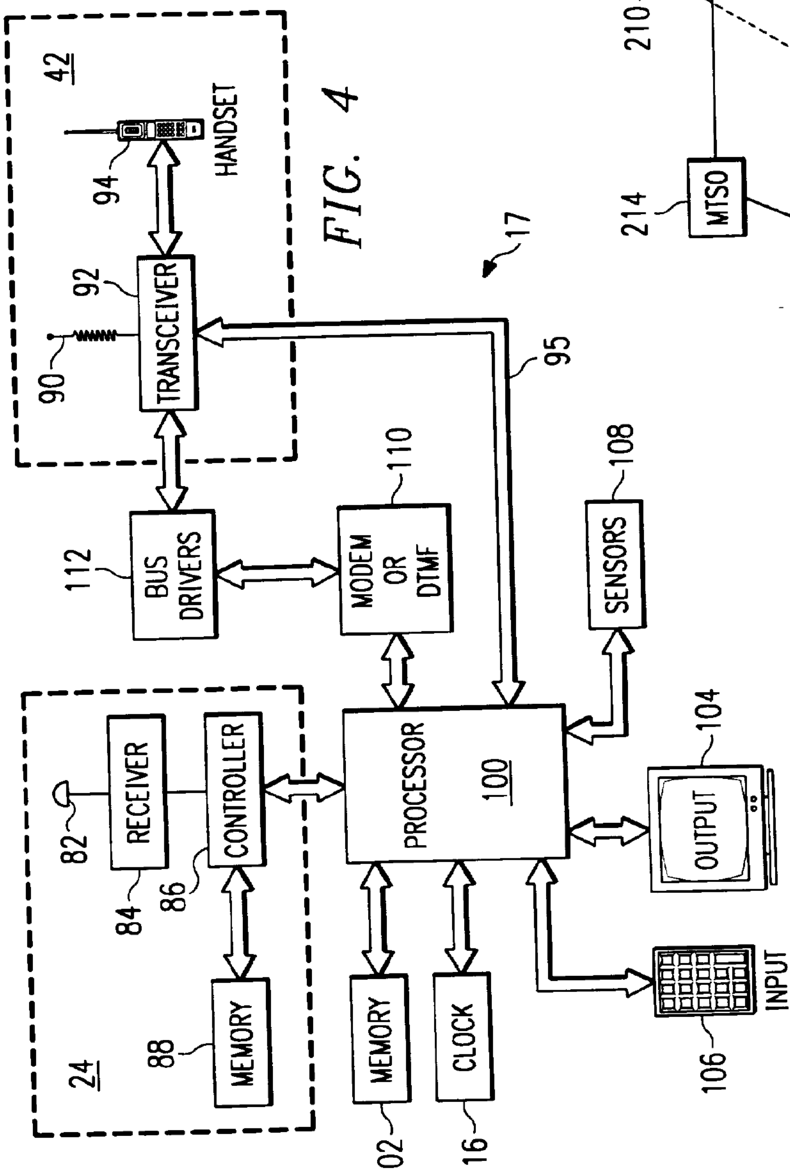
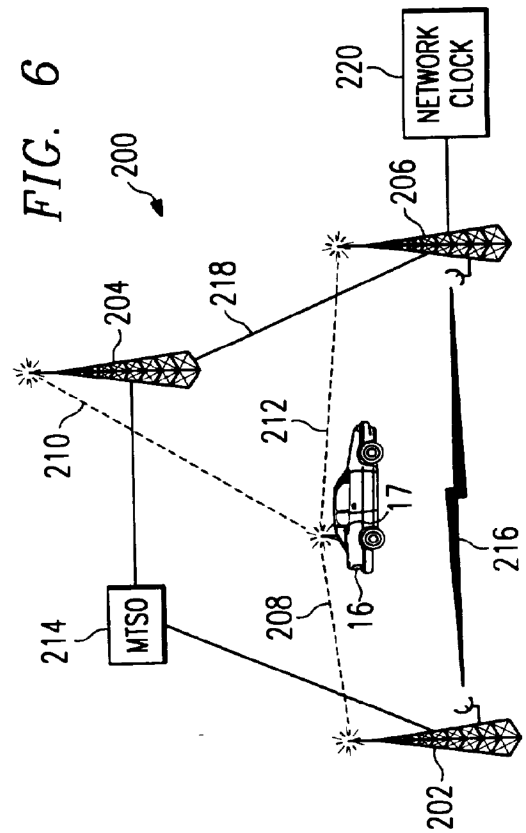
MODEM
OR DTMF
124
130
126
CENTRAL
CONTROLLER
120
MEMORY
128

FIG. 5



RECEIVER
CONTROLLER
MEMORY
24
82
84
86
88
PROCESSOR
100
MEMORY
CLOCK
102
116
INPUT
106
OUTPUT
104
SENSORS
108
MODEM
OR
DTMF
110
BUS
DRIVERS
112
TRANSCEIVER
90
92
94
HANDSET
42
95
17

FIG. 4



200
NETWORK
CLOCK
220
206
204
218
210
212
17
16
208
MTSO
214
216
202

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/14862

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04Q 7/00
US CL :455/33.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/33.1,89,54.1,56.1,33.4,53.1; 342/357, 379/61

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search terms: gps,global positioning system,cellular

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US, A, 5,389,934 (KASS) 14 February 1995, figs 1,2,col 1, line 20 - col 2, line 54)	1-50
Y	US, A, 5,225,842 (BROWN ET AL) 06 July 1993, fig 1, col 4, line 48 - col 6, line 43	1-50
Y	US, A, 5,119,102 (BARNARD) 02 June 1992, figs 1,3, col 1, line 57 - col 2, line 52.	24-29
Y	US, A, 5,155,490 (SPRADLEY, JR. ET AL) 13 October 1992, figs 1,2, col 1, line 44 - col 4, line 19.	4,6,16-18, 39, 41-43,46,48-50
A	US, A, 5,323,322 (MUELLER ET AL) 21 June 1994, fig 1, col 12, line 21-68.	1-50

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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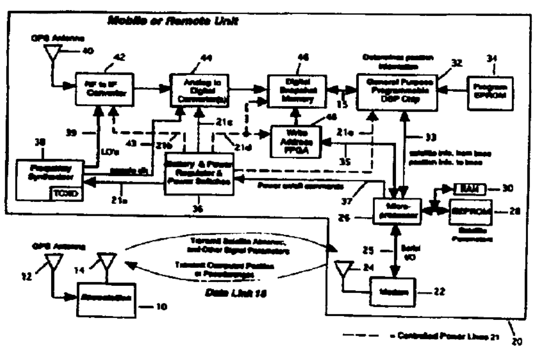
(54) Title: AN IMPROVED GPS RECEIVER UTILIZING A COMMUNICATION LINK



(57) Abstract

A precision carrier frequency signal for calibrating a local oscillator (56) of a GPS receiver which is used to acquire GPS signals. The precision carrier frequency signal is used to calibrate the local oscillator such that the output of the local oscillator, which is used to acquire GPS signals, is modified by a reference signal generated from the precision carrier frequency signal. The GPS receiver locks (53) to this precision carrier frequency signal and generates the reference signal. In another aspect of the invention, satellite almanac data is transmitted to a remote GPS receiver unit (20) from a base station (12) via a communication link. The remote GPS receiver unit uses this satellite almanac data to determine approximate Doppler data for satellites in view of the remote GPS receiver unit.

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AN IMPROVED GPS RECEIVER UTILIZING A COMMUNICATION LINK

BACKGROUND OF THE INVENTION

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application Serial No. 08/612,582, filed on March 8, 1996 by Norman F. Krasner.

This application is also related to and hereby claims the benefit of the filing date of a provisional patent application by the same inventor, Norman F. Krasner, which application is entitled Low Power, Sensitive Pseudorange Measurement Apparatus and Method for Global Positioning Satellites Systems, Serial No. 60/005,318, filed October 9, 1995.

1. FIELD OF THE INVENTION

The present invention relates to receivers capable of determining position information of satellites and, in particular, relates to such receivers which find application in global positioning satellite (GPS) systems.

2. BACKGROUND ART

GPS receivers normally determine their position by computing relative times of arrival of signals transmitted simultaneously from a multiplicity of GPS (or NAVSTAR) satellites. These satellites transmit, as part of their message, both satellite positioning data as well as data on clock timing, so-called "ephemeris" data. The process of searching for and acquiring GPS signals, reading the ephemeris data for a multiplicity of satellites and computing the location of the receiver from this data is time consuming, often requiring several minutes. In many cases, this lengthy processing time is unacceptable and, furthermore, greatly limits battery life in micro-miniaturized portable applications.

Another limitation of current GPS receivers is that their operation is limited to situations in which multiple satellites are clearly in view, without obstructions, and where a good quality antenna is properly positioned to receive such signals. As such, they normally are unusable in portable, body mounted applications; in areas where there is significant foliage or building blockage; and in in-building applications.

There are two principal functions of GPS receiving systems: (1) computation of the pseudoranges to the various GPS satellites, and (2) computation of the position of the receiving platform using these pseudoranges and satellite timing and ephemeris data. The pseudoranges are simply the time delays measured between the received signal from each satellite and a local clock. The satellite ephemeris and timing data is extracted from the GPS signal once it is acquired and tracked. As stated above, collecting this information normally takes a relatively long time (30 seconds to several minutes) and must be accomplished with a good received signal level in order to achieve low error rates.

Virtually all known GPS receivers utilize correlation methods to compute pseudoranges. These correlation methods are performed in real time, often with hardware correlators. GPS signals contain high rate repetitive signals called pseudorandom (PN) sequences. The codes available for civilian applications are called C/A codes, and have a binary phase-reversal rate, or "chipping" rate, of 1.023 MHz and a repetition period of 1023 chips for a code period of 1 msec. The code sequences belong to a family known as Gold codes. Each GPS satellite broadcasts a signal with a unique Gold code.

For a signal received from a given GPS satellite, following a downconversion process to baseband, a correlation receiver multiplies the received signal by a stored replica of the appropriate Gold code contained within its local memory, and then integrates, or lowpass filters, the product in order to obtain an indication of the presence of the signal. This process is termed a "correlation" operation. By sequentially adjusting the relative timing of this stored replica relative to the received signal, and observing the correlation output, the receiver can determine the time delay between the received signal and a local clock. The initial determination of the presence of such an output is termed "acquisition." Once acquisition occurs, the process enters the "tracking" phase in which the timing of the local reference is adjusted in small amounts in order to maintain a high correlation output. The correlation output during the tracking phase may be viewed as the GPS signal with the pseudorandom code removed, or, in common terminology, "despread." This signal is narrow band, with bandwidth commensurate with a 50 bit per second binary phase shift keyed data signal which is superimposed on the GPS waveform.

The correlation acquisition process is very time consuming, especially if received signals are weak. To improve acquisition time, many GPS receivers utilize a multiplicity of correlators (up to 12 typically) which allows a parallel search for correlation peaks.

Another approach to improve acquisition time is described in U.S. Patent No. 4,445,118. This approach uses the transmission of Doppler information from a control basestation to a remote GPS receiver unit in order to aid in GPS signal acquisition. While this approach does improve acquisition time, the Doppler information is accurate for only a short period of time as the GPS satellites orbit the earth at relatively high speeds. Thus, a further transmission of Doppler information will be necessary in order for a remote unit to use accurate Doppler information.

An approach for improving the accuracy of the position determination by a remote GPS receiver unit is also described in U.S. Patent No. 4,445,118, referred to as the Taylor patent. In the Taylor patent, a stable frequency reference is transmitted to a remote GPS receiver unit from a basestation in order to eliminate a source of error due to a poor quality local oscillator at the remote GPS receiver unit. This method uses a special frequency shift keyed (FSK) signal that must be situated in frequency very close to the GPS signal frequency. As shown in Figure 4 of the Taylor patent, the special FSK signal is about 20 MHz below the 1575 MHz GPS signal. Moreover, the approach described in the Taylor patent uses a common mode rejection mechanism in which any error in the local oscillator (shown as L.O. 52) of the receiver will appear in both the GPS channel and the reference channel and hence be canceled out. There is no attempt to detect or measure this error. This approach is sometimes referred to as a homodyne operation. While this approach provides some advantages, it requires that the two channels be closely matched, including closely matched in frequency. Moreover, this approach requires that both frequencies remain fixed, so frequency hopping techniques are not compatible with this approach.

SUMMARY

In one aspect of the present invention, a mobile GPS receiver receives a precision carrier frequency signal from a source providing the precision carrier frequency signal. The receiver locks to this frequency signal and provides a reference signal which is used to calibrate (e.g., stabilize or correct) a local oscillator that is used to acquire GPS signals. An apparatus which practices this aspect includes, in one embodiment, a first antenna which receives GPS signals and a downconverter coupled to the first antenna. The downconverter is coupled to a local oscillator which provides a first reference signal to the downconverter. The apparatus also includes a second antenna for receiving a precision carrier frequency signal from a source providing the precision carrier frequency signal and an automatic frequency control (AFC) circuit coupled to the second antenna. The AFC circuit provides a second reference signal to the local oscillator to calibrate the first reference signal which is used to acquire GPS signals received through the first antenna. The frequency of the precision carrier frequency signal may vary from transmission to transmission.

One embodiment of the present invention provides a method for determining the position of a remote GPS receiver by transmitting GPS satellite information, including satellite almanac data, to the remote unit or mobile GPS unit from a basestation via a data communication link. The satellite almanac data is then used to determine Doppler data for satellites in view of the remote unit. The remote unit uses this Doppler data and received GPS signals from in view satellites to subsequently compute pseudoranges to the satellites. The computed pseudoranges are then transmitted to the basestation where the position of the remote unit is calculated. Various embodiments of apparatuses which can perform this method are also described.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings in which references indicate similar elements and in which:

Figure 1A is a block diagram of the major components of a remote or mobile GPS receiving system utilizing the methods of the present invention, and shows data links that may exist between a basestation and the remote.

Figure 1B is a block diagram of an alternative GPS mobile unit.

Figure 1C is a block diagram of another alternative GPS mobile unit.

Figures 2A and 2B provide two alternatives for the RF and IF portions of a receiver which is an embodiment of the present invention.

Figure 3 shows a flow chart of the major operations (e.g. software operations) performed by the programmable DSP processor in accordance with the methods of the present invention.

Figures 4A-4E illustrates the signal processing waveforms at various stages of processing according to the methods of the present invention.

Figure 5A illustrates a basestation system in one embodiment of the present invention.

Figure 5B illustrates a basestation system in an alternative embodiment of the present invention.

Figure 6A illustrates a GPS mobile unit having, according to one aspect of the present invention, local oscillator calibration.

Figures 6B and 6C show other embodiments of GPS mobile units having local oscillator calibration.

Figure 7 is a flow chart which shows a power management method for a mobile unit according to one embodiment of the present invention.

Figure 8 shows a method for deriving Doppler information for satellites in view from satellite almanac data provided to a mobile unit.

DETAILED DESCRIPTION OF THE INVENTION

This invention concerns apparatuses and methods for computing the position of a mobile, or remote, object in a manner that results in the remote hardware having very low power dissipation and the ability to operate with very low received signal levels and yet provide accurate measurements of position information. That is, power consumption is reduced while receiver sensitivity and accuracy is increased. This is also made possible by the receipt and use at the remote unit of a stable frequency communication signal. This is made possible by the implementation of the remote receiving functions, as shown in Figure 1A, as well as the transmission of satellite almanac information from a separately located basestation 10 to the remote or GPS mobile unit 20.

It should be noted that pseudoranges may be used to compute the remote's geographical position in many different ways. Three examples are:

1. Method 1: By re-transmitting the satellite data messages to the remote 20 from the basestation 10, the remote 20 may combine this information with the pseudorange measurements to compute its position. See, for example, U.S. patent No. 5,365,450, which is incorporated herein by reference. Typically, the remote unit 20 performs the computation of position in the remote 20.
2. Method 2: The remote 20 may gather the satellite ephemeris data from the reception of GPS signals in the normal manner that is commonly practiced in the art. This data, which typically is valid for one to two hours, may be combined with pseudorange measurements to complete, typically in the remote unit, the position calculation.
3. Method 3: The remote 20 may transmit over a communications link 16 the pseudoranges to the basestation 10 which can combine this information with the satellite ephemeris data to complete the position calculation. See, for example, U.S. Patent No. 5,225,842, which is incorporated herein by reference.

In approaches (or Methods) 1 and 3, it is assumed that the basestation 10 and remote 20 have a common view of all satellites of interest and are positioned close enough to one another to resolve a time ambiguity associated with the repetition rate of the GPS pseudorandom codes. This will be met for a range between basestation 10 and remote 20 of 1/2 times the speed of light times the PN repetition period (1 millisecond), or about 150 km.

In order to explain the current invention, it is assumed that method 3 is utilized to complete the position calculation. However, upon review of this Specification, it will be appreciated by those skilled in the art that the various aspects and embodiments of the present invention could be used with any of the above three Methods as well as other approaches. For example, in a variation of Method 1, satellite data information such as data representative of satellite ephemeris may be transmitted by a basestation to a remote unit, and this satellite data information may be combined with pseudo ranges, computed according to the present invention from buffered GPS signals, to provide a latitude and longitude (and in many cases also an altitude) for the remote unit. It will be appreciated that the position information received from the remote may be limited to latitude and longitude or may be extensive information which includes latitude, longitude, altitude, velocity and bearing of the remote. Moreover, the local oscillator correction and/or the power management aspects of the present invention may be utilized in this variation of Method 1. Furthermore, satellite almanac information may be transmitted to the remote unit 20 and utilized by the remote unit 20 in accordance with aspects of the present invention.

Under Method 3, the basestation 10 commands the remote 20 to perform a measurement via a message transmitted over a data communications link 16 as shown in Figure 1A. The message from the basestation 10 which commands the remote 20 may typically also specify an identification of the particular satellites in view or other initialization data. The basestation 10 may also send within this message (or may have previously sent) satellite almanac information, which is a form of satellite data information. This satellite almanac information typically includes a description of the approximate position versus time of all satellites in the GPS constellation. U.S. Patent No. 4,445,118 describes some of the data which may be included in satellite almanac data. This message is received by a separate modem 22 that is part of the remote unit 20, and it is stored in a memory 30 coupled to a low-power microprocessor 26. The satellite almanac information may then be used to derive Doppler information for satellites in view; this derivation is described further below. The almanac data may be valid for periods up to one month. The microprocessor 26 handles data information transfer between the remote unit processing elements 32-48 and the modem 22, and it controls power management functions within the remote receiver 20, as will be evident in the subsequent discussion. Normally, the microprocessor 26 sets most or all remote unit 20's hardware to a low power, or power down, state, except when the pseudorange and/or other GPS calculations are being performed, or when an alternative source of power is available. However, the receiver portion of the modem is at least periodically turned on (to full power) to determine if the basestation 10 has sent a command to the remote to determine the remote's position.

The use of this satellite almanac information to derive Doppler information for satellites in view of the remote eliminates the requirement for the remote 20 to search for such Doppler, thereby reducing its processing time by in excess of a factor of 10. The use of the Doppler information also allows the GPS mobile unit 20 to process more quickly a sample of GPS signals and this tends to reduce the amount of time for which the processor 32 must receive full power in order to compute a position information. This alone reduces the power consumed by the remote unit 20 and contributes to improved sensitivity. Additional information may also be sent to the remote 20, including the epochs of the data in the GPS message.

The received data link signal may utilize a precision carrier frequency. The remote receiver 20 may employ, as shown in Figure 6 which is described below, an automatic frequency control (AFC) loop to lock to this carrier and thereby further calibrate its own reference oscillator (e.g., by correcting the output frequency of the GPS L.O. which is used to acquire GPS signals). A message transmission time of 10 msec, with a received signal to noise ratio of 20 dB, will normally allow frequency measurement via an AFC to an accuracy of 10 Hz or better. This will typically be more than adequate for the requirements of the present invention. This feature will also enhance the accuracy of the position calculations which are performed, either conventionally or using the fast convolution methods of the present invention. This feature is described below in further detail.

In one embodiment of the invention, the communication link 16 is a commercially available narrow bandwidth radio frequency communication medium, such as a two-way pager system. This system may be used in embodiments where the amount of data transmitted between the remote 20 and basestation 10 is relatively small. The amount of data required for the transmission of Doppler (instead of satellite almanac data) and other data (e.g. initialization data such as the identities of the satellites in view) is relatively small and similarly the amount of data required for the position information (e.g.. pseudoranges) is relatively small. Consequently, narrowband systems are adequate for this embodiment. Satellite almanac data may be compressed such that the amount of data necessary to describe the approximate position of all satellites in the GPS constellation may be transmitted efficiently in a narrowband width communication system. Those systems which require the transmission of large amounts of data over a short period of time may require a higher bandwidth radio frequency communication medium. These higher bandwidth systems may be required in those embodiments where uncompressed satellite almanac data is transmitted.

It will be appreciated that it may nevertheless be efficient to use a narrowband system even when uncompressed satellite almanac information is transmitted because the almanac information has good accuracy for long periods of time (e.g., a month, typically). Thus, this information may be transmitted once a month and then stored in the GPS mobile unit (e.g., in flash EEPROM memory) and used for the entire month; typically, in this case, this information is stored with a time stamp which indicates the date of receipt of the satellite almanac data. The remote unit may then, when receiving a command to provide its position information, determine whether the satellite almanac data is stale and receive or not receive the transmission of almanac data provided by the basestation. If the data is not stale (e.g. the almanac data, as indicated by its time stamp, is less than a month old or some other predetermined period of time), then the data may be used from storage and receipt of "fresh" satellite almanac data is not necessary and the automatic transmission of such data is ignored. Alternatively, the basestation may determine whether to transmit satellite almanac data by keeping a list of the remote units which have been sent satellite almanac data and a time stamp indicating the last transmission of satellite almanac data for each such remote unit. The basestation can then determine whether to transmit satellite almanac data with a position fix command based upon the staleness of the last satellite almanac data stored at the particular remote. If the almanac data at the particular remote is not stale (e.g., it is less than one month old) then the position fix command without the almanac data is transmitted from the basestation to the remote. If the almanac data is stale, then current satellite almanac data is transmitted to the remote unit.

Once the remote 20 receives a command (e.g., from the basestation 10) for GPS processing together with the satellite almanac information (or determines it may use a locally stored version of satellite almanac data), the microprocessor 26 activates the RF to IF Converter 42, Analog to Digital Converter 44 and Digital Snapshot Memory 46 via a Battery and Power Regulator and Power Switches circuit 36 (and controlled power lines 21a, 21b, 21c and 21d) thereby providing full power to these components. This causes the signal from the GPS satellite which is received via antenna 40 to be downconverted to an IF frequency, where it subsequently undergoes digitization. A set of such data, typically corresponding to a duration of 100 milliseconds to 1 second (or even longer), is then stored in a Snapshot Memory 46. The amount of data stored may be controlled by the microprocessor 26 such that more data may be stored in the memory 46 (to obtain better sensitivity) in those situations when conserving power is not as important as obtaining better sensitivity, and less data may be stored in those situations when conservation of power is more important than sensitivity. Typically, sensitivity is more important when the GPS signals may be obstructed partially, and power conservation is less important when a copious power supply (e.g. a car battery) is available. The addressing of this memory 46 to store this data is controlled by a Field Programmable Gate Array integrated circuit 48. Downconversion of the GPS signal is accomplished using a frequency synthesizer 38 which provides local oscillator signal 39 to the converter 42 as discussed further below.

Note that all this time (while the snapshot memory 46 is being filled with the digitized GPS signals from the in view satellites) the DSP microprocessor 32 may be kept in a low power state. The RF to IF

Converter 42 and Analog to Digital Converter 44 are typically only turned on for a short period of time, sufficient to collect and store the data required for pseudorange calculation. After the data collection is complete, these converter circuits are turned off or power is otherwise reduced via controlled power lines 21b and 21c (while the memory 46 continues to receive full power), thus not contributing to additional power dissipation during the actual pseudorange calculation. The pseudorange calculation is then performed using, in one embodiment, a general purpose, programmable digital signal processing IC 32 (DSP), as exemplified by a TMS320C30 integrated circuit from Texas Instruments. This DSP 32 is placed in an active power state by the microprocessor 26 and the circuit 36 via controlled power line 21e prior to performing such calculations.

This DSP 32 differs from others used in some remote GPS units in that it is general purpose and programmable, as compared to specialized custom digital signal processing IC's. Furthermore, the DSP 32 makes possible the use of a Fast Fourier Transform (FFT) algorithm, which permits very rapid computation of the pseudoranges by performing rapidly a large number of correlation operations between a locally generated reference and the received signals. Typically, 2046 such correlations are required to complete the search for the epochs of each received GPS signal. The Fast Fourier Transform algorithm permits a simultaneous and parallel search of all such positions, thus speeding the required computation process by a factor of 10 to 100 over conventional approaches.

Once the DSP 32 completes its computation of pseudoranges for each of the in view satellites, it transmits, in one embodiment of the invention, this information to the microprocessor 26 via interconnect bus 33. At this time the microprocessor 26 may cause the DSP 32 and memory 46 to again enter a low power state by sending an appropriate control signal to the Battery and Power Regulator circuit 36. Then, the microprocessor 26 utilizes a modem 22 to transmit the pseudorange data over a data link 16 to the basestation 10 for final position computation. In addition to the pseudorange data, a time tag may simultaneously be transmitted to the basestation 10 that indicates the elapsed time from the initial data collection in the buffer 46 to the time of transmission of the data over the data link 16. This time tag improves the capability of the basestation to compute position calculation, since it allows the computation of the GPS satellite positions at the time of data collection. As an alternative, in accordance with Method 1 above, the DSP 32 may compute the position (e.g. latitude, longitude or latitude, longitude and altitude) of the remote unit and send this data to the microprocessor 26, which similarly relays this data to the basestation 10 via the modem 22. In this case the position computation is eased by the DSP maintaining the elapsed time from the reception of satellite data messages to the time at which the buffer data collection begins. This improves the capability of the remote unit to compute position calculation, since it allows the computation of the GPS satellite positions at the time of data collection.

As shown in Figure 1A, modem 22, in one embodiment, utilizes a separate antenna 24 to transmit and receive messages over data link 16. It will be appreciated that the modem 22 includes a communication receiver and a communication transmitter which are alternatively coupled to the antenna 24. Similarly, basestation 10 may use a separate antenna 14 to transmit and receive data link messages, thus allowing continuous reception of GPS signals via GPS antenna 12 at the basestation 10.

It is expected, in a typical example, that the position calculations in the DSP 32 will require less than a few seconds of time, depending upon the amount of data stored in the digital snapshot memory 46 and the speed of the DSP or several DSPs.

It should be clear from the above discussion that the remote unit 20 need only activate its high power consumption circuits for a small fraction of time, if position calculation commands from the basestation 10 are infrequent. It is anticipated, in at least many situations, that such commands will result in the remote equipment being activated to its high power dissipation state only about 1% of the time or less.

This then allows battery operation for 100 times the length of time that would otherwise be possible. The program commands necessary for the performance of the power management operation are stored in EEPROM 28 or other suitable storage media. This power management strategy may be adaptable to different power availability situations. For example, when prime power is available the determination of position may occur on a continuing basis.

As indicated above, the digital snapshot memory 46 captures a record corresponding to a relatively long period of time. The efficient processing of this large block of data using fast convolution methods contributes to the ability of the present invention to process signals at low received levels (e.g., when reception is poor due to partial blockage from buildings, trees, etc.). All pseudoranges for visible GPS satellites are computed using this same buffered data. This provides improved performance relative to continuous tracking GPS receivers in situations (such as urban blockage conditions) in which the signal amplitude is rapidly changing.

A slightly different implementation exhibited in Figure 1B dispenses with the microprocessor 26 and its peripherals (RAM 30 and EEPROM 28) and replaces its functionality with additional circuitry contained within a more complex FPGA (field programmable gate array) 49. The structure and operation of the remote unit shown in Figure 1B is described in further detail in U.S. Patent Application Serial No. 08/612,669, filed March 8, 1996 by Norman F. Krasner, now U.S. Patent No._________, which application is hereby incorporated herein by reference. The remote unit of Figure 1B uses the DSP 32a to selectively power on or reduce power to different components according to a power management method such as that shown in Figure 7.

Figure 1C shows another embodiment according to the present invention of a GPS mobile unit which contains many of the same components as the GPS mobile units shown in Figures 1A and 1B.

Figure 1C shows a feature of the present invention which allows the GPS mobile unit to trade off sensitivity for power conservation. As described herein sensitivity of the GPS mobile unit may be increased by increasing the amount of buffered GPS signals which are stored in the memory 46. This is done by acquiring and digitizing more GPS signals and storing this data in the memory 46. While this increased buffering causes more power consumption, it does improve the sensitivity of the

GPS mobile unit. The structure and operation of the remote unit shown in Figure 1C is described in further detail in the above noted U.S. Patent Application Serial No. 08/612,669, filed March 8, 1996.

Representative examples of an RF to IF frequency converter and digitizing system for the mobile GPS unit are shown in Figure 2A and 2B. The structure and operation of these examples shown in Figure 2A and 2B are described in further detail in the above noted U.S. Patent Application Serial No. 08/612,669, filed March 8, 1996.

Details of the GPS signal processing performed in the DSP 32 may be understood with the aid of the flow chart of Figure 3 and the pictorial of Figures 4A, 4B, 4C, 4D and 4E. It will be apparent to those skilled in the art that the machine code, or other suitable code, for performing the signal processing to be described is stored in EPROM 34. Other non-volatile storage devices could also be used. The following assumes that the I/Q sampling of Figure 2A is employed and that the snapshot memory 46 contains two channels of digitized data at 2.048 MHz. The objective of the processing is to determine the timing of the received waveform with respect to a locally generated waveform. Furthermore, in order to achieve high sensitivity, a very long portion of such a waveform, typically 100 milliseconds to 1 second, is processed. It will also be appreciated that the Doppler information which is used in this signal processing may be Doppler information which was derived from stored or recently transmitted satellite almanac data (or may be Doppler information directly transmitted along with the position command to the remote unit so that no Doppler derivation in the remote unit is required). The derivation of Doppler information from satellite almanac data is described further herein in conjunction with Figure 8. Further details concerning the signal processing shown in Figures 3 and 4A-4E are described in the above noted U.S. Patent Application Serial No. 08/612,669, filed March 8, 1996.

A summary of the signal processing described above and shown in Figure 3 and in Figures 4A-4E will now be provided. The GPS signals from one or more in view GPS satellites are received at the remote GPS unit using an antenna on the remote GPS unit. These signals are digitized and stored in a buffer in the remote GPS unit. After storing these signals, a processor performs in one embodiment preprocessing, fast convolution processing, and post processing operations. These processing operations involve:

a) breaking the stored data into a series of blocks whose durations are equal to a multiple of the frame period of the pseudorandom (PN) codes contained within the GPS signals.

b) for each block performing a preprocessing step which creates a compressed block of data with length equal to the duration of a pseudorandom code period by coherently adding together successive subblocks of data, the subblocks having a duration equal to one PN frame; this addition step will mean that the corresponding sample numbers of each of the subblocks are added to one another.

c) for each compressed block, performing a matched filtering operation, which utilizes fast convolution techniques, to determine the relative timing between the received PN code contained within the block of data and a locally generated PN reference signal (e.g. the pseudorandom sequence of the GPS satellite being processed).

d) determining a pseudorange by performing a magnitude-squared operation on the products created from said matched filtering operation and post processing this by combining the magnitude-squared data for all blocks into a single block of data by adding together the blocks of magnitude-squared data to produce a peak.

and e) finding the location of the peak of said single block of data to high precision using digital interpolation methods, where the location is the distance from the beginning of the data block to the said peak, and the location represents a pseudorange to a GPS satellite corresponding to the pseudorandom sequence being processed.

Typically, the fast convolution technique used in processing the buffered GPS signals is a Fast Fourier Transform (FFT) and the result of the convolution is produced by computing the product of the forward transform of the compressed block and a prestored representation of the forward transform of the pseudorandom sequence to produce a first result and then performing an inverse transformation of the first result to recover the result. Also, the effects the Doppler induced time delays and local oscillator induced time errors are compensated for on each compressed block of data by inserting between the forward and inverse Fast Fourier Transform operations, the multiplication of the forward FFT of the compressed blocks by a complex exponential whose phase versus sample number is adjusted to correspond to the delay compensation required for the block.

In the foregoing embodiment the processing of GPS signals from each satellite occurs sequentially over time, rather than in parallel. In an alternative embodiment, the GPS signals from all in view satellites may be processed together in a parallel fashion in time.

It is assumed here that the basestation 10 has a common view of all satellites of interest and that it is sufficiently close in range to remote unit 20 in order to avoid ambiguities associated with the repetition period of the C/A PN code. A range of 90 miles will satisfy this criteria. The basestation 10 is also assumed to have a GPS receiver and a good geographical location such that all satellites in view are continuously tracked to high precision.

While several described embodiments of the basestation 10 show the use of a data processing component, such as a computer at the basestation in order to compute position information such as a latitude and a longitude for the mobile GPS unit, it will be appreciated that each basestation 10 may merely relay the information received, such as pseudoranges from a mobile GPS unit, to a central location or several central locations which actually perform the computation of latitude and longitude. In this manner the cost and complexity of these relaying basestations may be reduced by eliminating a data processing unit and its associated components from each relaying basestation. A central location, would include receivers (e.g. telecommunication receivers) and a data processing unit and associated components. Moreover, in certain embodiments, the basestation may be virtual in that it may be a satellite which transmits Doppler information or satellite almanac data to remote units, thereby emulating a basestation in a transmission cell.

Figures 5A and 5B show two embodiments of a basestation according to the present invention. In the basestation shown in Figure 5A, a GPS receiver 501 receives GPS signals through a GPS antenna 501a. The GPS receiver 501, which may be a conventional GPS receiver, provides a timed reference signal which typically is timed relative to GPS signals and also provides satellite almanac data for all the satellites in the constellation of GPS satellites and may provide Doppler information relative to the satellites in view. This GPS receiver 501 is coupled to a disciplined local oscillator 505 which receives the time reference signal 510 and phase locks itself to this reference. This disciplined local oscillator 505 has an output which is provided to a modulator 506. The modulator 506 also receives the satellite almanac data (or alternatively, Doppler data information signals for each satellite in view of the GPS mobile unit) and/or other satellite data information signals 511. The modulator 506 modulates the satellite almanac data (or alternatively, the Doppler) and/or other satellite data information onto the local oscillator signal received from the discipline local oscillator 505 in order to provide a modulated signal 513 to the transmitter 503. The transmitter 503 is coupled to the data processing unit 502 via interconnect 514 such that the data processing unit may control the operation of the transmitter 503 in order to cause the transmission of satellite data information, such as the satellite almanac information to a GPS mobile unit via the transmitter's antenna 503a. In this manner, a GPS mobile unit may receive the satellite almanac information, the source of which is the GPS receiver 501 and may also receive a high precision local oscillator carrier signal which may be used to calibrate the local oscillator in the GPS mobile unit as shown in Figure 6. It will be appreciated that the basestation may transmit the current satellite almanac data automatically with each transmission of a position fix command to the remote unit. Alternatively the basestation may, as described above, determine whether the remote's stored version of the satellite almanac data is stale and transmit the current almanac data only if the remote's stored version is stale. If a high bandwidth communication system is being used as the communication link (e.g., a cellular telephone system) then the former approach is preferred. If a narrow bandwidth communication system is being used, then the latter approach may be preferred.

The basestation as shown in Figure 5A also includes a receiver 504 which is coupled to receive communication signals from the remote or GPS mobile unit via a communication antenna 504a. It will be appreciated that the antenna 504a may be the same antenna as the transmitter's antenna 503a such that a single antenna serves both the transmitter and the receiver in the conventional fashion. The receiver 504 is coupled to the data processing unit 502 which may be a conventional computer system. The processing unit 502 may also include an interconnect 512 to receive the Doppler and/or other satellite data information from the GPS receiver 511. This information may be utilized in processing the pseudorange information or other information received from the mobile unit via the receiver 504. This data processing unit 502 is coupled to a display device 508, which may be a conventional CRT. The data processing unit 502 is also coupled to a mass storage device 507 which includes GIS (Geographical Information System) software (e.g. Atlas GIS from Strategic Mapping, Inc. of Santa Clara, California) which is used to display maps on the display 508. Using the display maps, the position of the mobile GPS unit may be indicated on the display relative to a displayed map.

An alternative basestation shown in Figure 5B includes many of the same components shown in Figure 5A. However, rather than obtaining the satellite almanac data or Doppler and/or other satellite data information from a GPS receiver, the basestation of Figure 5B includes a source of satellite almanac data or Doppler and/or other satellite data information 552 which is obtained from a telecommunication link or a radio link in a conventional matter. For example, this information may be obtained from a server site on the Internet. This Doppler and/or satellite information is conveyed over an interconnect 553 to the modulator 506. The other input the modulator 506 shown in Figure 5B is the oscillator output signal from a reference quality local oscillator such as a cesium standard local oscillator. This reference local oscillator 551 provides a precision carrier frequency onto which is modulated the Doppler and/or other satellite data information which is then transmitted via transmitter 503 to the mobile GPS unit.

Although the preceding discussion illustrates a basestation which integrates all functions of satellite data transmission and frequency reference information, in most practical situations this may be partially performed using commercial telecommunication systems, such as cellular or paging systems. For example, most digital cellular systems utilize a very stable local oscillator in their transmitted signals. In this case, a basestation need only gather the satellite data, as in blocks 501 or 552 and send this data over such a cellular system using a conventional wireline modem. The actual modulation functions, including the precision frequency reference transmission, are then performed by the cell site transmitter. This approach results in a very low cost basestation with no special RF circuitry. Similarly, on the remote to basestation link, the cellular system provides the receiving and demodulation functions of block 504 and the basestation need only utilize a modem to receive such data over normal wirelines.

It is an important characteristic of this invention that the transmission frequency and format of the data signals are unimportant, as long as the carrier frequency is very stable. It should also be noted that this carrier frequency may vary from one transmission to the next, as it commonly does in cellular systems, which utilize a large number of frequency channels to service a large number of users. In some cases the carrier frequency may also vary within one call. For example, frequency hopping is utilized in some digital cellular systems. Again, this invention can utilize such signaling, as long as the remote receiver can frequency lock to the stable transmitted frequencies.

Figure 6A shows an embodiment of a GPS mobile unit of the present invention which utilizes the precision carrier frequency signal received through the communication channel antenna 601 which is similar to the antenna 24 shown in Figure 1A. The antenna 601 is coupled to the modem 602, which is similar to the modem 22 in Figure 1A, and this modem 602 is coupled to an automatic frequency control circuit 603 which locks to the precision carrier frequency signal sent by the basestation (which may be considered to be or include a cellular telephone cell site transmitter) described herein according to one embodiment of the present invention. The automatic frequency control circuit 603 provides an output 604, which is typically locked in frequency to the precision carrier frequency. This signal 604 is compared by the comparator 605 to the output of the GPS local oscillator 606, via interconnect 608. The result of the comparison performed by the comparator 605 is an error correction signal 610 which is provided as a correction signal to the GPS local oscillator 606. In this manner, the frequency synthesizer 609 provides a higher quality, calibrated local oscillation signal over interconnect 612 to the GPS down converter 614. It will be appreciated that the GPS local oscillator 606 and the frequency synthesizer 609 may together be considered a local oscillator which provides a GPS clock signal that is inputted to the downconverter to acquire the GPS signals received through the GPS antenna 613. As used herein, "calibrated", "calibrate" or "calibration" refers to either a system which measures and corrects a local oscillator (by using a reference signal derived from a measurement of an error in a local oscillator) or a system which stabilizes a local oscillator signal (e.g., by feeding a local oscillator signal from the communication receiver to frequency synthesizing circuits that generate GPS clock signals which are used to downconvert/acquire GPS signals).

It will be appreciated that the signal provided over interconnect 612 is similar to the local oscillator signal provided by interconnect 39 on Figure 1A to the converter 42; also, the converter 42 is similar to the GPS down converter 614 which is coupled to the GPS antenna 613 to receive GPS signals.

In an alternative embodiment the signal 604 provided by the AFC unit in the communication receiver is an LO which at the proper frequency serves as a reference for the frequency synthesizer 609. In this case no GPS local oscillator is required (shown in Figure 6A as optional for this reason) and this signal 604 will be fed directly to the synthesizer 609 in substitution for the signal 607 from the GPS local oscillator. In this manner, a precise, stable local oscillator clock signal is provided to the GPS downconverter for the downconverter to acquire GPS signals received through a GPS antenna.

In another alternative embodiment, the result of the comparison performed by comparator 605 may be output via interconnect 610a as an error correction to the DSP component 620 which is similar to the DSP chip 32 shown in Figure 1A. In this instance, no error correction signal 610 will be provided indirectly to the frequency synthesizer 609. The automatic frequency control circuit may be implemented using a number of conventional techniques including a phase lock loop or a frequency lock loop or a block phase estimator.

Figure 6B shows another embodiment of a mobile GPS unit for calibrating the GPS local oscillator used to acquire (e.g., downconvert) the GPS signals in the mobile unit of the present invention. The approach is to derive a stable frequency from the receiving circuitry of a communication receiver. Many communication signals, such as digital cellular and PCS signals have carrier frequencies stable to as good as 0.1 parts per million. The receivers for such signals provide, as part of their operation, a phase locking procedure applied to the receiver signal carrier so that such a carrier may be removed allowing the demodulation of the digital data imposed upon the carrier. The phase locking procedure normally produces as part of its process a stable local oscillator which can then be utilized to separately stabilize the local oscillators of a GPS receiver, thereby eliminating expensive components on this receiver.

The communication signal received by the communication receiver 640 may have one of a multiplicity of possible carrier frequencies, depending upon which channel it is tuned to. The first stage (converter 642) of the receiver downconverts the input signal to a single IF frequency, for example 140 MHz. This downconversion is controlled by the oscillator VCO1 643 which provides an oscillator signal input to the downconverter 642. The output of VCO1 is in turn controlled by the frequency synthesizer 644 which provides an input to oscillators VCO1 643 and VCO2 647. The mixer 646 forms a second stage RF to IF downconverter which is controlled by an input oscillator signal from oscillator 647. The following stage (Costas Loop Demodulator 648 and Temperature Compensated Voltage Controlled Oscillator (TCVCXO) 645) of the communication receiver is a phaselocking circuit whose purpose is to construct a local oscillator signal which is phaselocked to the incoming signal's carrier frequency. For a signal that is phase-shift keyed, a common circuit well known in the art to perform this circuit is the Costas Loop (e.g. see Gardner, Phaselock Techniques, 2nd Edition, John Wiley & Sons, 1979). In Figure 6B the Costas Loop provides a frequency correction voltage to the reference frequency generator TCVCXO 645 which causes the output of TCVCXO 645 to be phase and frequency aligned with the carrier frequency of the IF signal.

The VCO output 645a (from TCVCXO 645) may then be supplied as a reference frequency to a frequency synthesizer 654 used with the GPS downconverter 652 of the GPS receiver portion 650. In this manner the frequency synthesizer produces inputs for local oscillators (VCO3 653 and VCO4 655) for use in the GPS system that has the same frequency stability as that of the received communication signal. The oscillator 653 controls the first stage of the RF to IF downconversion, and the oscillator 655 controls the second stage of the RF to IF downconversion. The mixer 656 forms a second stage RF to IF downconverter which receives a first intermediate frequency from downconverter 652 and provides a second intermediate frequency to the digitizer circuits (shown together with the buffer and GPS processor in block 657).

Note that the above approach is applicable even though the frequency of the received communication signal may vary from one reception time to the next, if the signal is assigned to a different frequency channel.

An alternative to the above approach is shown in Figure 6C. Here a Direct Digital Synthesizer (DDS) 677 integrated circuit is provided with a digital tuning word from the Costas Loop 679, which is also implemented as a digital circuit. This tuning word can also then be supplied to the frequency synthesizer 689 that is part of the GPS receiver in order to stabilize its local oscillators. In this case this frequency synthesizer may also utilize a DDS 689b in order to allow precision adjustment of its frequency, an inherent feature of a DDS.

There are alternative hybrid combinations of the above approaches--e.g. a DDS in the communication receiver, but the DDS LO output being fed to the GPS system. The general approach is that a frequency locking or phaselocking circuit in the communication receiver produces either a tuning voltage or local oscillator signals which is fed to a frequency synthesis circuit on the GPS receiver in order to stabilize the local oscillators provided by this system.

It should be noted that the phaselocking circuits in receivers 640 and 670 may be alternatively implemented wholly or in part via digital signal processing means instead of analog means. In this case the input to these circuits may be digitized via an A/D converter and the circuit functions of these blocks may be constructed using hardwired or programmable (i.e. programmable DSP) digital signal processing elements.

Figure 7 illustrates a particular sequence of power management according to one embodiment of the invention. It will be appreciated that there are numerous ways which are known in the art in order to reduce power. These include slowing down the clock provided to a synchronous, clocked component as well as completely shutting down power to a particular component or turning off certain circuits of a component but not others. It will be appreciated, for example, that phase lock loops and oscillator circuits require start up and stabilization times and thus a designer may decide not to power down completely (or at all) these components. The example shown in Figure 7 begins in step 701 in which the various components of the system are initialized and placed in a reduced power state. Either periodically or after a predetermined period of time, the communication receiver in the modem 22 is returned to full power to determine whether commands are being sent from the basestation 10. This occurs in step 703. If a request is received in step 705 for location information from a base unit, the modem 22 alerts the power management circuit in step 707. At this point in time, the communication receiver in the modem 22 may be turned off for either a predetermined period of time or turned off to be turned on periodically again at a later time; this is shown as step 709. It will be appreciated that the communication receiver may maintained at a full power state rather than turning it off at this point in time. Then in step 711, the power management circuit returns the GPS receiver portion of the mobile unit to full power by powering up the converter 42 and the analog to digital converters 44; if the frequency oscillator 38 was also powered down, this component is powered up at this time and returned to full power and allowed some time to stabilize. Then in step 713, the GPS receiver, including components 38, 42 and 44 receive the GPS signal. This GPS signal is buffered in the memory 46 which has also been returned to full power when the GPS receiver was returned to full power in step 711. After collection of the snapshot information is completed, then the GPS receiver is returned to a reduced power state in step 717; this typically comprises reducing power for the converter 42 and 44 while keeping the memory 46 at full power. Then in step 719, the processing system is returned to full power; in one embodiment, this involves providing full power to the DSP chip 32; it will be appreciated however that if the DSP chip 32 is also providing power management functions as in the case of the embodiment shown in Figure 1C, then the DSP chip 32a is typically returned to full power in step 707. In the embodiment shown in Figure 1A where the microprocessor 26 performs power management function, the processing system, such as DSP chip 32 may be returned to full power at step 719. In step 721, the GPS signal is processed according to the method of the present invention, such as that shown in Figure 3. Then, after completing the processing of the GPS signal, the processing system is placed in a reduced power state as shown in step 23 (unless the processing system is also controlling power management as noted above). Then, in step 725 the communication transmitter in the modem 22 is returned to full power in order to transmit in step 727 the processed GPS signal back to the basestation 10. After completing transmission of the processed GPS signal, such as pseudorange information or latitude and longitude information, the communication transmitter is returned to reduced power state in 729 and the power management system waits for a delay of a period of time such as predetermined period of time in step 731. Following this delay the communication receiver in the modem 22 is returned to full power in order to determine whether a request is being sent from a basestation.

Figure 8 shows a method for deriving Doppler information for satellites in view from the satellite almanac data transmitted to a remote unit according to the present invention. The remote unit receives, in step 801, the satellite almanac data and stores this data in the remote unit (e.g., storing it in flash EEPROM). Optionally, the remote unit may stamp the data with the current date and time in order to determine staleness of the almanac data later as described herein.

In step 803, the remote unit determines the approximate time of day and its approximate position. Using the approximate time and position with the satellite almanac data, the remote in step 805 determines the Doppler of all in view satellites. The remote unit, when receiving the position fix command from the basestation, may also receive an identification of satellites in view and use this identification to calculate Dopplers for only these satellites from the almanac data and from the approximate time and position determined in step 803. Although almanac data is provided in a specific form within the transmitted signal from the GPS satellites, it is not necessary that this information be supplied over the communication link in this form. For example, this data can be compressed by reducing the accuracy of the various transmitted quantities. Reduction in accuracy may reduce the Doppler accuracy, but such reduction may still be within the allowed error budget of the GPS receiver. Alternatively, another representation of the almanac data may be preferable, e.g. fitting the satellite position data to a set of curves, such as spherical harmonics. This approach may allow the GPS receiver to more easily compute Doppler from the supplied almanac data.

Approximate Doppler may be computed by computing the range from the remote to the satellites of interest at times separated by an appropriate interval (e.g. 1 second). This is done utilizing the supplied Almanac data and the approximate user position (e.g., based upon the fixed location of the cell site in a cellular phone system). The difference in these ranges is a range rate, which can be divided by the speed of light to yield a Doppler expressed in seconds per second (or another suitable set of units such as nanoseconds per second).

Although the methods and apparatus of the present invention have been described with reference to GPS satellites, it will be appreciated that the teachings are equally applicable to positioning systems which utilize pseudolites or a combination of satellites and pseudolites. Pseudolites are ground based transmitters which broadcast a PN code (similar to a GPS signal) modulated on an L-band carrier signal, generally synchronized with GPS time. Each transmitter may be assigned a unique PN code so as to permit identification by a remote receiver. Pseudolites are useful in situations where GPS signals from an orbiting satellite might be unavailable, such as tunnels, mines, buildings or other enclosed areas. The term "satellite", as used herein, is intended to include pseudolite or equivalents of pseudolites, and the term GPS signals, as used herein, is intended to include GPS-like signals from pseudolites or equivalents of pseudolites.

In the preceding discussion the invention has been described with reference to application upon the United States Global Positioning Satellite (GPS) system. It should evident, however, that these methods are equally applicable to similar satellite positioning systems, and in, particular, the Russian Glonass system. The Glonass system primarily differs from GPS system in that the emissions from different satellites are differentiated from one another by utilizing slightly different carrier frequencies, rather than utilizing different pseudorandom codes. In this situation substantially all the circuitry and algorithms described previously are applicable with the exception that when processing a new satellite's emission a different exponential multiplier is used to preprocess the data. This operation may be combined with the Doppler correction operation of box 108 Figure 3, without requiring any additional processing operations. Only one PN code is required in this situation, thus eliminating block 106. The term "GPS" used herein includes such alternative satellite positioning systems, including the Russian Glonass system.

Although Figures 1A, 1B and 1C illustrate a multiplicity of logic blocks that process digital signals (e.g. 46, 32, 34, 26, 30, 28 in Figure 1A), it should be appreciated that several or all of the these blocks may be integrated together onto a single integrated circuit, while still maintaining the programmable nature of the DSP portion of such a circuit. Such an implementation may be important for very low power and cost sensitive applications.

It will be appreciated that the various aspects of the present invention, including the use of satellite almanac data at the remote unit to derive Doppler information and including the use of a precision carrier frequency signal to calibrate the output of a GPS local oscillator which is used to acquire GPS signals, may be used in GPS mobile units having architectures such as those described in U.S. Patent Application Serial No. 08/652,833, filed May 23, 1996 by Norman F. Krasner, which application is hereby incorporated herein by reference.

It should also be appreciated that one or several of the operations of Figure 3 may be performed by hardwired logic in order to increase the overall processing speed, while retaining the programmable nature of the DSP processor. For example, the Doppler correction capability of block 108 may be performed by dedicated hardware that may be placed between the digital snapshot memory 46 and the DSP IC 32. All other software functions of Figure 3 may in such cases be performed by the DSP processor. Also, several DSPs may be used together in one remote unit to provide greater processing power. It will also be appreciated that it is possible to collect (sample) multiple sets of frames of GPS data signals and process each set as shown in Figure 3 while accounting for the time between the collection of each set of frames.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

CLAIMS

What is claimed is:

1. In a method for determining the position of a remote unit, a process comprising:

receiving, at said remote unit, a satellite almanac information for a plurality of satellites in view of said remote unit; and

computing, in said remote unit, a position information for said satellite by using a Doppler information derived from said satellite almanac information.

2. A process as in claim 1, further comprising:

transmitting said satellite almanac information from a basestation to said remote unit.

3. A process as in claim 2 wherein said satellite almanac information is obtained from a reference storage medium at said basestation.

4. A process as in claim 2 wherein said position information comprises pseudoranges to a plurality of satellites in view of said remote unit, including said satellite.

5. A process as in claim 2 wherein said position information comprises a latitude and longitude which indicates the position of said remote unit.

6. A process as in claim 4 further comprising:
transmitting said pseudoranges from said remote unit to said basestation, and wherein said basestation computes a latitude and longitude which indicates the position of said remote unit.

7. A process as in claim 4 further comprising transmitting satellite data information of said satellite to said remote unit, said satellite data information comprising data representative of ephemeris for said satellite.

8. A process as in claim 5 further comprising transmitting satellite data information of said satellite to said remote unit, said satellite data information comprising data representative of ephemeris for said satellite.

9. A mobile unit which uses data representative of GPS signals to provide the position of said mobile unit, said mobile unit comprising;
a receiver in said mobile unit, said receiver operable for coupling through a communications link to receive a satellite almanac information for a plurality of satellites in view of said mobile unit;
a processing unit in said mobile unit, said processing unit coupled to said receiver to receive said satellite almanac information and compute a position information for said satellite by using a Doppler information derived from said satellite almanac information.

10. A method of using a basestation for providing a communications link to a mobile GPS unit, said method comprising:
determining a satellite almanac information for a plurality of satellites in view of said mobile GPS unit;
transmitting said satellite almanac information to said mobile GPS unit for determination of a Doppler information.

11. A method as in claim 10, wherein said Doppler information represents the Doppler shift of GPS signals from said satellite to said basestation.

12. A method as in claim 11 wherein said Doppler information approximately represents the Doppler shift of GPS signals from said satellite to said mobile GPS unit.

13. A method as in claim 10 wherein said Doppler information is obtained from a GPS receiver at said basestation and wherein said Doppler information represents the Doppler shift of GPS signals from said satellite to said basestation.

14. A method as in claim 13 wherein said Doppler information approximately represents the Doppler shift of GPS signals from said satellite mobile GPS unit.

15. A method as in claim 14 further comprising:

receiving a position information from said mobile GPS unit, said position information being received at said basestation such that said basestation obtains a latitude and longitude which indicates the position of said mobile GPS unit.

16. A method as in claim 15 wherein said position information comprises pseudoranges to said plurality of satellites in view of said mobile GPS unit, and wherein said basestation computes said latitude and longitude from said pseudoranges.

17. A method as in claim 15 wherein said position information comprises said latitude and longitude.

18. A method as in claim 10 further comprising:

transmitting satellite data information of said satellite to said mobile GPS unit, said satellite data information comprising data representative of ephemeris for said satellite.

19. A process as in claim 1 wherein a processing unit uses said Doppler information to compensate for a Doppler shift of GPS signals from said satellite.

20. A mobile unit as in claim 9 wherein said processing unit uses said Doppler information to compensate for a Doppler shift of GPS signals from said satellite.

21. A mobile unit as in claim 20 wherein said communication link comprises a radio frequency communication medium.

22. A mobile unit as in claim 20 further comprising;
a transmitter coupled to said processing unit, said transmitter for transmitting said position information.

23. A mobile unit as in claim 22 wherein said position information comprises pseudorange to said plurality of satellites in view of said mobile unit.

24. A mobile unit as in claim 22 wherein said position information comprises a latitude and longitude which indicates the position of said mobile unit.

25. A mobile unit as in claim 20 wherein said processing unit comprises a digital signal processing integrated circuit (DSP) and wherein said DSP processes said GPS signals and said Doppler information using a fast convolution algorithm.

26. A mobile unit as in claim 25 further comprising:
a transmitter coupled to said processing unit, said transmitter for transmitting said position information.

27. A mobile unit as in claim 9 wherein said receiver is operable to receive satellite data information of said satellite from a source other than said

satellite, wherein said satellite data information comprises data representative of ephemeris for said satellite.

28. A basestation for providing a communication link to a mobile GPS unit, said basestation comprising:

a source of a satellite almanac information for a plurality of satellites in view of said mobile GPS unit;

a transmitter coupled to said source of said satellite almanac information, said transmitter for transmitting through said communications link said satellite almanac information to said mobile GPS unit for determination of a Doppler information.

29. A basestation as in claim 28 wherein said source of said satellite almanac information is a storage unit coupled to said basestation.

30. A basestation as in claim 28 further comprising:

a receiver for receiving a position information from said mobile GPS unit;

a processor coupled to said receiver.

31. A basestation as in claim 28, wherein said Doppler information approximately represents the Doppler shift of GPS signals from said satellite to said basestation.

32. A basestation as in claim 30, wherein said position information is received at said basestation such that said basestation obtains a latitude and longitude which indicates the position of said mobile GPS unit.

33. A basestation as in claim 32, wherein said position information comprises pseudoranges to at least some of said plurality of satellites in view of said mobile GPS unit, and wherein said processor of said basestation computes said latitude and longitude from said pseudorange.

34. A basestation as in claim 28 wherein said transmitter is also for transmitting satellite data information of said satellite to said mobile GPS unit, said satellite data information comprising data representative of ephemeris for said satellite.

35. A basestation as in claim 31 wherein said basestation and said mobile GPS unit are within approximately 150 kilometers of each other.

36. A method of calibrating a local oscillator in a mobile GPS receiver, said method comprising:

receiving a precision carrier frequency signal from a source providing said precision carrier frequency signal;

automatically locking to said precision carrier frequency signal and providing a reference signal;

calibrating said local oscillator with said reference signal, said local oscillator being used to acquire GPS signals.

37. A method as in claim 36 wherein said receiving step comprises extracting said precision carrier frequency signal from a data signal containing satellite data information communicated over a communication link.

38. A method as in claim 37 wherein said satellite data information comprises a satellite almanac information for a plurality of satellites in view of said mobile GPS receiver.

39. A method as in claim 37 wherein said satellite data information comprises data representative of ephemeris for a satellite.

40. A method as in claim 37 wherein said communication link is selected from the group consisting of a two-way pager link or a cellular telephone link or personal communication system or specialized mobile radio or a wireless packet data system.

41. A method as in claim 37 wherein said communication link is a radio frequency communication medium.

42. A method as in claim 36 wherein said automatic frequency control logic comprises one of a phase lock loop or a frequency lock loop or a block phase estimator.

43. A method as in claim 42 wherein said reference signal provides a reference frequency which is compared to a frequency provided by said local oscillator to calibrate said local oscillator.

44. A mobile GPS receiver comprising:

a first antenna for receiving GPS signals;

a downconverter coupled to said first antenna, said first antenna providing said GPS signals to said downconverter;

a local oscillator coupled to said downconverter, said local oscillator providing a first reference signal to said downconverter to convert said GPS signals from a first frequency to a second frequency;

a second antenna for receiving a precision carrier frequency signal from a source providing said precision carrier frequency signal;

an automatic frequency control (AFC) circuit coupled to said second antenna, said AFC circuit providing a second reference signal to said local oscillator to calibrate said first reference signal of said local oscillator, wherein said local oscillator is used to acquire said GPS signals.

45. A mobile GPS receiver as in claim 44 further comprising a comparator coupled to said AFC circuit and to said local oscillator, said comparator comparing said first reference signal and said second reference signal to adjust the frequency of said first reference signal from said local oscillator.

46. A mobile GPS receiver as in claim 45 wherein said AFC circuit comprises a phase lock loop coupled to a receiver which is coupled to said second antenna.

47. A mobile GPS receiver as in claim 44 further comprising a receiver coupled to said second antenna, said receiver for receiving said precision carrier frequency signal from said second antenna, wherein said receiver receives said precision carrier frequency signal with a data signal containing satellite data information communicated through said second antenna.

48. A mobile GPS receiver as in claim 47 wherein said satellite data information comprises a Doppler information of a satellite in view of said mobile GPS receiver.

49. A mobile GPS receiver as in claim 48 wherein said satellite data information comprises an identification of a plurality of satellites in view of said mobile GPS receiver and a corresponding plurality of Doppler information for each satellite of said plurality of satellites in view of said mobile GPS receiver.

50. A mobile GPS receiver as in claim 47 wherein said satellite data information comprises data representative of ephemeris for a satellite.

51. A method of using a basestation to calibrate a local oscillator in a mobile GPS receiver, said method comprising:

producing a first reference signal having a precision frequency;

modulating said first reference signal with a data signal to provide a precision carrier frequency signal;

transmitting said precision carrier frequency signal to said mobile GPS receiver, said precision carrier frequency signal being used to calibrate a local oscillator in said mobile GPS receiver, said local oscillator being used to acquire GPS signals.

52. A method as in claim 51 wherein said data signal contains satellite data information which comprises a satellite almanac information for a plurality of satellites in view of said mobile GPS receiver.

53. A method as in claim 51 wherein said data signal contains satellite data information which comprises data representative of ephemeris for a satellite.

54. A basestation for providing a calibration signal for use in a mobile GPS receiver to calibrate a local oscillator in said mobile GPS receiver, said basestation comprising:

a first source for a first reference signal have a precision frequency;

a modulator coupled to said first source and to a second source of satellite data information said modulator providing a precision carrier frequency signal;

a transmitter coupled to said modulator, said transmitter for transmitting said precision carrier frequency signal to said mobile GPS receiver, said precision frequency signal being used to calibrate said local oscillator, said local oscillator being used to acquire said GPS signals.

55. A basestation as in claim 54 wherein said precision carrier frequency signal has a first frequency which is substantially different from a frequency of said GPS signals.

56. A basestation as in claim 54 wherein said satellite data information comprises data representative of ephemeris for a satellite in view of said mobile GPS receiver.

57. A basestation as in claim 54 further comprising a processor coupled to said transmitter, said processor instructing said transmitter to transmit to said mobile GPS receiver.

58. A basestation as in claim 57 wherein said processor determines a plurality of satellites in view of said mobile GPS receiver and obtains said satellite data information for each satellite of said plurality of satellites, and wherein said processor instructs said transmitter to transmit to said mobile GPS receiver an identification of said plurality of satellites and said satellite data information.

59. A basestation as in claim 58 wherein said satellite data information comprises Doppler information for said plurality of satellites.

60. A basestation as in claim 58 wherein said satellite data information comprises data representative of ephemeris for said plurality of satellites.

61. A method of deriving a local oscillator signal in a mobile GPS receiver, said method comprising:

receiving a precision carrier frequency signal from a source providing said precision carrier frequency signal;

automatically locking to said precision carrier frequency signal and providing a reference signal;

using said reference signal to provide a local oscillator signal to acquire GPS signals.

62. A method as in claim 61 wherein said receiving step comprises extracting said precision carrier frequency signal from a data signal containing satellite data information communicated over a communication link.

63. A method as in claim 62 wherein said satellite data information comprises a satellite almanac information for a plurality of satellites in view of said mobile GPS receiver.

64. A method as in claim 62 wherein said satellite data information comprises data representative of ephemeris for a satellite.

65. A method as in claim 62 wherein said communication link is selected from the group consisting of a two-way pager link or a cellular telephone link or personal communication system or specialized mobile radio or a wireless packet data system.

66. A method as in claim 62 wherein said communication link is a radio frequency communication medium.

67. A method as in claim 61 wherein said step of using said reference signal comprises providing said reference signal to a frequency synthesizer and

producing said local oscillator signal from said reference signal and said frequency synthesizer.

68. A method as in claim 61 further comprising downconverting GPS signals received through a GPS antenna, said downconverting step using said local oscillator signal to downconvert said GPS signals.

69. A method as in claim 61 wherein said step of using said reference signal comprises downconverting GPS signals received through a GPS antenna, said downconverting using said local oscillator signal to downconvert said GPS signals.

70. A mobile GPS receiver comprising:

a first antenna for receiving GPS signals;

a downconverter coupled to said first antenna, said first antenna providing said GPS signals to said downconverter, said downconverter having an input for receiving a local oscillator signal to convert said GPS signals from a first frequency to a second frequency;

a second antenna for receiving a precision carrier frequency signal from a source providing said precision carrier frequency signal;

an automatic frequency control (AFC) circuit coupled to said second antenna, said AFC circuit being coupled to said downconverter to provide said local oscillator signal which is used to acquire said GPS signals.

71. A mobile GPS receiver as in claim 70 further comprising a frequency synthesizer coupled to said AFC circuit and to said downconverter, said downconverter receiving said local oscillator through said frequency synthesizer.

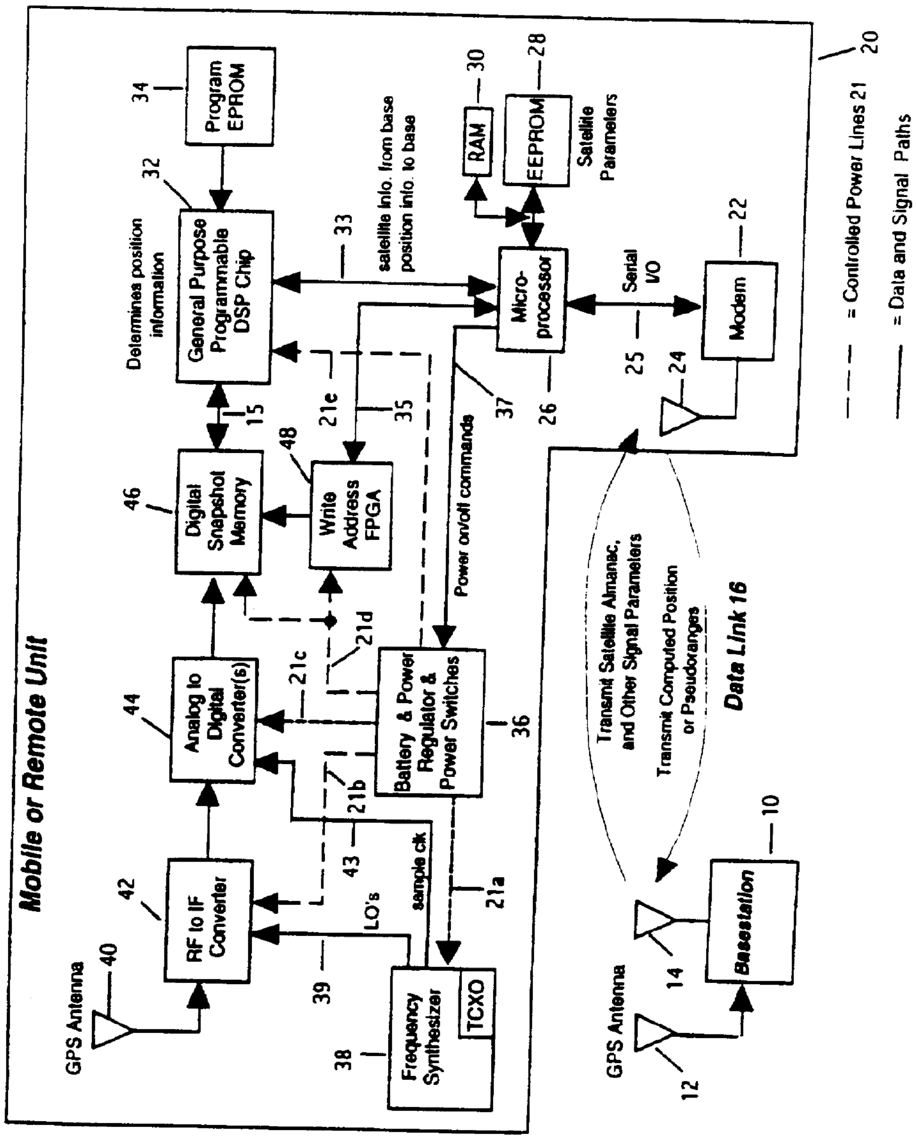

Mobile or Remote Unit
GPS Antenna
40
RF to IF Converter
42
Analog to Digital Converter(s)
44
Digital Snapshot Memory
46
General Purpose Programmable DSP Chip
32
Determines position information
Program EPROM
34
15
Write Address FPGA
48
21e
35
21c
21d
21b
43
LO's
sample clk
39
Frequency Synthesizer
TCXO
38
Battery & Power Regulator & Power Switches
36
21a
Power on/off commands
37
Micro-processor
26
33
satellite info. from base
position info. to base
RAM
30
EEPROM
28
Satellite Parameters
Serial I/O
25
Modem
22
24
20
= Controlled Power Lines 21
= Data and Signal Paths
Transmit Satellite Almanac, and Other Signal Parameters
Transmit Computed Position or Pseudoranges
Data Link 16
GPS Antenna
12
14
Basestation
10

FIG. 1A

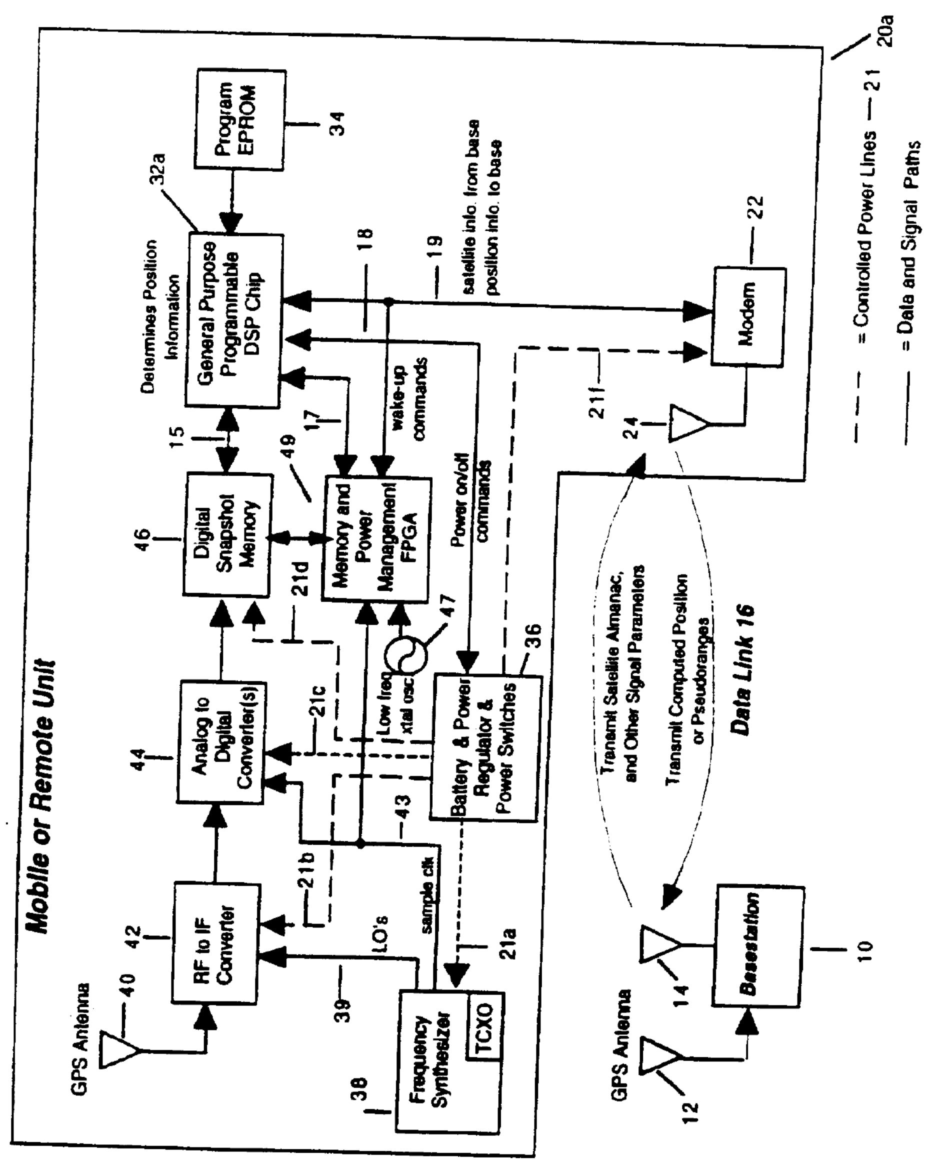

Mobile or Remote Unit
GPS Antenna
40
RF to IF Converter
42
Analog to Digital Converter(s)
44
Digital Snapshot Memory
46
General Purpose Programmable DSP Chip
32a
Determines Position Information
Program EPROM
34
15
17
49
Memory and Power Management FPGA
21d
47
Low freq xtal osc
21c
43
21b
LO's
sample clk
21a
39
Frequency Synthesizer
TCXO
38
Battery & Power Regulator & Power Switches
36
Power on/off commands
wake-up commands
18
19
satellite info. from base
position info. to base
Modem
22
21
24
20a
Transmit Satellite Almanac, and Other Signal Parameters
Transmit Computed Position or Pseudoranges
Data Link 16
GPS Antenna
12
14
Basestation
10
= Controlled Power Lines — 21
= Data and Signal Paths

FIG. 1B

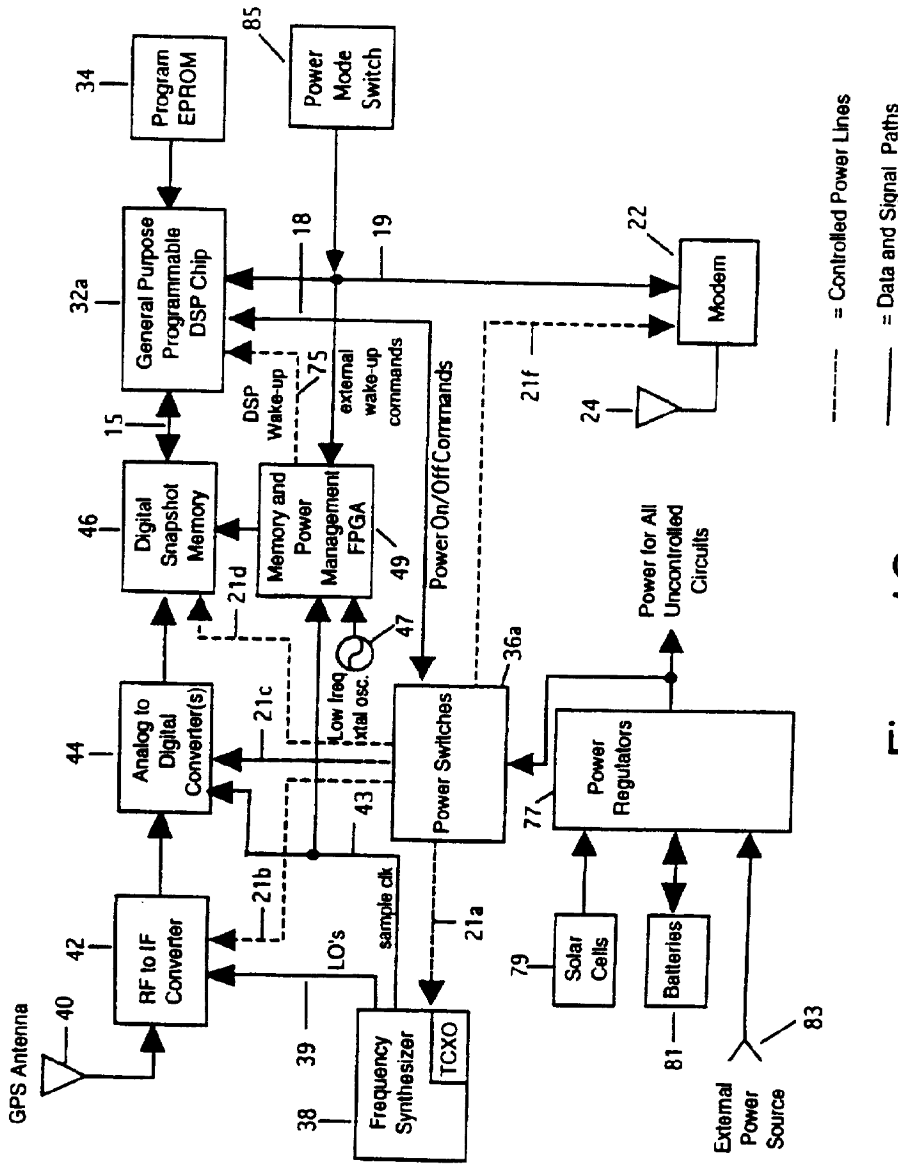

GPS Antenna
40
RF to IF Converter
42
Analog to Digital Converter(s)
44
Digital Snapshot Memory
46
General Purpose Programmable DSP Chip
32a
Program EPROM
34
15
Power Mode Switch
85
18
19
Modem
22
24
21f
DSP Wake-up
75
external wake-up commands
Memory and Power Management FPGA
49
21d
Low freq xtal osc.
47
Power On/Off Commands
Power Switches
36a
21c
43
21b
LO's
sample clk
39
Frequency Synthesizer
TCXO
38
21a
Power for All Uncontrolled Circuits
Power Regulators
77
Solar Cells
79
Batteries
81
External Power Source
83
= Controlled Power Lines
= Data and Signal Paths

Figure 1C

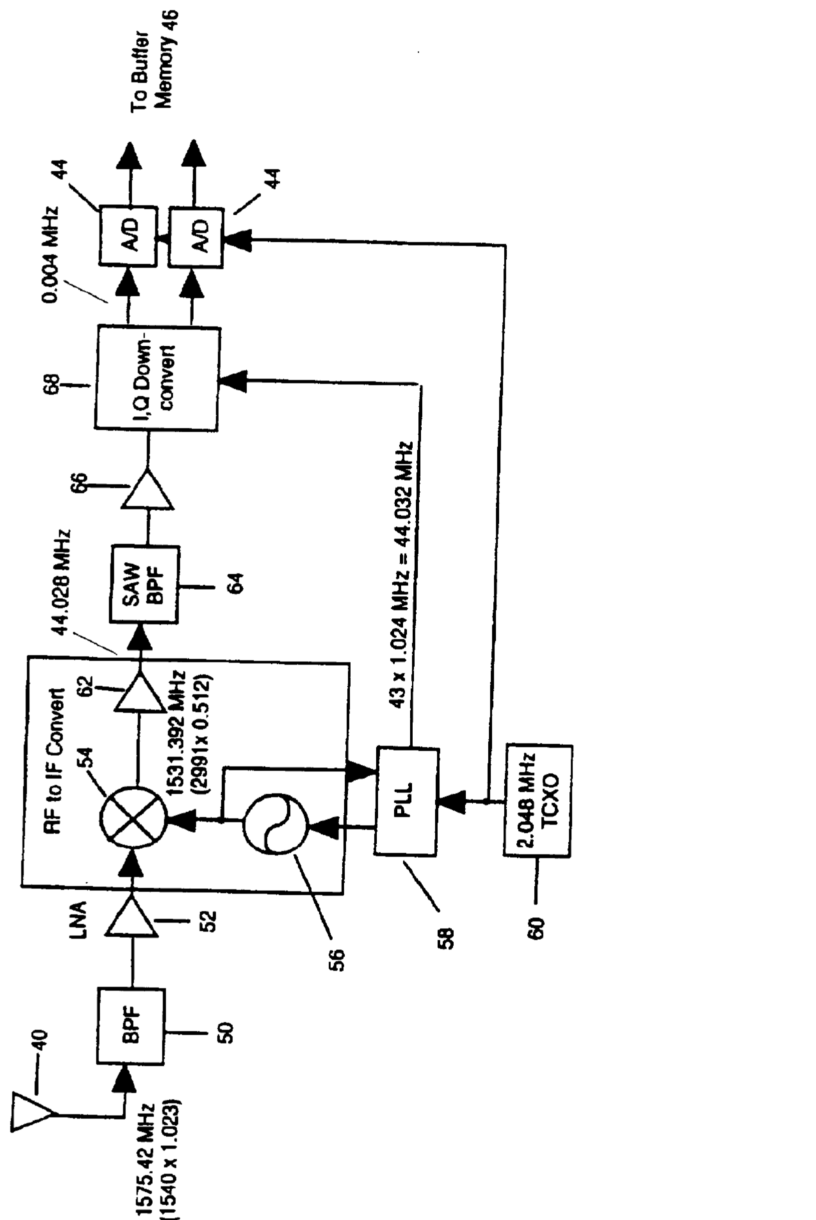

1575.42 MHz
(1540 x 1.023)
40
BPF
50
LNA
52
RF to IF Convert
54
1531.392 MHz
(2991 x 0.512)
62
56
44.028 MHz
SAW
BPF
64
66
68
I,Q Down-
convert
0.004 MHz
A/D
A/D
44
44
To Buffer
Memory 46
43 x 1.024 MHz = 44.032 MHz
PLL
58
2.048 MHz
TCXO
60

Figure 2A

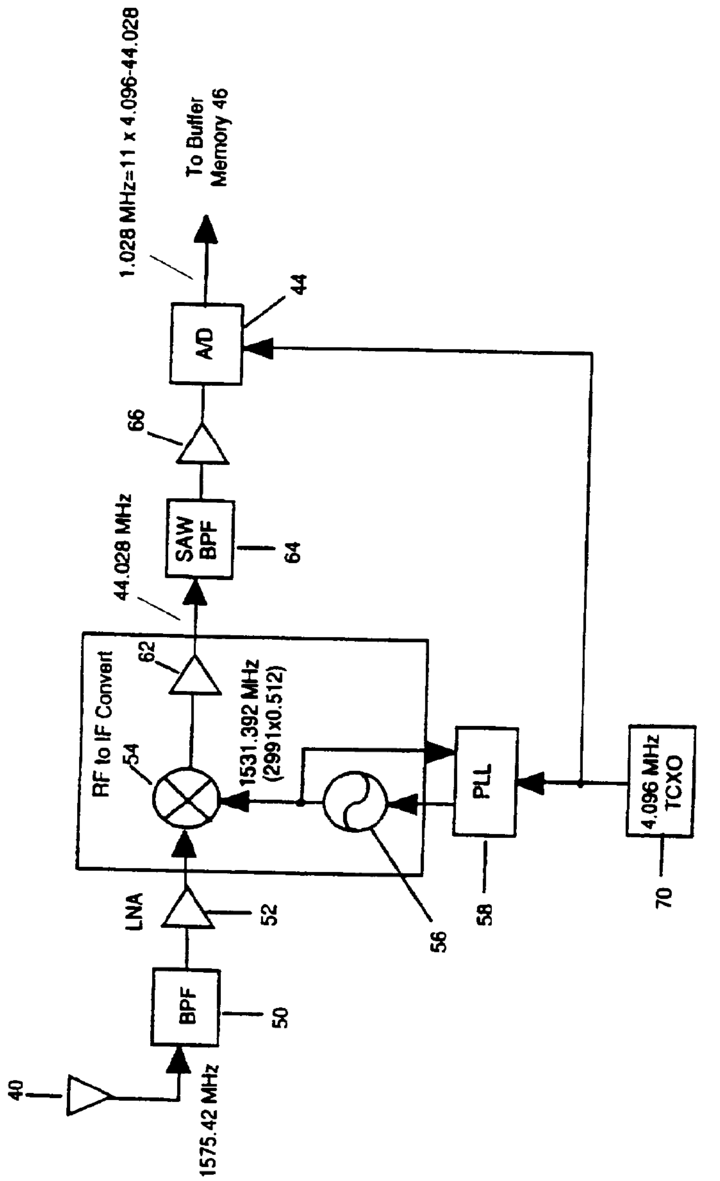

1575.42 MHz
40
BPF
50
LNA
52
RF to IF Convert
54
56
1531.392 MHz
(2991x0.512)
62
PLL
58
4.096 MHz
TCXO
70
44.028 MHz
SAW
BPF
64
66
A/D
44
1.028 MHz=11 x 4.096-44.028
To Buffer
Memory 46

Figure 2B

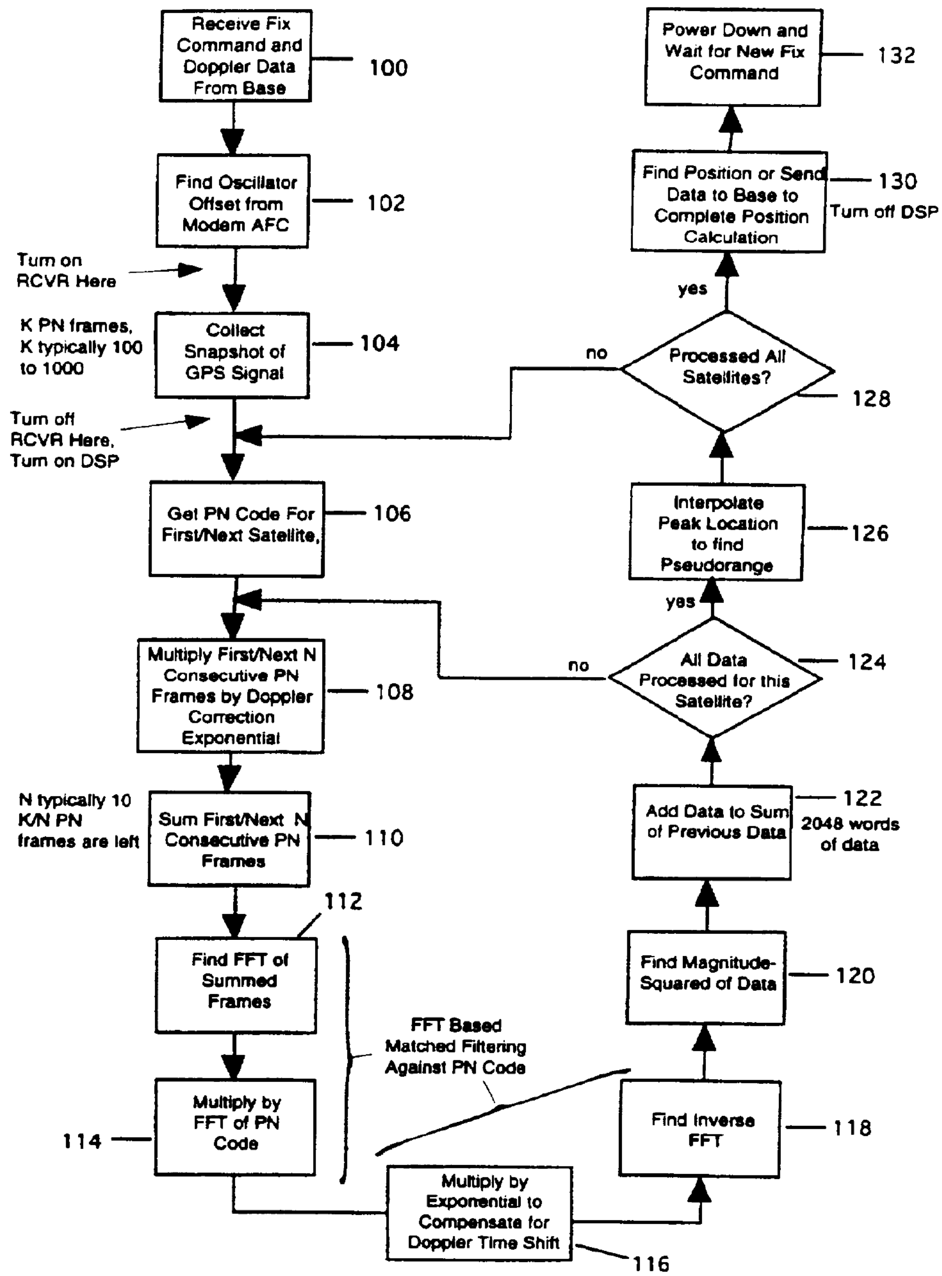
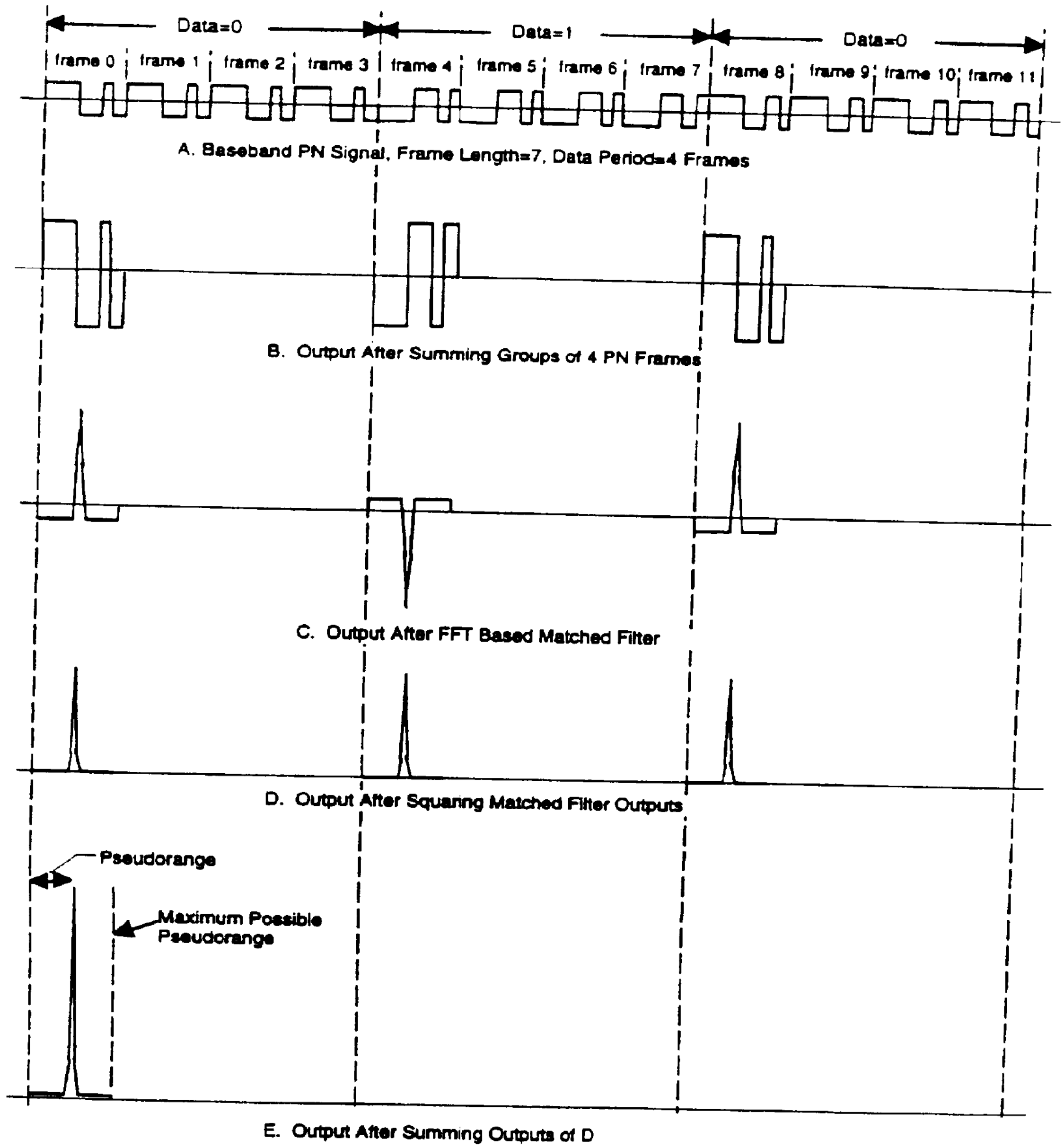
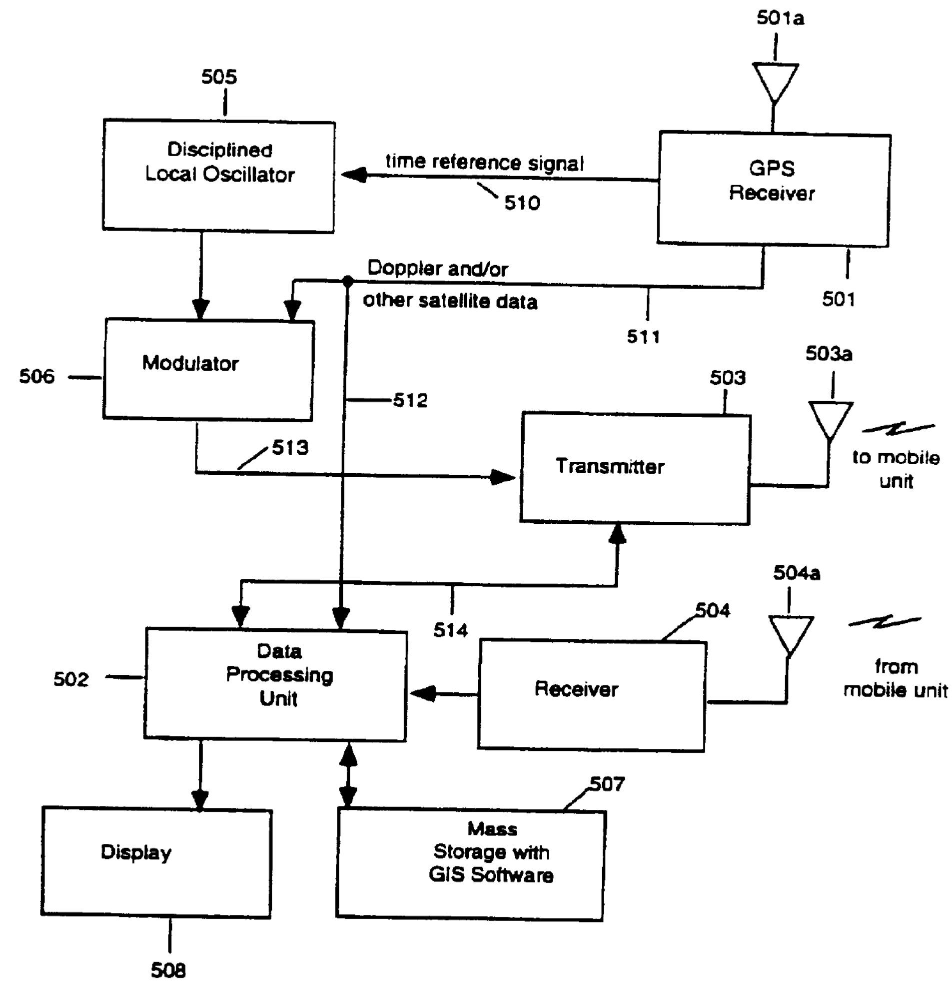

Receive Fix Command and Doppler Data From Base
100
Find Oscillator Offset from Modem AFC
102
Turn on RCVR Here
K PN frames, K typically 100 to 1000
Collect Snapshot of GPS Signal
104
Turn off RCVR Here, Turn on DSP
Get PN Code For First/Next Satellite,
106
Multiply First/Next N Consecutive PN Frames by Doppler Correction Exponential
108
N typically 10 K/N PN frames are left
Sum First/Next N Consecutive PN Frames
110
112
Find FFT of Summed Frames
Multiply by FFT of PN Code
114
FFT Based Matched Filtering Against PN Code
Multiply by Exponential to Compensate for Doppler Time Shift
116
Find Inverse FFT
118
Find Magnitude-Squared of Data
120
Add Data to Sum of Previous Data
122
2048 words of data
All Data Processed for this Satellite?
124
no
yes
Interpolate Peak Location to find Pseudorange
126
Processed All Satellites?
128
no
yes
Find Position or Send Data to Base to Complete Position Calculation
130
Turn off DSP
Power Down and Wait for New Fix Command
132

Figure 3



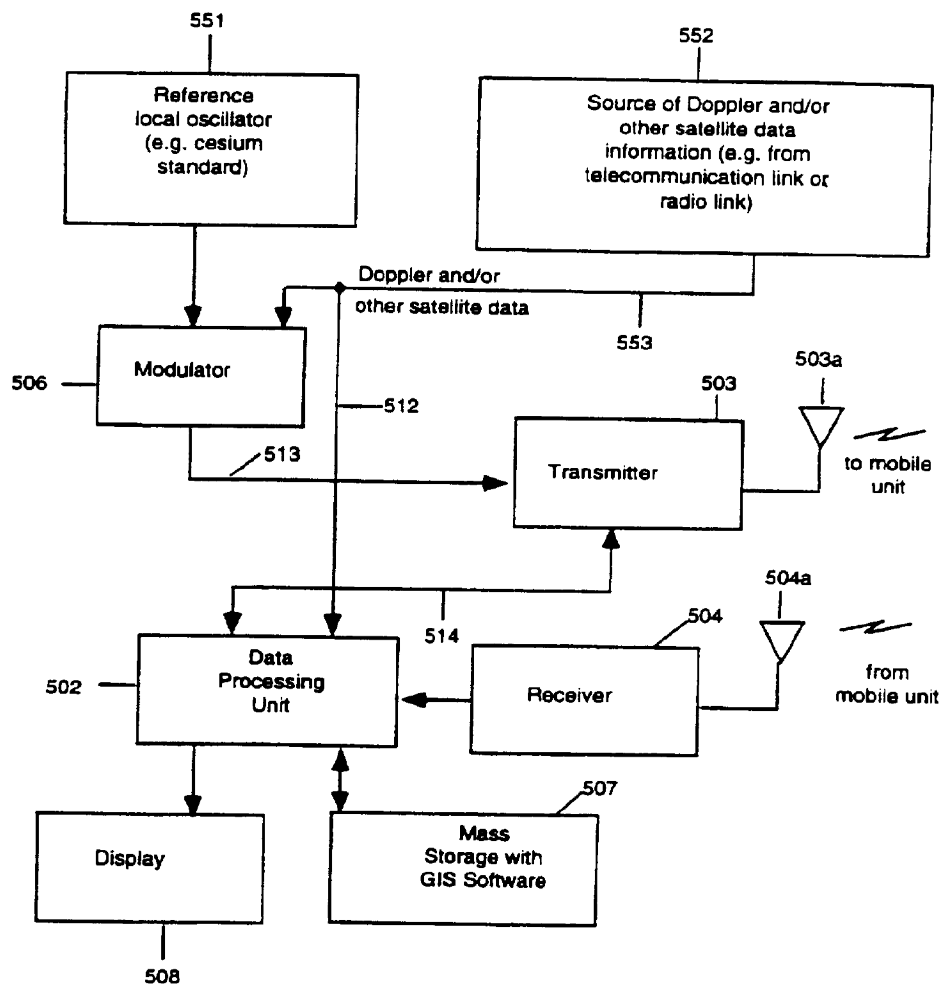
Figures 4A, 4B, 4C, 4D, 4E

FIGURE 5A



501a
505
Disciplined Local Oscillator
time reference signal
510
GPS Receiver
501
Doppler and/or other satellite data
511
Modulator
506
512
503a
503
513
Transmitter
to mobile unit
504a
504
514
Data Processing Unit
502
Receiver
from mobile unit
507
Display
Mass Storage with GIS Software
508

FIGURE 5B


551
Reference local oscillator (e.g. cesium standard)
552
Source of Doppler and/or other satellite data information (e.g. from telecommunication link or radio link)
Doppler and/or other satellite data
553
506
Modulator
512
513
503a
503
Transmitter
to mobile unit
504a
504
514
502
Data Processing Unit
Receiver
from mobile unit
507
Display
Mass Storage with GIS Software
508

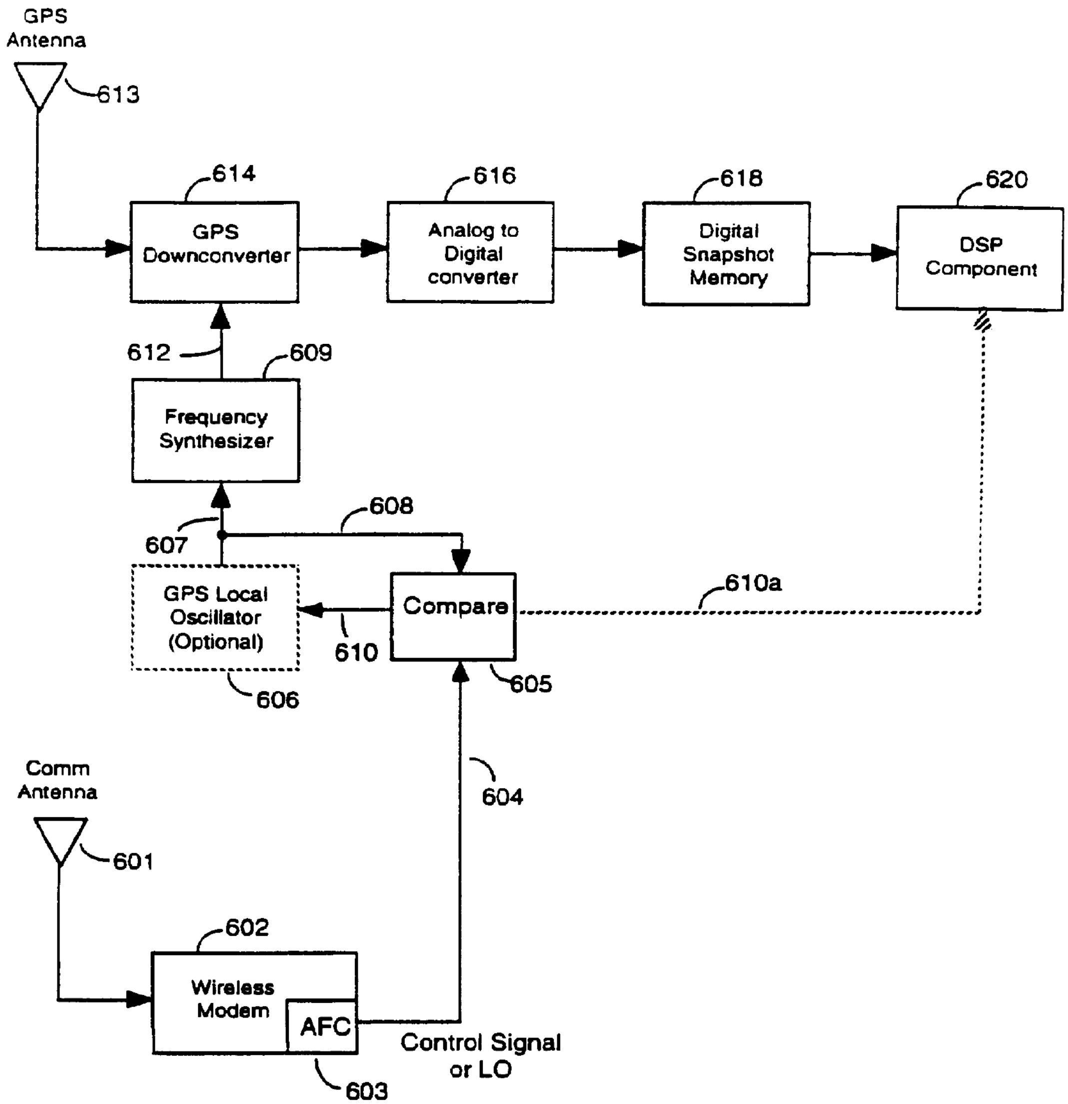

GPS
Antenna
613
614
GPS
Downconverter
616
Analog to
Digital
converter
618
Digital
Snapshot
Memory
620
DSP
Component
612
609
Frequency
Synthesizer
608
607
GPS Local
Oscillator
(Optional)
Compare
610a
610
605
606
604
Comm
Antenna
601
602
Wireless
Modem
AFC
Control Signal
or LO
603

FIGURE 6A

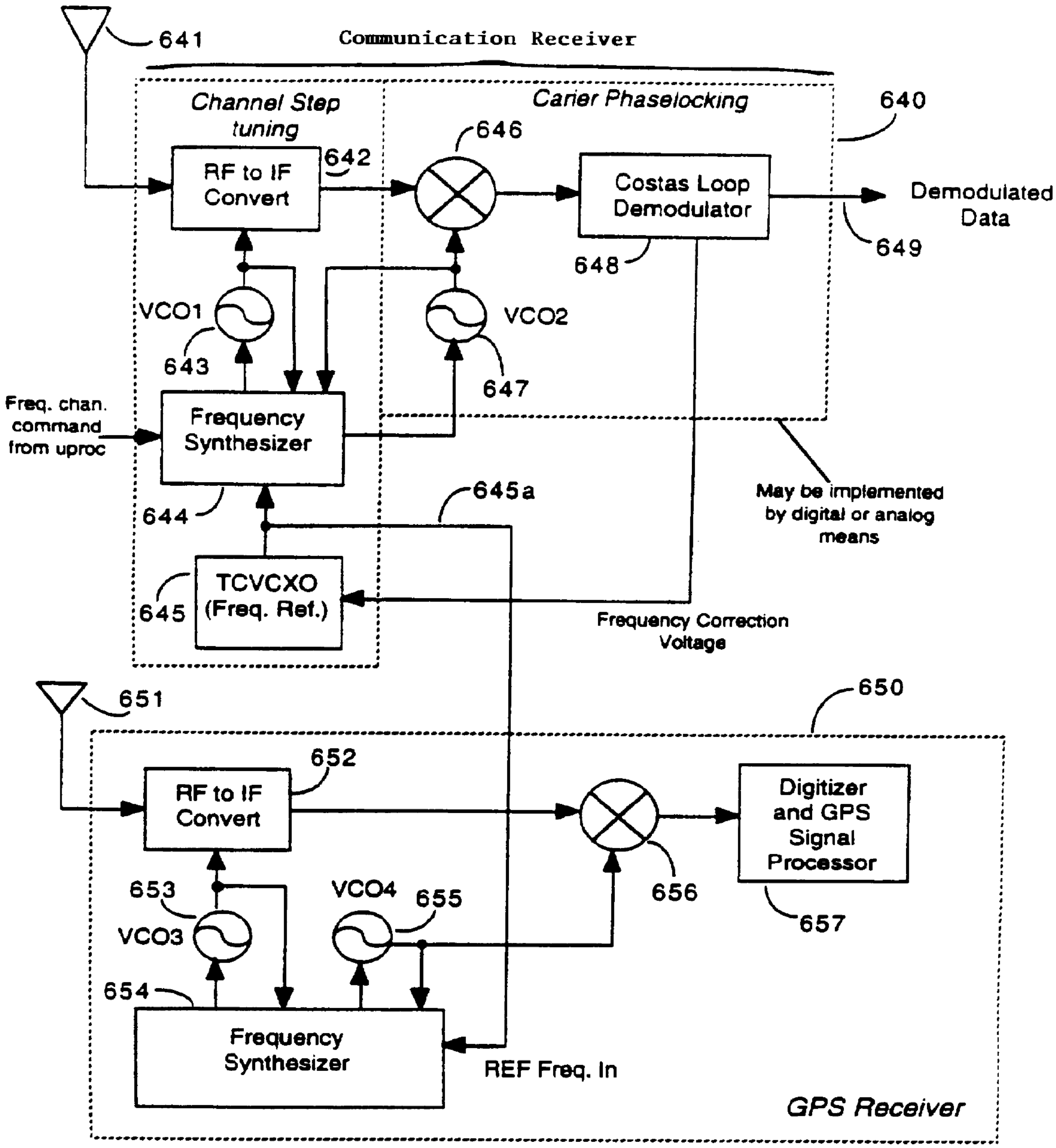

641
Communication Receiver
Channel Step tuning
Carier Phaselocking
640
646
642
RF to IF Convert
Costas Loop Demodulator
Demodulated Data
649
648
VCO1
VCO2
643
647
Freq. chan. command from uproc
Frequency Synthesizer
May be implemented by digital or analog means
644
645a
TCVCXO (Freq. Ref.)
645
Frequency Correction Voltage
651
650
652
RF to IF Convert
Digitizer and GPS Signal Processor
653
VCO4
655
656
VCO3
657
654
Frequency Synthesizer
REF Freq. In
GPS Receiver

Figure 6B

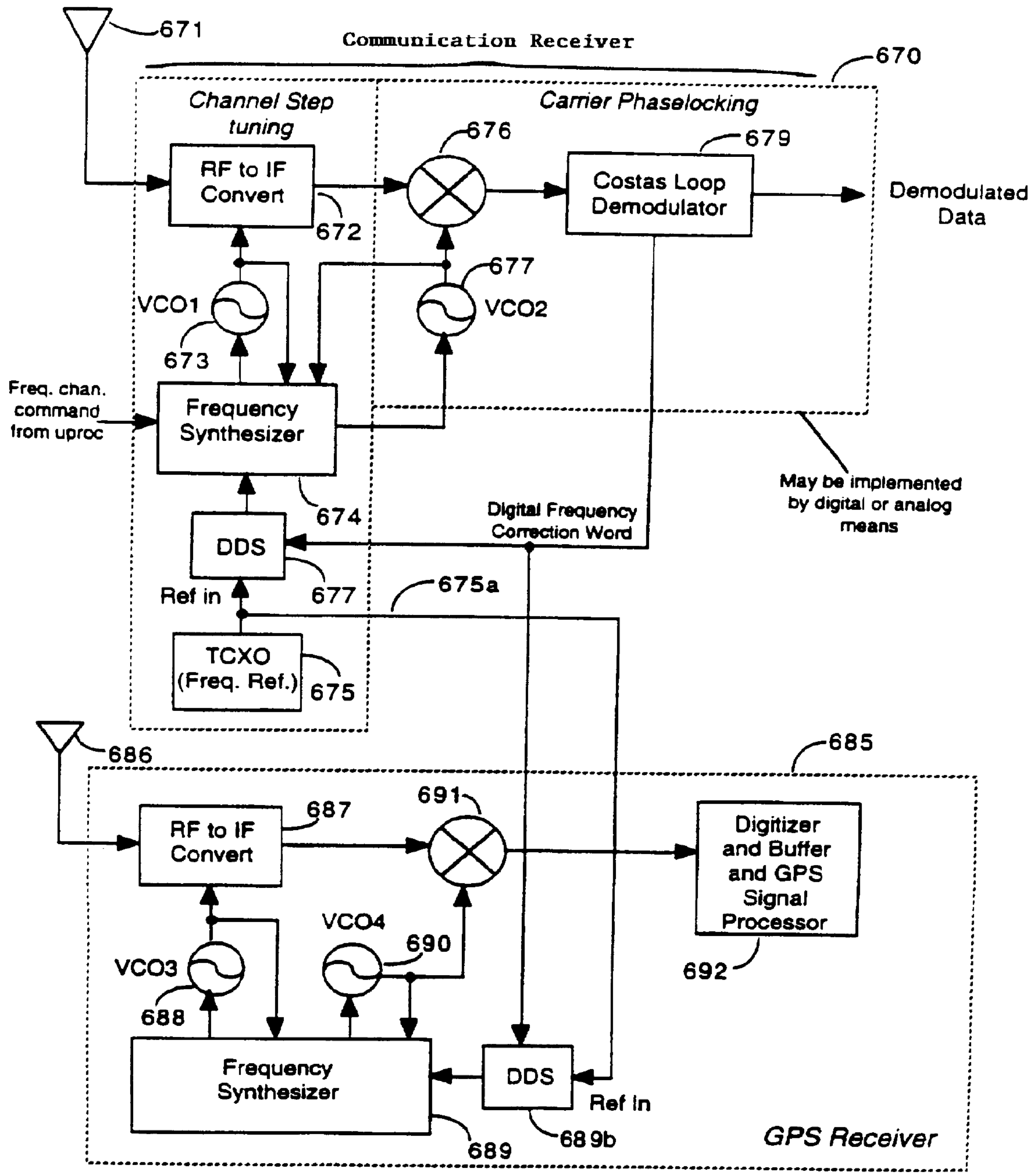

671
Communication Receiver
670
Channel Step tuning
Carrier Phaselocking
676
679
RF to IF Convert
Costas Loop Demodulator
Demodulated Data
672
677
VCO1
VCO2
673
Freq. chan. command from uproc
Frequency Synthesizer
May be implemented by digital or analog means
674
Digital Frequency Correction Word
DDS
Ref in
677
675a
TCXO (Freq. Ref.)
675
686
685
RF to IF Convert
687
691
Digitizer and Buffer and GPS Signal Processor
VCO4
690
VCO3
692
688
Frequency Synthesizer
DDS
Ref In
689
689b
GPS Receiver

Figure 6C

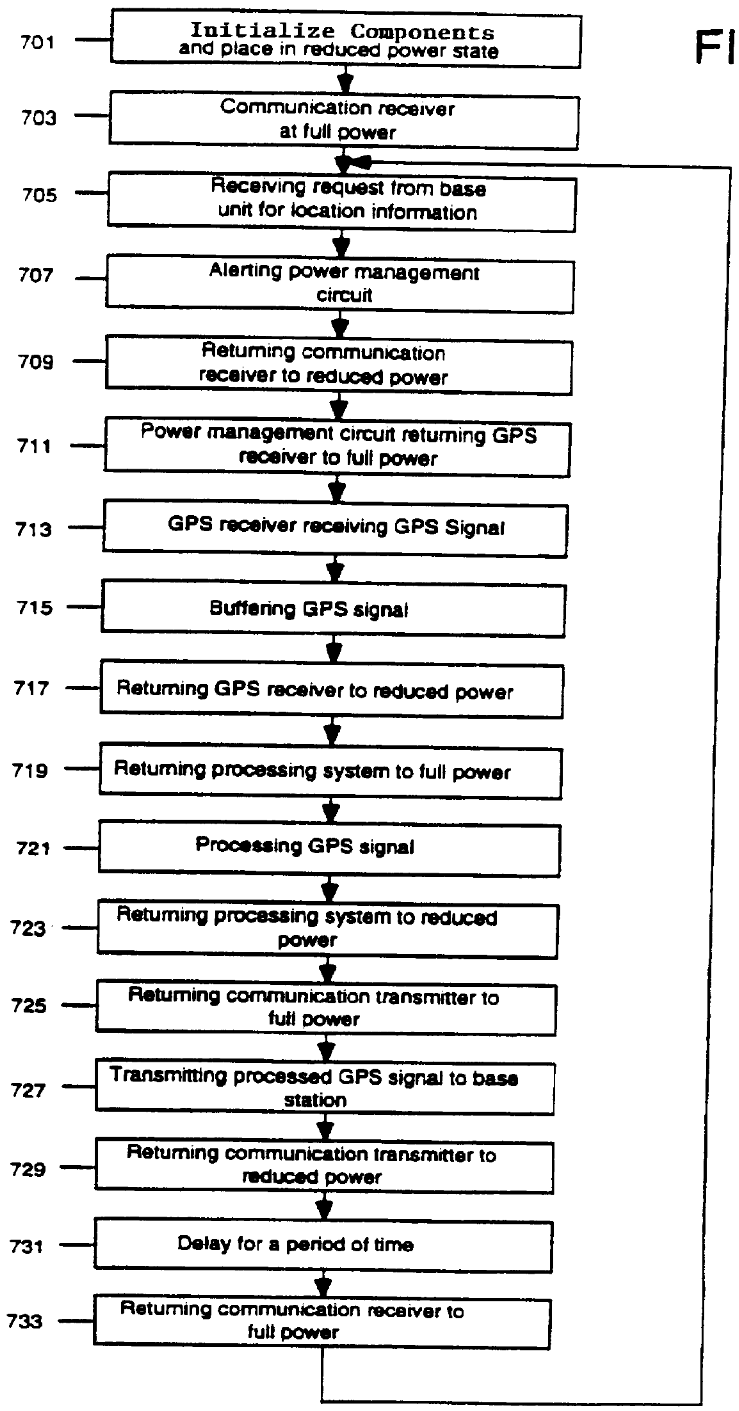

701
Initialize Components and place in reduced power state
703
Communication receiver at full power
705
Receiving request from base unit for location information
707
Alerting power management circuit
709
Returning communication receiver to reduced power
711
Power management circuit returning GPS receiver to full power
713
GPS receiver receiving GPS Signal
715
Buffering GPS signal
717
Returning GPS receiver to reduced power
719
Returning processing system to full power
721
Processing GPS signal
723
Returning processing system to reduced power
725
Returning communication transmitter to full power
727
Transmitting processed GPS signal to base station
729
Returning communication transmitter to reduced power
731
Delay for a period of time
733
Returning communication receiver to full power

FIGURE 7

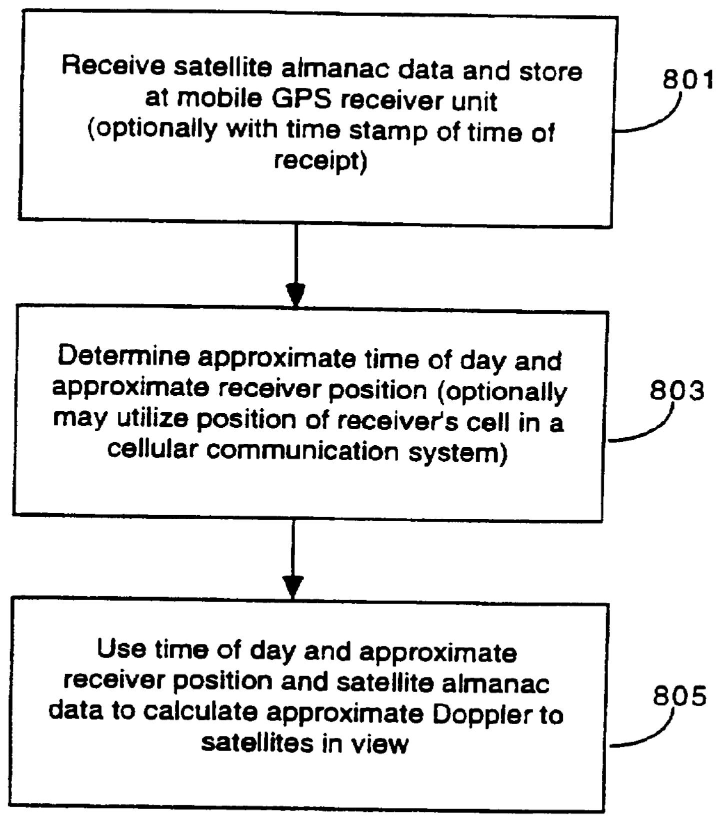

Receive satellite almanac data and store at mobile GPS receiver unit (optionally with time stamp of time of receipt)
801
Determine approximate time of day and approximate receiver position (optionally may utilize position of receiver's cell in a cellular communication system)
803
Use time of day and approximate receiver position and satellite almanac data to calculate approximate Doppler to satellites in view
805

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03512

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 7/185; G01S 5/02
US CL :342/357; 364/449.7
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 342/357; 364/449.7
449.9, 449.95

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,153,598 (ALVES, JR.) 06 October 1992, See Figure 1.	1-35
X	US, A, 5,323,322 (MUELLER ET AL) 21 June 1994, See Figure 3	1-35
X	US, A, 4,445,118 (TAYLOR ET AL) 24 April 1984, See Figure 3	1-35
X	US, A, 5,119,102 (BARNARD) 02 June 1992, See Figure 3	1-35
X	US, A, 5,420,592 (JOHNSON) 30 May 1995, See Figure 2	1-71
X	US, A, 4,457,006 (MAINE) 26 June 1984, See column 4, lines 63+	36-71

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search	Date of mailing of the international search report
05 JUNE 1997	11 JUL 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	THEODORE BLUM
Facsimile No. (703) 305-3230	Telephone No. (703) 305-1833

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03512

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,365,450 (SCHUCHMAN ET AL) 15 November 1994, See claims 3, 9, and 11	36-71

Form PCT/ISA/210 (continuation of second sheet)(July 1992)*

CORRECTED VERSION*

CORRECTED VERSION**

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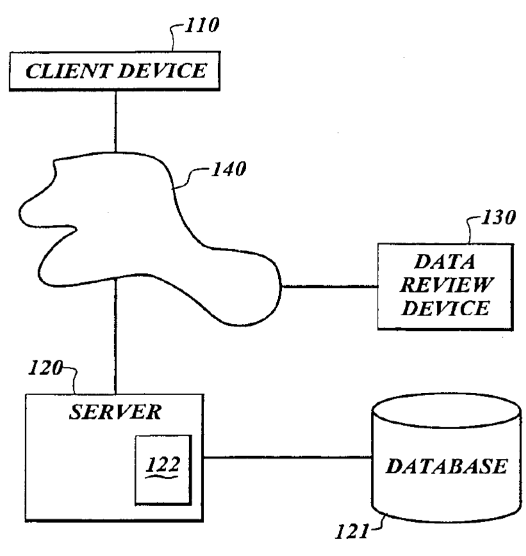
Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: REDUCING RISK USING BEHAVIORAL AND FINANCIAL REWARDS



(57) Abstract

The invention provides a set of techniques and products in which one or more insured persons and one or more associated beneficiaries are monitored with regard to dynamic risk reassessment, given feedback information in response to that dynamic risk reassessment, and are encouraged to comply with the feedback. The insured persons and associated beneficiaries are coupled to a client–server system disposed for dynamic measurement of medical information, and the client–server system is disposed for alerting the insured persons and associated beneficiaries to suggested behaviors for reducing risk. The invention includes an insurance product in which portions of the insurance premium are allocated to one or more components, in response to compliance with the suggested behaviors.

*(Referred to in PCT Gazette No. 31/2000, Section II) **(Referred to in PCT Gazette No. 40/2000, Section II)

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REDUCING RISK USING BEHAVIORAL AND FINANCIAL REWARDS

Field of the Invention

These known methods increase the incentive for the insured entity to reduce the insured-against risk. However, these methods are subject to several drawbacks. Where the insured-against risk is relatively inevitable (such as with life insurance or long-term care insurance0, the insurance company finds it difficult to avoid the inevitability of a claim. Rather, it is in the underwriter's interest to stave off the claim for as long as possible.

Certain kinds of insurance (such as long-term care insurance) also have a substantial effect on the family of the insured person. For example, the insured person is often faced with the dilemma of either (1) reduction to penury to quality for government support, or (2) spending their entire estate on long-term care. The family of the insured person also has interests against these options.

Accordingly, it would be advantageous to provide a method and system to increase the incentive for the insured entity to reduce the insured-against risk, even when that insured-against risk is relatively inevitable. In the case of long-term care insurance, it is in the underwriter's interest to provide incentives for the insured person and their family to maintain the insured person's health and independence for as long as possible (quite apart from the emotional incentives they already have).

Application Serial No. _________, Express Mail Mailing No. EE 261 914 722 US, filed S September 23, 1998, in the name of Stephen J. Brown, titled "Dynamic

Modeling and Scoring Risk Assessment," assigned to the same assignee, attorney docket number HHN-003 describes techniques for modeling and scoring risk assessment that are time-dependent, and in one embodiment are responsive to progression of a disease or degenerative condition in a patient.

One aspect of this co-pending application is that the insurer can dynamically adjust the risk assessment of individual insured persons in response to action taken (or not taken) by those insured persons to maintain their own health. The underwriter can thus dynamically adjust the cost or the benefits of the insurance policy in response to those actions. By doing so, the underwriter, the insured person, and the insured person's family have the common goal of maximizing the useful life and independence of the insured person.

As described in the co-pending application, dynamic reassessment can be performed in conjunction with a monitoring and scoring system for determining risk assessment for populations and for individuals with regard to those populations.

It would also be desirable for the insured person (and associated others) to make use of dynamic risk are assessment to monitor and influence the behavior of the insured person, to reduce the risk. It would also be desirable to provide the insured person, and the insured person's family with information available to the underwriter, and to suggest particular prescribed or proscribed actions that would reduce short-term risk and provide a greater payoff for all concerned.

Accordingly, it would be advantageous to provide the insured person, and associated others, with feedback information from dynamic reassessment of the risk associated with the insured person, so that the insured person, and associated others, can act to minimize that risk. This advantage is achieved in an embodiment of the invention in which the insured person and their beneficiaries are provided with feedback information and instruction responsive to dynamic risk reassessment, and in which payments form an associated set of insurance products are allocated dependant on compliance with that feedback. For example, one such insurance product includes a long-term care component and a life insurance component, and devotes a fraction of the product premium to one or the other component in response to compliance with the feedback offered by the underwriter.

Summary of the Invention

The invention provides a set of techniques and products in which one or more insured persons and one or more associated beneficiaries are monitored with regard to dynamic risk reassessment, are given feedback information responsive to that dynamic risk reassessment, and are encouraged to comply with the feedback information. In a preferred embodiment, the insured persons and associated beneficiaries are coupled to a client-server system that is configured to obtain dynamic measurement of medical information (for example, using bio-medical devices or using a question and answer format), and the client-server system is configured to alert the insured persons and associated beneficiaries to suggested behaviors for reducing risk. The preferred embodiment includes an insurance product in which portions of the insurance premium are allocated to one or more components (such as a long-term care benefit or a life insurance benefit), in response to compliance with the suggested behaviors. Thus, the insured is provided with an incentive for compliance with the suggested behaviors for reducing risk by receiving a more beneficial allocation of the premium to the components of the insurance product.

In a preferred embodiment, an insured patient is examined at intervals by medical personnel, to determine medical information that can be used as factors for dynamically determining a risk assessment for that insured patient. The medical personnel can determine a medical regimen (possibly including diet, exercise, prescribed medication, or other factors) that are intended to reduce the insured-against risk. The insured patient, and where appropriate, associated beneficiaries or other close relations, use a client device with a client-server system to provide dynamic medical information regarding the condition of the insured. For example, the client device can periodically measure blood glucose, blood pressure, heart rate, weight, and the like. Similarly, the client device can periodically question the insured patient or the close relations for information about the insured, such as affect or mutation, diet or exercise, and the like.

In response to the prescribed medical regimen and information from the insured patient, a server device receiving that information from the client device can dynamically reassess risk factors associated with the insured patient, and can alert medical personnel or close relations in response thereto. In response to dynamic risk assessment, the server device can modify which portions of an insurance premium (or other financial product payments) are allocated to one or more components (such as a long-term care component or a life insurance component). The server device can use patient compliance with the suggested medical regimen as one measure to be factored into the dynamic risk assessment.

Brief Description of the Drawings

FIGURE 1A shows a diagram of a system for data collection and interpretation for a population;

FIGURE 1B shows details of the client device shown in **Fig. 1A**;

FIGURE 1C shows devices that may be connected to client device;

FIGURE 1D shows details of the data review device;

FIGURE 2 illustrates a data flow diagram indicating some of the data paths used in a preferred embodiment;

FIGURE 3A illustrates a process for determining dynamic risk assessment;

FIGURE 3B illustrates a process used to evaluate patient information;

FIGURE 4 illustrates a process used to respond to risk; and

FIGURE 5 illustrates a process used to determine feedback information.

Description of the Preferred Embodiments

In the following description, a preferred embodiment of the invention is described with regard to preferred process steps and data structures. Embodiments of the invention can be implemented using general-purpose processors or special purpose processors operating under program control, or other circuits, adapted to particular process steps and data structures described herein. Other embodiments include computer program products that contain computer code embodied in a computer readable media for causing a computer to perform the process steps. Implementation of the process steps and data structures described herein would not require undue experimentation or further invention.

Related Applications

Inventions described herein can be used in combination or conjunction with inventions described in the following patent applications. These patent applications are hereby incorporated by reference as if fully set forth herein:

Application Serial No. 09/041,809, filed November 21, 1997 in the name of Stephen J. Brown titled "Phenoscope and Phenobase," assigned to the same assignee, attorney docket number RYA-136.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown titled "Health Management Process Control System," assigned to the same assignee, attorney docket number RYA-114.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown and Erik K. Jensen, titled "On-Line Health Education and Feedback System Using Motivational Driver Profile Coding and Automated Content Fulfillment," assigned to the same assignee, attorney docket number RYA-115.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown titled "Multiple Patient Monitoring System for Proactive Health Management," assigned to the same assignee, attorney docket number RYA-116.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown titled "On-Line Health Education Using Composites of Entertainment and Personalized," assigned to the same assignee, attorney docket number RYA-116.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown titled "On-Line Health Education Using Composites of Entertainment and Personalized Health Information," assigned to the same assignee, attorney docket number RYA-119a.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown titled "Monitoring System for Remotely Querying Individuals," assigned to the same assignee, attorney docket number RYA-126.

Application Serial No. _____________, filed _____________, in the name of Stephen J. Brown titled "Multi-User Remote Health System," assigned to the same assignee, attorney docket number RYA-131a.

Application Serial No. _____________, Express Mail Mailing No. EE 261 914 722 US, filed September 23, 1998, in the name of Stephen J. Brown titled "Dynamic Modeling and Scoring Risk Assessment," assigned to the same assignee, attorney docket number HHN-003.

System for Reducing Risk

The invention enables dynamic risk determination of an insured's condition. An example of when the invention can be used is if the insured has a progressive condition, whichwill eventually require long-term care (such as diabetes), but for which in-home care is currently appropriate. Another example where dynamic risk determination can be used is if the insured is at risk for a medical setback (such as an MI or a stroke) but currently is capable of self-care. Yet another example is when the insured is currently being cared for by family, but the care burden is increasing and the insured will eventually require long-term care. The invention allows the underwriter to dynamically determine the current risk to the insured and to provide incentives to the insured to reduce that risk.

Fig. 1A shows a block diabram of a system for data collection and interpretation for a population.

Referring to **Fig. 1A**, a system 100 includes a client device **110**, a server device **120** including a database of information **121** and a program memory **122**, and a data review element **130**. These devices are connected via a communication channel **140**, such as a communication network as is well known in the art, and as more fully described in the Phenoscope and Phenobase patent application (serial no. 90/041,809).

The communication channel **140** may be a simple point-to-point network (for example a wire connecting the client device **110** with the server device **120**), or a complex network such as the Internet.

Referring to **Fig. 1B**, the client device **110** is disposed locally to a patient **111** (the insured), and includes an output element **112** for presenting information to the patient **111**, and an input element **113** for entering information from the patient **111**. As used herein, "locally" refers to a logical relationship to the patient **111**, and does not have any necessary implication with regard to actual physical position. In a preferred embodiment, the client device **110** is relatively small or compact, and can be disposed on a night table or otherwise near the patient **111**.

The output element **112** includes a display screen **114**, on which questions and suggested answers can be displayed for the patient **111**, to facilitate information entry, or on which instructions can be displayed for the patient **111**, to instruct the patient **111**. The output element **112** can also include a speaker **115**, to present information in conjunction with or in alternative to the display screen **114**. The output element **112** can also include a bell or other sound element, or a bright light **119** or a flag, to alert the patient **111** that the client device **110** has questions or information for the patient **111**.

The input element **113** includes a plurality of buttons **116A-D** for entering information.

The input element **113** can also include one or more data ports **117A-D** for entering information from other devices. Referring to **Fig. 1C**, such other devices **118** can include a medical measurement device, such as a blood glucose meter or a blood pressure monitor. Such other devices **118** can also include a general purpose or special purpose client workstation, such as a personal computer or a hand-held digital calendar.

The server device **120** is disposed logically remotely from the patient **111**, and includes a database **121** of information about the patient **111** and about other patients in a related population thereof. As used herein "remotely" refers to a logical relationship to the patient **111**, and does not have any necessary implication with regard to actual physical position.

The database **121** includes medical history, medical regimen, and risk progression information for the insured and a similarly situated population. The database **121** also includes the compliance background for the insured indicating how well the insured follows the prescribed medical regimen and avoids the proscribed activities.

The server device **120** also includes the program memory **122** that contains program code and data to cause the server device **120** to perform subsequently described processes.

In a preferred embodiment, the server **120** and database **121** are preferably accessible using a standard network connection (such as a world wide web connection). The server **120** and database **121** may include single stand-alone computers or multiple computers distributed throughout a network.

The data review element **130** is disposed logically remotely from the patient **111**, and includes an interface **131** disposed for use by an operator **132**. The operator **132** can comprise medical personnel, a device operated by medical personnel, or a similar device, capable of interacting with the interface **131** to receive information from the data review element **130** and possibly to enter information into the data review element **130**. Information entered into the data review element **130** can be entered for ultimate transmission to the server device 120 or to the client device **110**.

The date review element **130** is preferably a personal computer remote terminal, web TV unit, Palm Pilot unit, interactive voice response system, or any other communication technique. The data review element **130** functions as a remote interface for entering server **120** or client device **110** messages and queries to be communicated to the individuals. The data review element **130** also functions to provide the professional to evaluate the progression of the insured and to monitor the insured's medical regimen.

Other and further information regarding the system **100** is shown in Application Serial No. 09/041,809, titled "Phenoscope and Phenobase," attorney docket number RYA-136 and Application Serial No. ____________, titled "Dynamic Modeling and Scoring Risk Assessment," attorney docket number HHN-003.

Fig. 2 illustrates a data flow diagram, indicated by general reference character **200**, that indicates how data flows within a preferred embodiment. The nodes include an insured **201**, a client device **203**, a server device **205**, an accounting server **207**, a workstation **209**, and a professional **211**. These nodes are connected by data flows that include an 'insured-client device' data stream **221**, a client device-insured data stream **223**, a client-server data stream **225**, a server-client data stream **227**, a server-workstation data stream **229**, a workstation-server data stream **231**, a workstation-professional data stream **233**, a professional-workstation data stream **235**, a 'workstation-accounting server' data stream **237**, an 'accounting server-insured' data stream **239**, and an 'accounting server-server device' data stream **241**. Each of these data streams transfer data between the nodes connected by the data stream.

In particular the server device sends patient protocol and interrogatories to the insured by sending this information across the server-client data stream **227** to the client device **203**. The client device **203** then instructs or queries the insured **201** utilizing the client device-insured data stream **223**. The insured **201** responds to the queries, instructions, or through bio-medical input devices to the client device **203** using the 'insured-client device' data stream **221**. The client device **203** passes this acquired information to the server device **205** over the client-server data stream **225**. The server device **205** stores the information acquired from the insured **201**.

Feedback is provided to the insured **201** by sending feedback information from the server device **205** to the client device **203**. This feedback information can include additional medical regimens for the insured **201** to timely follow (for example, additional tests that are determined by the server device **205** responsive to the information just gathered from the insured).

The professional **211** uses the workstation **209** (passing data over both the workstation-professional data stream **233** and the professional-workstation data stream **235**) to access and/or modify data received by, stored on or created on the server device **205**. This data is access using the server-workstation data stream **229**. The professional **211** can also modify the medical regimen for the insured or provide other information for the insured. These modifications are sent to the server device **205** over the workstation-server data stream **231** and then to the insured using the ever-client data stream **227**, the client device **203**, and the client device-insured data stream **223**. The professional **211**, using the workstation 209 can send information (reflecting benefits to the insured) to the accounting server **207** using the 'workstation-accounting server' data stream **237**. The status of benefits can be sent directly to the insured using the 'accounting server-insured' data stream **239** (for example by using postal mail, FAX or other traditional mechanism) or the information can be sent over the 'accounting server-server device' data stream **241** to the server device **205** and on to the insured sing previously discussed paths.

The professional **211** assesses the insured-against risk using both the static data most recently collected from the insured, the progression over time of the data collected from the insured and information known to, or accessible by the professional **211**. this assessment includes the insured's compliance with the prescribed medical regimens and other environmental and behavioral factors. This assessment can also include information and recommendations provided by artificial intelligence expert systems that are accessible to the professional **211** through the workstation **209**.

Fig. 3A illustrates a dynamic risk assessment process, indicated by general reference character 300, for determining dynamic risk assessment. The dynamic risk assessment process 300 is cyclic in normal circumstances. A 'gather patient information' step 301 obtains medical information (such as bio-medical information) from the insured (using the client device 110) by using a series of questions or by using bio-medical sensors. The medical information is gathered according to a protocol provided by the server device 120. This medical information is sent to a server device that performs an 'evaluate patient information' step 303 that determines one or more risk factors for the insured as is subsequently described with respect to

Fig. 3B. Next, the dynamic risk assessment process 300 delays for an appropriate time at a delay step 305. This delay can be varied as appropriate for the insured, the insured's condition, the caregivers, and the insurance provider. The delay step 305 determines the time interval between gathering information from the insured and is appropriately set to be (for example and without limitation) some number of days, weeks or months. Eventually, the delay ends at a 'delay complete' step 307 and the dynamic risk assessment process 300 repeats at the 'gather patient information' step 301 to re-determine the insured-against risk for the insured.

The medical information gathered by the 'gather patient information' step **301** is specific to the insured's current risk and progression of the condition. For example, the insured or caregiver may be periodically instructed to check for sores on extremities if the insured is diabetic. In addition, the caregiver can provide information about affect or mentation. If the insured interacts with the client device **110**, the response time to questions can also be gathered.

The 'gather patient information' step **301** and the evaluate patient information step **303** can be repeated dependent on the data acquired from the insured by the previous iteration. Thus, if the previous iteration returned data that indicates that a subsequent test should be performed, the server device **120** can send the client device **110** a protocol to cause the client device **110** to obtain the new information from the insured, caregiver, or other person.

Fig. 2B illustrates an 'evaluate patient information' process, indicated by general reference character **320** that reassesses the risk based on the gathered information and responds to that risk. The 'evaluate patient information' process **320** is invoked by the evaluate patient information' step **303** of **Fig. 3A** and initiates at a 'start' terminal **321**. The 'evaluate patient information' process **320** continues to a 'send data to server device' procedure **323**, performed by the client device **110**, that sends the medical information gathered by the client device **110** to the server device **120**. The medical information is stored on the database **121** by a 'store data' procedure **325**.

Once the medical information is stored, a 'reassess risk' procedure **327** (as disclosed in Application Serial No. ____________, attorney docket number HHN-003) can use the medical information, a risk-assessment model and the database **121** to determine the current risk of the insured. The risk includes one or more risk factors. These risk factors are used to determine an insured-against risk.

Example risk factors include information such as "patient smokes," "patient has diabetes," "patient has diabetes and doesn't bother to check his blood sugar regularly," etc.

Once the insured-against risk has been determined, the 'evaluate patient information' process **320** continues to a 'respond to risk' procedure **329** (subsequently described with respect to **Fig. 4**). The 'respond to risk' procedure **329** determines one or more medical regimens for the insured. These medical regimens are selected to reduce the risk factors and thus to reduce the insured-against risk of the insured. The 'respond to risk' procedure **329** can also adjust the proportion of the insurance cost allocated to components of the financial product used by the insured. The 'reassess risk' procedure **327** and the 'respond to risk' procedure **329** need not be performed every time data is received by the server device **120**. These procedures can be executed independent of the following procedures.

Once the medical information is stored by the 'store data' procedure **325** the dynamic risk assessment process **300**, can also continue to a 'determine feedback information' procedure **331** that develops feedback for the insured that can include one or more medical regimens, display of bio-medical information, encouragement to follow the suggested medical regimen or follow-on protocols. The feedback information is sent back to the client device **110** by a 'send feedback information' procedure **333**. A 'resent feedback information' procedure **335** then presents the feedback information to the insured and/or the caregiver. The 'evaluate patient information' process **320** completes through an 'end' terminal **337**.

The 'determine feedback information' procedure **331** can also provide the client device **110** with additional data gathering protocols that are dependent on the just-gathered information -- to obtain additional information. In addition, the 'determine feedback information' procedure **331** checks to determine whether the just gathered information is out-to-limit, indicates a trend, or should be forwarded to a medical professional.

Other preferred embodiments can allocate these processes between the client device **110** and the server device **120** in a different manner. For example as the relative cost/performance ratio changes for the client device **110** and the server device **120**, more of these procedures can be moved to the client device **110**.

Fig. 4 illustrates a 'respond to risk' process, indicated by general reference character **400**, that is configured to adjust the cost of the financial product between