aspects of the invention, wherein the SS threshold, the limit of N and the maximum values of AFT toward which the capacitors are considered to be respectively charging are adjusted in accordance with the ambient temperature within the radio.

The assumed limit value for noise can also be set at the voltage produced across the N capacitor when the noisiest channel is tuned in.

Another way to set the assumed limit value for noise is to measure the voltage across the N capacitor when the antenna of the radio is connected to ground.

In AM receivers, tuning stops on a channel when the voltage across a threshold capacitor exceeds a given value. The voltage on this capacitor is derived from a circuit measuring the IF amplitude and the signal strength indicated by an AGC circuit having filter capacitors. Faster operation is attained by charging the threshold capacitor and capacitors that are used in the AGC circuit to neutral values at each channel change.

Brief Description Of The Drawings

Various embodiments of the invention are shown and described herein with reference to the drawings, in which like items are identified by the same reference designation, wherein:

Fig. 1 shows the basic components of a single tuner FM receiver incorporating this invention including the circuits for clamping the SS, N and AFT capacitors;

Fig. 1A is a schematic diagram of a circuit for converting the differential voltage on the AFT capacitor to a unipolar voltage for application to the digital logic circuits;

Fig. 2 illustrates the basic steps of an initialization procedure for selecting a station that provides a reference or nominal value of AFT;

Fig. 2A illustrates the sampling procedure of this invention;

Fig. 2B describes a procedure for balancing the SS and N measurements between tuners in a dual tuner system.

Fig. 3 is a graph illustrating the application of the extrapolation techniques of this invention to the noise limit used in the portion of the flowchart of Fig. 2 that is designed to select the strongest station;

Fig. 4 is a graph illustrating the application of the extrapolation techniques of this invention to the noise limit used in the portion of the flowchart of Fig. 2 that makes a final check on the suitability of the strongest station selected in the first part of the flowchart of Fig 2;

Fig. 5 is a flowchart of the procedure for selecting a station that is to provide the reference value of AFT if a given amount of time has elapsed since the initialization procedure illustrated in Fig. 2;

Fig. 6 is a simplified flowchart illustrating the operation in accordance with the invention of a single tuner FM receiver having no display or memory buttons;

Fig. 7 is a flowchart for the operation of a single tuner FM receiver having memory buttons but no display of listenable channels;

Fig. 7A is an alternative algorithm for use in Fig. 7 in eliminating a station because of noise;

Fig. 8 is a flowchart illustrating operation in accordance with this invention of a single tuner FM receiver in which listenable channels are displayed;

Fig. 9 is a flowchart illustrating the way in which the station tuned in by an FM receiver is monitored;

Fig. 10 is a flowchart illustrating the dual pass operation of an FM receiver in accordance with this invention;

Fig. 11 is a block diagram of an FM receiver incorporating a listening tuner and a scanning tuner in accordance with this invention;

Fig. 12 is a flowchart of the operation of a listening tuner in a two tuner display system of this invention;

Fig. 13 is a flowchart for the calibration of a reference AFT by a listening tuner of a two tuner display system;

Fig. 14 illustrates the sequence of the various flowcharts used by a scanning tuner;

Fig. 15 is a flowchart of the operation of a scanning tuner in a two tuner display system of this invention;

Fig. 15A is a flowchart of the data monitoring cycle of the scanning tuner of a two tuner display system;

Fig. 15B is a flowchart for the averaging of the SS and QF in Fig. 15 to compensate for momentary signal variations;

Fig. 15C is a flowchart for determining whether signal strength of a station is increasing or decreasing;

Fig. 16 is a flowchart for the calibration of a reference AFT in the scanning tuner of a two tuner display system;

Fig. 17 is a schematic diagram of a circuit for sensing temperature;

Fig. 18 is a table of values to be used in connection with Fig. 19.

Figs. 19 and 19A are respective flowcharts for calibrating a reference AFT, the SS threshold, and the N rejection limit in response to temperature;

Fig. 20 is a flowchart for the calibration of a noise rejection limit based on the noisiest channel;

Fig. 21 is a schematic diagram of a circuit for clamping the antenna to ground so as to attain a measure of receiver generated noise;

Fig. 22 is a flowchart for calibrating a noise limit from the measurement attained in the circuit of Fig. 21;

Figs. 23 and 24 are schematic diagrams illustrating connections for commercially available components of a single tuner FM receiver in accordance with this invention;

Fig. 25 is a block diagram of an AM radio utilizing this invention;

Fig. 26 is a flowchart for the operation in accordance with this invention of an AM radio having a single tuner and no display;

Fig. 27 is a flowchart for the operation in accordance with this invention of an AM radio having a single tuner and a display;

Fig. 27A is a flowchart for monitoring the signal of an AM station and updating the display;

Fig. 28 is a flowchart of the operation in accordance with this invention of the listening tuner in a dual tuner AM radio having a display of listenable stations;

Fig. 29 is a flowchart of the operation in accordance with this invention of the scanning tuner in a dual tuner AM system having a display of listenable stations;

Fig. 30 illustrates a display of listenable stations including RDS data;

Fig. 30A illustrates an alternative display of listenable stations broadcasting a specific type of RDS-coded program material.

Fig. 30B illustrates an alternative style of presenting stations broadcasting specific types of RDS-coded program material.

Fig. 31 illustrates a display of listenable stations with statistics for S, N, AFT and QF of tuned in stations;

Fig. 32 illustrates a display showing the listenable station with the numbers of the buttons for the four strongest stations shown at the locations for the respective station;

Fig. 32A illustrates a display similar to Fig. 32 with indicator bars as upward or downward pointing arrows to indicate stations increasing or decreasing in strength;

Fig. 33 illustrates a display showing listenable FM and AM stations;

Fig. 34 illustrates a display in which listenable FM and AM stations are identified by dots;

Fig. 35 illustrates a display in which listenable FM and AM stations are indicated by bars of LCD's;

Fig. 36 illustrates a menu that may be displayed;

Fig. 37 illustrates a display of graphical information relating to a tuned in station;

Fig. 38 illustrates a display of statistics for a tuned in station; and

Fig. 39 illustrates a display with touch entry and voice input for changing stations.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows the basic elements of an FM radio having a tuning system of this invention. An antenna 2 supplies RF signals to a tuner 4, which by way of example may be an FE3U128A tuner module. A local oscillator and mixer, not shown, within the tuner 4 produce an IF signal that is applied to a phase locked loop (PLL) 6 via a lead 8, and the loop provides a correction voltage via a lead 10 to the tuner 4 so as to control the frequency of the local oscillator. The phase locked loop may by way of example be a DS-8907.

The IF signal produced by the tuner 4 is also supplied to a means 12 for providing amplification as well as the limiting and discriminating functions necessary to produce an audio signal on an output lead 14. In addition to an audio signal, the means 12 provides at an output 16 a DC voltage SS corresponding to the average amplitude of the RF signal, and at an output 18 a DC voltage N corresponding to the average amplitude of the noise. An AFT DC voltage is produced at an output 20, and a regulated DC voltage is produced at an output 22.

As in the prior art, the SS, N and AFT voltages at the outputs 16, 18 and 20 are respectively applied to one side of capacitors 24, 26 and 28, the other sides of which are connected to ground. Discharge resistors 30 and 32 are connected in shunt with the SS and N capacitors 24 and 26, respectively, so that the voltages across them follow the variations in SS and N, respectively.

And as in the prior art, a resistor 34 is provided for the AFT capacitor 28 which converts the AFT deviation current 20 into a measurable voltage measured in respect to the DC reference voltage 22. The sampling technique described in this application allows the use of smaller values for resistor 34 and capacitor 28 than in prior art designs which results in faster channel changes.

The SS, N and AFT voltages are connected in the prior art to hard wired trip-level circuits which will cause the system to mute or bypass a channel during the tuning process whenever one or more of them is outside its predetermined respective limit. In this invention, however, they are connected to an Analog-To-Digital-Converter chip 36, such as an ADC 808, that derives digital samples of the voltages under the control of a CPU 38 such as a Z80. The CPU 38 uses these samples to identify the very listenable and listenable channels. Since the AFT voltage on the capacitor 28 can be higher or lower than the DC reference voltage 22, it is coupled to the ADC chip 36 via a differential amplifier circuit 40 which also incorporates a level shifting feature.

The CPU 38 is controlled by a keyboard 42 so as to carry out seek and scan functions by operation on the phase locked loop 6. When these functions are carried out, it may be controlled by the CPU 38 so as to provide vertical bars or other indicia on a display device 44, at the frequencies of listenable and very listenable stations, representing their values of SS. Other keys on the keyboard provide for selection of a menu on the display 44, rescanning to identify very listenable and unlistenable channels and update the display, and for changing the values of signal strength and quality factor to be used in the identification process. In addition, a key may be provided for changing the minimum quality level and signal strength in the identification process depending on whether the radio is being operated in the country or in a city.

In accordance with one aspect of this invention, the speed with which any signals in a channel can be analyzed for listenability is increased by charging or discharging the SS, Noise, and AFT capacitors 24, 26, and 28, respectively, to a neutral value using transistors 46, 48, and 50, respectively, at the initiation of each channel change by the CPU 38. Toward this end, transistors 46 and 48 are respectively connected in shunt with the capacitors 24 and 26, and transistor 50 is connected in shunt with resistor 34. Upon initiation of a seek or scan function at the keyboard 42, the CPU 38 applies an enabling voltage to the PLL 6 to cause it to simulate a local oscillator frequency for the next channel, and an enabling voltage on lead 395 is applied to respective base electrodes of transistors 46 and 48, and an enabling voltage on lead 395' which is inverted and level shifted by inverter 45 is applied to the base of transistor 50, so as to cause momentary conduction of each. The SS and N capacitors 24 and 26 are completely discharged through the main current paths of transistors 46 and 48 to a source of reference potential, ground in this example, and the AFT capacitor 28 is charged to a predetermined voltage, equivalent to zero AFT current, through transistor 50. In this manner, capacitors 24 and 26 can be quickly charged to the values of the SS and N voltages at terminals 16 and 18, respectively, without waiting for them to discharge via their respective discharge resistors 30 and 32. The AFT capacitor 28 is charged to the voltage at the terminal 22 so that less charging or discharging is required on a statistical basis.

Next is a comparison of the capacitor charge and discharge times in the radio system described in Fig. 1 using the features of this invention versus the same radio system using the manufacturer's standard circuitry. The standard circuitry for SS charges through an internal LM1865 resistor of 760Ω into a capacitor (24) of 10μF, for a charge time constant of 7.6ms; the equivalent circuit based on this invention charges a 2.2μF capacitor (24) through the same internal 760Ω resistor, and has a charge time constant of 1.67ms, which is a five-fold improvement. The discharge path for SS in the standard design is from capacitor (24) through resistor (30), which is set at 10kΩ. and results in a discharge time constant of 100ms. In the circuit based on this invention the capacitor (24) is shorted directly to ground on channel changes, resulting in a negligible discharge time (<1ms). The N circuit is similarly arranged. In the standard circuit, N charges through an internal 9kΩ resistor into 2.2μF capacitor (26) resulting in a charge time constant of 19.8ms. In the equivalent circuit based on this invention the charge path is via the same internal 9kΩ resistor into 1μF capacitor (26), resulting in a 9ms charge time constant and a two-fold improvement. The discharge path in the standard circuit is from capacitor (26) through resistor (32), which is set at 25kΩ, which would yield a discharge time constant of 55ms except that the discharge time constant is dominated by the fall from the maximum voltage of .8v to below the hard-wired trip level of .6v, and this results in a discharge time constant of 15ms. As with the SS circuit, in the N circuit based on this invention the capacitor (26) is shorted directly to ground on channel changes, resulting in a negligible discharge time (<1ms).

The standard design AFT circuit charges and discharges capacitor (28) through resistor (34). In the standard design resistor (34) is 5kΩ and capacitor (28) is 5μF, resulting in a time constant of 25ms for both charging and discharging. In the equivalent circuit based on this invention the AFT charge path is through resistor (34) set 2.7kΩ to capacitor (28) set 4.7μF, resulting in a charge time constant of 12.7ms for a two-fold improvement; the discharge path for capacitor (28), meaning the path by which the capacitor is set to a neutral level on channel changes, shunts across resistor (34) and results in a negligible discharge time (<1ms). As is obvious from the above, the procedures of this invention of clamping the capacitors to a neutral level on channel changes result in radically faster circuit discharge times. Also, however, the fact that smaller resistor and capacitor components are required because of the sampling and averaging procedures of this invention results in faster charge times as well, which is another factor contributing to the fast tuning speed of this invention.

Reference is made to Fig. 1A for a description of a circuit that can be used for the differential AFT amplifier circuit 40. AFT voltage from the output 20 fluctuates above and below the approximate center point value of the regulated voltage at the output 22. The resistor 34 converts the AFT current to a measurable voltage, and together with capacitor 28, determines the R-C time constant of the AFT circuit. The AFT voltage is measured between circuit leads 20 and 22 via their connections to an operational amplifier 62, which is arranged to measure the difference between the two voltages. The terminal 20 is coupled via a buffer amplifier 58 and a resistor 60 to the inverting input of an operational amplifier 62, and a resistor 64 is connected between the amplifier's output and inverting inputs. The terminal 22 is connected via a resistor 66 to the non-inverting input of the amplifier 62. A resistor 68 is also connected from the non-inverting input of the amplifier 62 to the junction of resistors 70 and 72, that are connected in series between a point 74 of voltage V_1 and ground. The values of the resistors 70 and 72 are such as to apply a predetermined positive bias voltage, 2.5 volts in this case, to the non-inverting input of the amplifier 62. The voltage of circuit lead 20 can be either positive or negative with respect to the DC reference voltage 22, but for reasons of compatibility with the ADC-808 36 which expects positive voltages, the output of the operational amplifier 62 is level shifted upward by 2.5 volts via the input coming through resistor 68 so that zero AFT current is represented by the center of the ADC's dynamic range and so that positive and negative voltages in respect to the DC reference voltage 22 can be properly measured by the ADC. Thus, as long as the sum of the AFT voltage at the terminal 20 plus the predetermined positive bias voltage is greater than the regulated voltage at the output 22, the output of the amplifier 62 will always be positive, and the neutral level will be at 2.5 volts.

In the flowcharts to be explained, certain voltage limits and ranges are indicated. It is to be understood that they are just examples and refer to preferred values for the particular receiver components of Figs. 23 and 24. Other values may be used.

In operating a tuning system of this invention, it is necessary to find a nominal or reference value of AFT. One way to do this is to find a very listenable station and use its AFT voltage as the AFT nominal or reference voltage. Such a station may be found as shown in the flowchart of Fig. 2. Power is turned on, step 86, and at a step 88 the next station is tuned in. The SS, N and AFT capacitors 24, 26 and 28 of Fig. 1 are then momentarily clamped so that they are charged to the neutral voltages previously described.

The next portion of the procedure involves unlistenable station identification. As indicated at step 90, the first step is to obtain the values of a first group of individual samples or the averages of a first group of multiple samples of each of the SS, N and AFT voltages that are developed on the capacitors 24, 26 and 28 within a few milliseconds (ms) after the clamping is released. By way of example, the first group has five samples occurring within 4 ms.

An important aspect of the invention is the averaging of multiple samples to obtain values of SS, N and AFT that are used in the tests of a step 92 that identifies unlistenable channels. Fig. 2A illustrates the sampling and averaging process as applied to the AFT voltage on the capacitor 28. The voltage 91 on the AFT capacitor 28 varies in amplitude, but the average of samples taken during a time period 95 is not affected by the variations as shown by the line 97. This procedure can resolve the AFT current level to 2 μAmps +/- a 2μAmp ADC rounding error, depending upon the number of samples taken and the duration of the time period during which they are taken. 2μAmps in this design represents approximately 320Hz frequency deviation of the 10.7Mhz IF frequency. The average value 97 is compared to the DC reference voltage 99 to arrive at the AFT offset voltage as used in steps 92' and 134 of Figure 7 and elsewhere. Although not illustrated, the averages of the samples of the voltages across the SS and N capacitors 24 and 26 respectively are less affected by noise and artifacts.

The diamond decision step 92 compares the averages of the SS, N and AFT samples as compared with respective limits. The average for the SS capacitor 24 can be compared with the minimum or threshold value of SS specified by the manufacturer, i.e. approximately .6v in the design of Figures 23 and 24, even though the capacitor 24 is not fully charged because it is about 90% charged. The situation is different in the case of the N samples because of the long charging time constant of the capacitor 26. If, as in the receiver components used as an example, the maximum permissible noise is specified to be such that the N capacitor 26 will be charged to 0.6 v in five time constants, a time constant being the product of the capacitance of the capacitor 26 and resistance in series with it, the noise limit charge curve in the presence of this maximum noise is as shown in Fig. 3. Thus, if the average of the samples of N is above the curve, the station is considered to be too noisy to be listenable. Since the first group of samples are indicated in the flowchart to occur within 4 ms, which is slightly less than one-half a charging time constant of 9 ms of the components used in the example, i.e. at point 87 in Fig. 3, a station will be too noisy if the average voltage of the first group of samples exceeds .16 v. This is the extrapolation technique previously referred to that permits faster tuning. Additionally however, the noise capacitor is integrating the noise pulses, as indicated by the spikes 89 riding on top of the charge curve. These noise pulses will introduce errors if not accounted for. Taking the average of multiple samples will tend to average out the noise pulses, but since only five samples are taken in this example there could still be an error factor. Since the noise pulses are of approximately constant amplitude regardless of where they occur on the charge curve, the errors will be greatest lower on the curve where the noise pulses represent a greater percentage of the value of the curve. Therefore, samples taken earlier will require a greater allowance for errors than samples taken later. The average value of the first five samples will be about 6% less than the individual sample taken at 4 ms and so will tend to be somewhat conservative in rejecting stations and could represent the error adjustment factor. An additional error adjustment factor could be inserted if desired to more fully compensate for this error condition.

Lastly, the diamond decision step 92 tests to see if the average of the first group of samples of the AFT voltage on the capacitor 28 exceeds a limit. In the circuit described herein the capacitor 28 will not be fully charged when the last of the first group of samples is taken so that an extrapolation technique such as that used with noise must be used. In this case, however, two noise limit charge curves would be required because the maximum AFT voltage for marginally listenable channels can range up to approximately +3 v or -3 v in relation to the DC reference voltage 22. A 5 TC value of +/-.8v, equivalent to +/- 300μAmps, or to a frequency deviation of 48,000Hz, is indicative of a very bad channel. (The manufacturer's recommended hard-wired trip circuit is set at +/-130μAmps in a circuit with a 5kΩ resistor 34; the equivalent circuit described in this application has a 2.7kΩ resistor 34 which will cause a channel to generate approximately twice the AFT current in the equivalent circuit. Therefore, +/-300 μAmps (48,000Hz frequency deviation) in the equivalent circuit is approximately equal to +/-130μAmps (40,000Hz frequency deviation) in the manufacturer's recommended circuit.) In the circuit used as an example herein the approximate charging time constant of the capacitor 28 is 12.7 ms so that the first group of samples occur during a time of approximately 0.4 of a time constant at which the absolute value of the charging curves is about 0.27 v. However, since the AFT signal is dominated by the super-imposed audio the extrapolation process must be adjusted to allow for that audio so that stations are not rejected in error. Once the capacitor is at full charge, the audio fluctuates above and below the center point of the AFT level by about .5v. By also extrapolating the charge curve for the super-imposed audio in the same way as just described, an allowance of .17v must be added to the .27v previously calculated, and thus the actual rejection level will be set at +/-.5v (.27 + .17, rounded up) and is equivalent to +/-185μ Amps. Therefore, if the average of the first group of samples is greater than +0.5v or less than -0.5v, the AFT is too large and the channel is identified as being unlistenable.

As indicated in a step 94, any channel having a station that is not rejected in the diamond decision step 92 is recorded along with its value of SS. A determination is made in a diamond decision step 96 as to whether all of the channels in the FM band have been analyzed, and the procedure just described is repeated until they are.

When all stations in the FM band have been analyzed, limits for N can be calibrated, if desired, as indicated at a step 98 by following the procedures of Figs. 17 through 22 to be described, and the calibrated value used in place of the 0.1 v applied signal in a step 104 to be described.

Whether or not the noise calibration is made, the station having the largest SS is tuned in, step 100, and checked to see if it is consistently listenable by following a more restrictive procedure starting with a step 102. This involves taking second and third groups of equally spaced samples of the SS, N and AFT voltages during successive intervals of 64 ms, computing the respective averages for each group and the SS range for each group. The sampling period of 64ms is used in this circumstance of attempting to find a very listenable station to use as an AFT reference because precision is important at this step -- if the reference level of AFT is inaccurate, the evaluation of every station in comparison to it will be inaccurate. A sampling period of 64ms is long enough to remove audio down to 15Hz in order to arrive at a pure AFT deviation signal. At other steps, shorter sampling periods might be used for the sake of a faster scanning speed, but at the risk that some AFT measurements might include an error due to the existence of super-imposed audio. The probability of an error is based on the probability of the presence of the very low frequency audio that was not averaged out, along with the relative strength of this very low frequency audio. If there is no very low frequency audio present on the AFT signal at the time the samples are taken, there will be no error. The errors could be reflected in a station being incorrectly accepted or rejected, or in an incorrect QF. The following Table 2 illustrates the design trade-offs between sampling period and scanning speed. The worst case scenario for a scanning radio is a broadcast area with very many stations, as illustrated in the table. The table assumes a listening area with 25 very good stations, 25 very bad channels, and 50 other channels that would require detailed measurements to properly analyze. The aspect of this invention that allows making the acceptance of very good stations and the rejection of very bad channels based on an initial sample or samples minimizes the required scanning time. The portion of the scanning from the following table that is allocated to this initial decision step is just two tenths of a second for the total of 50 channels that would include the 25 very good stations and the 25 very bad channels. The remaining 50 channels which must be evaluated via an additional set of measurements consume the majority of the time, as indicated. System designers will need to evaluate these parameters to determine the performance parameters of their target system.

Table 2

		64ms	32ms	16ms
Number of Channels				
Very Good	25	.1 sec.	.1 sec.	.1 sec.
Very Bad	25	.1 sec.	.1 sec.	.1 sec.
Remainder	50	3.2 sec.	1.6 sec.	.8 sec.
Total Scan Time		3.4 sec.	1.8 sec.	1.0 sec.
Audio Removed Down to:		15 Hz	31 Hz	62 Hz

Every time a channel change is made the SS, N, and AFT capacitors are clamped and released as described earlier, but reference to this procedure is omitted from intermediate steps in the flowcharts, such as step 100, for the sake of brevity. Flowchart steps that implicitly incorporate the clamping and releasing procedure include: steps 100 and 108 of Figures 2 and 5; step 175 of Figure 10; step 224 of Figures 13 and 16; step 216 of Figure 12; steps 470 and 476 of Figure 27; step 482 of Figure 28, and any other steps that specify a channel change.

Then, in a diamond decision step 104, the strongest channel is rejected if the SS averages for both groups of samples are not greater than the threshold value used in step 92, the SS ranges for the groups are not within 10% of each other, the averages of N for both groups is above the curve of Fig. 4, or the variance between the AFT averages for the groups is greater than .02 v, which is equivalent to approximately ± 2μA or 320Hz frequency deviation. Since the search is for a stable, listenable, noise-free station, the noise limit at 5 TC (time constants) is reduced to 0.1 v as indicated in Fig. 4 so that the noise limit is much lower than in the step 92.

If the channel having the largest SS is rejected on any of the criteria in the diamond decision step 104, a check is made in diamond decision step 106 to see if another channel has been recorded in memory at step 94. If so, the next strongest station is tuned in (step 108) and examined as in the step 102 and the diamond decision step 104. If no satisfactory station is found, the AFT is not calibrated, step 110, and the range of AFT values used in diamond decision step 92' is increased, e.g. to ± 3 v, in determining the listenability of channels as described in connection with subsequent flowcharts.

If a station passes the criteria of the diamond decision step 104, the average of the AFT averages for the two groups of samples is used, step 112, as the reference value of AFT for the computation of the AFT offset as required in other procedures to be described herein. In a dual tuner system, an optional step 113 can be undertaken at this time to balance the measurements of the two tuners so that both will respond identically to broadcast signal parameters. Step 113 refers to Fig. 2B, which is described next. After both tuners have executed the power up routine of Fig. 2, step 101, the SS average for the calibration station measured by the scanner tuner is subtracted from the same measurement made by the listening tuner in step 103 to arrive at the SS dual tuner balancing factor. In step 105 this SS balancing factor will be added to all subsequent measurements of SS by the scanner tuner that are described in the flowcharts in this document. An N dual tuner balancing factor is similarly arrived at in step 107, and is used to adjust all subsequent scanner tuner N measurements in step 109.

Now returning to Fig. 2, when this startup calibration procedure has been completed, the radio can shift into its normal operation modes, as indicated in step 111 and which will be described in other flowcharts in detail. In either case, the tuner is tuned to a predetermined startup station, step 114 which may be the station the radio was tuned to when the radio was last powered off.

In view of the fact that there is considerable redundancy in the flowcharts for operating listening and scanning tuners, identical steps and diamond decision steps are designated by the same number and those that differ only slightly are designated by the same number primed.

Whether or not the reference value of AFT found by the initialization procedure of Fig. 2 just described is still valid, depends on the amount of time that has elapsed from the last determination of a reference value. Therefore, after a seek or scan mode of operation is activated in a single tuner receiver or the listening tuner of a dual tuner receiver, the elapsed time is noted, diamond decision step 115 of Fig. 5, and the value of AFT found in the initialization procedure is used, step 116, if the elapsed time is less than some arbitrary amount such as the five minutes shown in the diamond decision step 115. If too much time has elapsed, the procedure followed to derive a suitable reference value of AFT is shown in Fig. 5. Fig. 5 proceeds from a State 1 to a State 2. It is nearly the same as Fig. 2, but differs therefrom in the following respects.

If the weakest station listed in memory at the step 94 of Fig. 2 is not satisfactory, there is no other station that can be used to provide the reference AFT, but in Fig. 5 there may be another station so that instead of not calibrating AFT as in step 110 of Fig. 2, a search is made, diamond decision step 118, to see if there is a previous calibrated value of AFT stored in the system's memory, in which event it is used, step 120. Although five minutes may have elapsed since the initialization procedure, the procedure of Fig. 5 may have been performed in the meantime in the normal course of seek or scan tuning operations.

Whether or not five minutes has elapsed since the reference AFT was determined by the initialization procedure, the procedure of Fig. 5 may be used if there has been a significant change in temperature. The change in temperature is indicated by a sensor voltage, step 121, and if it does not indicate a given change in temperature since the last reference value of AFT was determined, step 123, whether during initialization or otherwise, the previous reference value for AFT is used, step 125, but if a greater change in temperature has occurred, the procedure of Fig. 5, beginning with the step 88, is followed.

Fig. 6 is a flowchart of the tuning operation in accordance with basic aspects of this invention of an FM receiver having only one tuner and no display or "best station memory" feature. Each channel is accepted as a listenable station or rejected as an unlistenable station as it is addressed in the seek or scan mode of operation, but the decisions are made more accurately and quickly than in the prior art.

After the seek or scan mode operation is initiated, as indicated by a step 122, the procedure passes from a state 1 to a state 2 so as to attain a calibration of AFT on a very good station in the same manner as indicated by the flowchart of Fig. 5. Unlistenable stations are identified in much the same manner as in Fig. 5. The step 88 for momentarily clamping the SS, N and AFT capacitors and the step 90 for sampling are the same as in Fig. 5, but a new step 124 is added that determines the difference, or offset, between the AFT voltage of a current channel and the reference AFT voltage. No offset could be used in Figs. 2 or 5 because their purpose was to obtain a reference value of AFT for determination of the offset. Therefore only a range of AFT values could be used in Fig. 5, as in the prior art, but in Fig. 6 a diamond decision step 92' is the same as the diamond decision step 92 of Fig. 5 except for the fact that the AFT offset, rather than the AFT voltage itself, is compared with the voltage limits indicated. If a station passes the criteria of the diamond decision step 92', it is accepted and the audio signal is turned on, step 126. Because the selection of acceptable stations is made on the basis of a few samples and rather loose criteria, they may well include stations that are barely listenable or even unlistenable as in the prior art, but unlike the prior art, the same channels are accepted by the same radio at different temperatures and by different radios of the same basic design.

Fig. 7 is a flowchart that adds further steps to the flowchart of Fig. 6 for distinguishing between listenable and unlistenable stations with greater accuracy. It provides for assigning the strongest channels to memory buttons (push button switches associated with respective memory locations) commonly referred to as "best station memory" buttons, but has no display. Except for adjusting the minimum quality level and SS threshold in accordance with the position of a country driving/city driving switch as optionally indicated at a phantom step 126, the first part of the procedure is the same as in Fig. 6. At a start step 122' seek or scan buttons can be activated as in the step 122 of Fig. 6, but in addition there is a best memory button.

Very listenable stations are now identified. If a channel is not rejected at the diamond decision step 92', a diamond decision step 128 determines whether or not it is very listenable on the basis of its having virtually no noise. Thus, an unlistenable channel is identified in the diamond decision step 92', and a very listenable channel is identified in the diamond decision step 128 on the basis of a very few samples taken in the step 90, therein shown by way of example to occur in 4 ms.

Only a channel that is not rejected in the diamond decision step 92' as being unlistenable or not classified as being very listenable in the diamond decision step 128 is subjected to further sampling and analysis for determining whether it is listenable or not. Much time is saved because the number of channels subjected to further analysis is reduced. Further samples are taken of SS, N and AFT and the averages of each determined as indicated in a step 130. In this example, 32 samples are taken at 0.5 ms intervals during the next 16 ms. If a quality factor, QF, is to be computed, the ranges of SS and N are found. The offset of the average AFT from the nominal value of AFT is determined in a step 132, and a diamond decision step 134 determines whether the SS average is greater than a given threshold, the N average is less than a given limit, and the AFT average is less than a given limit. The acceptance/rejection values reflect the charge curve, as illustrated in Fig. 3, for the time period when the samples were taken. If an affirmative answer is attained for all three, the channel is considered to be listenable, but if a negative answer occurs, the channel is rejected and the procedure loops back to the step 88 as indicated by the step 93.

Note that in order to be accepted as listenable by the step 134, a channel must be more listenable or better than that required for acceptance by the step 92' because there are more samples which refine the measurement. By example, an average of 0.5 v for the samples taken in this step 130 would be a much lower noise limit than in the step 92', and an AFT offset of 73mv (equivalent to 27μAmps) is much less than the offset of 0.5 v (equivalent to 185μAmps) used in the step 92'.

As a further refinement of the system, station listenability may be analyzed by use of the quality factor determined by steps 136 and 138 that are shown in dashed lines. This is a mathematical procedure that combines the effects of multiple signal parameters into a single result. This procedure yields better results than would be obtained by depending on any single signal parameter. Stations may be graded into two or more groups based on their respective quality factors, and the gradings may be distinctly indicated by various means on systems with a display unit. A means may be provided for selecting stations of certain gradings, and of rejecting stations of other gradings. The use of QF to accept or reject stations may be done sequentially, following diamond decision step 134, as shown by the solid line in the flowchart, or it may be done in lieu of diamond step 134, as indicated by the dashed line in the flowchart proceeding from step 132 directly to step 136. The quality factor, QF, expression is repeated here for convenience, as follows:

$$QF = \sqrt{AVG\ N \cdot AFT\ offset} + \frac{N\ range}{2}$$

Since this is a simple calculation, the associated procedures can be easily provided by one skilled in the art. If, as indicated in a dashed diamond decision step 138, the QF is equal to or greater than a preselected value, the channel is considered to be listenable. Ordinarily, the preselected value would be set at 9, but if noisy channels are not desired, it could be set at 5. A key on the keyboard 42 controls means for varying the value of the QF used as a criteria for selection of a channel as listenable.

If a channel is rejected as unlistenable at any of the diamond decision steps 92', 134 or 138, the next channel is analyzed beginning at the step 88 as indicated by the step 93, but if a channel is determined to be very listenable by the diamond decision step 128 or listenable by the diamond decision steps 134 or 138, the best stations are assigned to channel selection or memory buttons as immediately described. A diamond decision step 140 determines whether one of the seek or scan tuning buttons, or a best station memory scanning button has been activated. If a seek or scan button has been activated, the audio is turned on, step 142, and the procedure stops. If the best memory scanning button has been activated, the channel is recorded on a tuning list for subsequent loading into a memory location associated with a channel selection button via step 144. Next, diamond decision step 146 determines if the entire FM band has been scanned. If not, the procedure loops back to the step 88. If so, the tuning or memory buttons are respectively associated with the stations in accordance with their SS. Alternatively, only the very good stations having no noise, as determined by diamond decision step 128, could be assigned to the memory or channel selection buttons, but if there are less of such stations than there are channel selection buttons, the remaining buttons could be assigned on the basis of their SS.

The procedures for finding listenable stations as illustrated in Fig. 7 and elsewhere are designed to minimize the time required to scan the frequency band and make this determination. However, if speed were not an issue the AFT calibration procedures of Fig. 1 or Fig. 5 could be used instead since they essentially are simply more rigorous algorithms for finding a good station.

An important aspect of the invention is the speed with which the channels of a band can be classified as unlistenable, very listenable, or listenable. In addition to the clamping of the SS, N and AFT capacitors 24, 26, and 28, respectively, before they are fully charged, as was explained in connection with Figs. 1, 3 and 4, the speed is contributed to by the fact that unlistenable and very listenable channels are quickly identified on the basis of a first group of a very few samples by the diamond decision steps 92' and 128, respectively, so that these channels do not have to be analyzed on the basis of the second group of samples referred to in the step 130 or in the step 138 if used.

Another factor contributing to the speed of scanning a band of frequencies is that satisfactory values of SS, N and AFT can be attained by averaging the samples taken from a circuit with a smaller filter, rather than by using a larger filter in conjunction with a hard-wired trip circuit as in the prior art. This is especially advantageous in deriving the value of AFT, because in the prior art the AFT filter circuit should be designed to filter out the lowest audio frequency which may be present. The sampling period of 16ms as used in this application is adequate to remove the super-imposed audio down to 62Hz.

Other sampling periods could be selected for either faster or more precise operation as previously described. A large filter capacitor introduces considerable delay. Typical engineering practices in prior art radio design allow 70 ms to evaluate each channel due to this filter. Fig. 2A, previously discussed, shows an AFT signal 91 as it would appear with a reduced low pass filter when the IF signal is modulated with a low audio frequency. This signal is the summation of the audio signal and the more slowly changing AFT signal. The second group of samples are indicated at s_1 - s_{16}, and it can be seen that their average will be substantially unaffected by the audio signal as shown by the dashed line 95.

Fig. 7A illustrates a different procedure that can be used in Fig. 7 if the diamond decision step 92' rejects a channel. Certain types of radio interference patterns will cause intermittent ultrasonic noise bursts that are barely detectable audibly, but which exceed the noise rejection limit for a few milliseconds during each burst. A diamond decision step 150 determines whether only the noise N exceeded the limit in the diamond decision step 92'. If not, the channel was rejected for other reasons and the procedure loops back to the step 88 via step 93, but if only N exceeded the limit, there is a slight delay before another sample is taken of the noise, step 152. This additional sample must confirm the continued presence of noise in order for the station to be rejected. Then at a diamond decision step 154 it is determined whether the amplitude of the sample exceeds the amplitude of the curve of Fig. 3 at the time the sample occurred. If so, the next channel is tuned in, step 93, and the procedure loops back to the step 88. If not, the channel is not considered to be unlistenable because of N and the procedure goes to the diamond decision step 128.

Fig. 8 illustrates the flowchart for the tuning of an FM receiver in which the very listenable and listenable channels are recorded in memory and displayed as shown at 44 of Fig. 1. The FM band is scanned so as to update the display 44 upon request of the operator if such an update has not been done within a given time. Thus a step 122'' differs from the steps 122 and 122' in Figs 6 and 7, respectively, by indicating that a refresh scan button is included with the seek and scan tuning buttons. After finding a nominal or reference value of AFT in going from state 1 to state 2 in a manner such as illustrated in Fig 5, it is determined via diamond decision step 156, whether a scan of the FM band has been made more than a given time previously. Thirty seconds is suggested, but other times could be used. If not, the next station in the existing tuning list is tuned in and its audio turned on (see step 158), so as to enter a state 3 in which the station is monitored as will be explained in connection with Fig. 9. If the allocated time has elapsed since the last scan, the procedure for identifying unlistenable, very listenable and listenable channels described in connection with Fig. 7 is carried out. Very listenable and listenable channels are recorded on a tuning display list and their SS and N values are recorded via step 160. If the QF is used (see step 136 and decision step 138), it is recorded. As in Fig. 7, a diamond decision step 146 determines whether or not all the channels in the FM band have been analyzed. If not, the procedure loops back to step 88. If so, the display is updated via step 162, with the very listenable and listenable stations found in the most recent scan along with indications of their respective noise levels N and their quality factors, QF, if the latter are used.

It is then determined at a diamond decision step 140 whether a seek or scan tuning button has been activated. If so, the radio is tuned, step 166, to the next listenable or very listenable channel, in reference to the channel that was tuned in at the time of step 122", as determined in the updating procedure. As indicated by a state 3, this station is then monitored as will be described in connection with Fig. 9. However, if a display refresh button has been activated, the scanning process will have cycled the tuner back to the starting channel. Step 164 indicates that the tuning process stop at this point for continued listening at that channel. Implicit in this step is the unstated requirement to turn the audio back on.

Fig. 9 is a flowchart for monitoring a tuned in channel in state 3. As noted in step 168, when a station is tuned in, samples are taken of SS, N and AFT and their averages as well as the ranges of SS and N are computed. The offset of the average AFT is also determined, via step 170, and, if desired a QF is computed, step 172. A determination is made if the station is drifting in step 173 by comparing the SS range to some predetermined value such as 0.2v, and if so the display may be caused to indicate that fact such as by updating location 511 of Fig. 31 to display the word "Drifting". Updating of the display of SS and N and QF, if used, is performed in step 174. If a station is broadcasting digital data, relative data is presented on the display 44 via step 175. Next, the procedure loops back to step 168. Thus, a tuned in channel is repeatedly updated.

Reference is now made to the flowchart of Fig. 10 for a description of a dual pass method for tuning a single tuner FM radio having a display. During a first pass, the unlistenable and very listenable channels are identified in the same way as in Fig. 8, i.e., by the actions in steps 88, 90 and 124 and the decisions in the diamond decision steps 92' and 128. A diamond decision step 146 causes the procedure to loop back to the step 88 until all the channels of the FM band have been analyzed. Any unlistenable channels detected at the diamond decision step 92' are marked in memory via step 168. The very listenable channel detected in step 128 are assigned the best QF and are also marked in memory, in step 170. These stations are assigned the best QF because an insufficient number of samples have been taken, over an insufficiently long period of time, in order to accurately determine the station's AFT. However, since the station has passed the tests in steps 92' and 128, and therefore is known to exhibit virtually no noise, it is presumed to offer the best listenability and therefore is assigned the best QF. When diamond decision step 146 indicates that the first pass is complete, a second pass is entered.

The purpose of the first step 174 of the second pass is to run a side channel elimination algorithm. The SS of the channels on either side of each listenable channel noted in the first pass are compared with the SS of the listenable channel between them, and if the latter is stronger than both by a certain percentage, > 30% in this case, they are considered to be invalid and are not to be placed in memory. The broadcast energy of strong stations overflows into the adjacent channel frequencies. In this situation the signal energy of the center channel will be substantially stronger than that of the adjacent channels (which
are referred to as "side channels"). Occasionally side channels will not be rejected in Pass #1 because the noise and AFT parameters sometimes fluctuate into the "listenable" range. The intent of this feature is to discover these situations and classify the side channels as unlistenable without subjecting them to the Pass #2 analysis. As stated earlier, this algorithm may be enhanced to require that both adjacent channels possess greater than a certain minimum noise level in order to be rejected as side channels.

Next, in a step 175 the radio is tuned to the next channel which has not been marked in memory as being listenable or unlistenable, and a second group of samples is taken of SS, N and AFT, their respective averages are computed and the ranges of SS and N are derived in step 130′, which differs from step 130 by an initial wait state due to the fact that the channel was just tuned in. The offset of the average AFT with respect to the

AFT determined in going from state 1 to state 2 by the procedure of Fig. 5 is calculated in step 132. The diamond decision step 134 then checks to see if the SS > a given threshold, its noise average is < .5v, and its AFT offset is < 73mv. An AFT offset of 73mv is equivalent to an offset of 30μAmps, or a frequency deviation of 4,800Hz. It is to be understood that the voltages used are only examples. Any channel that fails to pass these tests is noted in memory as being invalid, via step 176, and SS and N levels for channels that pass the test are noted in memory, via step 178. If desired, a further sorting out of listenable channels can be effected by computing the QF in step 136 and checking in the diamond decision step 138 as to whether the QF exceed a selected value. If the last procedure is used, the QF's above the selected level are recorded via step 178. A diamond decision step 180 determines whether all channels not marked as invalid at step 168 or marked as valid at step 170 have been analyzed in the second pass. If not, the procedure loops back to step 130. If so, the display is refreshed with indications of listenable channels and their N and QF factors are indicated, via step 162. If the refresh scanning button has been actuated as determined by the diamond decision step 140, the procedure terminates, but if a seek or scan button has been activated, the next station on the tuning list is tuned in, its audio turned on and the tuning procedure enters the state 3, wherein the channel tuned in is monitored in accordance with Fig. 9.

Dual Tuner System

In a dual tuner system of another embodiment of the invention, a listening tuner provides the IF signals for the audio program of the channel that is tuned in and a scanner tuner periodically updates the tuning list and provides RDS information for display. In the block diagram of a dual tuner system shown in Fig. 11, an antenna 182 provides RF signals to a listening tuner 184 and to a scanner tuner 186. An IF amplifier 188, audio amplifier 190, and a loudspeaker 192 are coupled to the listening tuner 184. An IF amplifier 194 is coupled to the scanner tuner 186. Although not shown, the IF amplifiers 188, 194 include limiters and discriminators for deriving the audio signals. A controller 196 for the tuners 184 and 186 includes a CPU (central processing unit) 198, for controlling both a phase locked loop (PLL) 200 for tuning the listening tuner 184, and another phase locked loop 202 for tuning the scanner tuner 186. An analog-to-digital converter (ADC) 204, connected to the CPU 198, is coupled to receive the S, N and AFT voltages derived from the IF amplifier 188, and an ADC 206 that is connected to the CPU 198 is coupled to receive S, N and AFT voltages derived from the IF amplifier 194. RDS information, that may be transmitted along with the channel to which the listening tuner 184 is tuned, is coupled from the IF amplifier 188 to the CPU 198 via RDS means 208. RDS information, that may be transmitted in the channel to which the scanner tuner 186 is tuned, is coupled from the IF amplifier 194 to the CPU 198 via RDS means 210.

A display 212 is controlled by the CPU 198 for presenting both indications of the listenable and very listenable channels identified by the scanner tuner 186 at respective frequencies along the band, and indications as to certain information such as their SS and QF, and any pertinent RDS information.

The arrangement described in Fig. 11 is that of an FM receiver system, but the illustration is intended to convey the general case, and therefore also apply to an AM receiver system, or to a system incorporating both AM and FM receivers. In the AM case, boxes 184 and 188 together, as well as boxes 186 and 194 together, would generally be incorporated in the same physical device, such as a National Semiconductor LM1863 AM receiver system. RDS features are not generally considered for deployment on AM broadcasting systems, and so the RDS decoders 208 and 210 may be unnecessary. In the case of a combined AM and FM receiver, a single CPU 198 could connect to and control the associated PLL, ADC, and RDS subcomponents for both receiver systems, and all of these devices could be incorporated into a single controller as 196. In addition, both listening and scanner tuners 184 and 186 might be constructed into a single physical unit 185, and both listening and scanner IF stages 188 and 194 might be constructed into a single physical unit 189.

Fig. 12 is a flowchart of the operation of the listening tuner 184. Step 214 calls for activation of either a seek or scan tuning button. If either button is activated, the procedure goes from a state 4 to a state 5 so as to find a nominal or reference value for AFT in accordance with the procedure of Fig. 13, described below. In step 216 the listening tuner 184 is then tuned to the next station on the tuning list displayed on display 212, as a result of the last scan of the scanner tuner 186, and the audio is turned on. The operation of the scanner tuner 186 for identifying listenable stations will be explained by reference to Fig. 15. Data held in memory for the channel which was provided by the scanner tuner 186 is presented, via step 218, on the display 212. Next, as in the case of Figs. 8 and 10, a state 3 is entered wherein the channel tuned in on the listening tuner 184 is monitored as previously described in connection with Fig. 9.

Reference is now made to Fig. 13 for a description of the calibration procedure followed by the listening tuner 184 in going from the state 4 to the state 5 of Fig. 12 to find the nominal or reference value of AFT to be used in the monitoring operation in state 3. The purpose for calibrating AFT by the listening tuner 184 is so that the QF displayed for a station by the scanner tuner 186 is the same as that displayed by the listening tuner when the station is tuned in for listening. This is possible because although the tuners may have different absolute values of AFT, their AFT offsets for a given station will be the same, and AFT offset is predominant in the determination of QF that is performed in accordance with Fig. 9. Although, as will be explained in connection with Fig. 14, the scanner tuner 186 has already found a numerical value of AFT, this value may differ from the value found in Fig. 13 since the respective components in each tuner section may differ slightly in value. At diamond decision step 220, a determination is made as to whether a predetermined amount of time, such as the suggested 5 minutes, has elapsed since the last AFT calibration of the listening tuner. If not, the previous nominal or reference value of AFT is used, step 222, so as to place the system in the state 5. If, however, more than the given time has elapsed since the last calibration, the listening tuner 184 is tuned, step 224, to the station on the tuning list developed by the scanner tuner 186 in a manner to be explained by Fig. 15 that has the greatest value of SS.

The following is a description by example of the procedure just described. Assume that the scanner tuner is precisely aligned for AFT such that when AFT is calibrated on a very listenable station it measures zero current and zero volts. Next, assume that the listener tuner is misaligned for AFT such that when AFT is calibrated on the same very listenable station it measures +50μAmps and, therefore +135mV. In each tuner, the measured AFT values become the Nominal AFT for computing the AFT Offset of other stations. Now assume that both tuners will tune to a poor station such that when the scanner tuner tunes it in its AFT measures +10μAmps. The AFT Offset for this station for the scanner tuner will be +10μAmps - 0μAmps, and so will be the absolute value of 10μAmps. When the listening tuner is tuned to this same station the AFT will measure +60μAmps, and +60μAmps - +50μAmps equals an absolute value Offset of 10μAmps. This is because in each case what is really being measured is the difference in transmission quality between two radio signals, and no matter which tuner does the measuring, the difference between the two signals will always be the same.

At this point, the procedure is like that of the last portion of the initialization procedure of Fig. 2 in which, after a brief delay, such as 4.5 ms, two successive groups of samples of S, N and AFT are taken and the respective averages for each group computed (see step 102). Also computed is the range of the values of SS for each group. In diamond decision step 104, a determination is made of whether the SS averages of both groups of samples are greater than a given threshold, the ranges of SS for the two groups are within some percentage like the suggested 10% of each other, and both averages of N are within a given limit. The limit suggested is less than .03v when the 5 TC (time constant) limit is .1v as explained in connection with Fig. 4. Diamond decision step 104 also determines whether the variance between the AFT averages for the two groups is less than a given voltage such as the suggested .01v, equivalent to approximately 3µAmps or a frequency deviation of 480Hz.

When the step 104 indicates that the strongest station has not met the criteria stated therein, it is determined at a diamond decision step 226 whether there are any listenable stations that have passed the criteria in step 104. If so, the next strongest station is tuned in, via step 228, and it is processed as indicated in step 102 and in decision step 104. If there is no other listenable station on the tuning list, it is determined in step 106 whether there is a previous nominal or reference value of AFT. If so, it is used in step 230. If not, the AFT is not calibrated, and the range of acceptable AFT values to be used in a manner to be explained in the flowchart of Fig. 15 is increased in step 110; in this example the values are doubled. Thus, at the state 5 there is either a nominal value of AFT to be used or the acceptable ranges of AFT are increased.

Reference is made to Fig. 14 depicting the overall operation of the scanning tuner 186. After a reference value of AFT is determined by the initialization procedure at step 111 of Fig. 2, the process enters state 6 of Fig. 15 in which the band of channels is scanned in a manner to be described to select and display listenable channels and certain data relating to their quality. At the end of Fig. 15, the process goes to a state 7 at the beginning of Fig. 15A that monitors listenable stations in a manner to be described for digital data that might be broadcast if such is desired. From the end of Fig. 15A, the process enters a state 8 of Fig. 16 to find in a manner to be described a reference value of AFT. At the end of Fig. 16 the process loops back to the state 6 at the beginning of Fig. 15. There may be an optional delay of arbitrary duration before the state 6 of Fig. 15 is re-entered. Fig. 15A is omitted if digital data broadcast by the stations is not desired.

Reference is made to the flowchart of Fig. 15 showing the scanning cycle of operation of the scanner tuner 186. Optional but desirable features of the invention are shown in phantom diamond step 138, and phantom block steps 126, 136, 244, 253, and 254. The steps of Fig. 15 are similar to those in the flowchart of Fig. 8, and are identified by the same numerals. Nevertheless, a brief summary is presented here for convenience. The S, N and AFT capacitors 24, 26, and 28, are respectively clamped to reference voltages as previously described, and clamps are released in step 88', which differs from step 88 in that, since this is a scanner tuner, not a listening tuner, its audio output would normally not be connected, and so 88' omits the action item of "Turn off audio". A first group of samples is taken of S, N and AFT voltages and the respective averages attained in step 90. The AFT offset is computed in step 124. If used, step 126 adjusts the minimum SS and QF in accordance with the position of a city driving/country driving switch if present. The value of SS, N and AFT derived from the first group of samples taken in step 90 are subjected to certain loose criteria in step 92'. If the channel does not pass the criteria, in step 93 the next channel is tuned in, and the procedure loops back to step 88.

If a channel meets the criteria of the decision step 92' and is found at decision step 128 to have virtually no noise, it is accepted as very listenable and stored via step 160 in memory along with its values of SS, N and QF. This leaves channels of questionable listenability. Some may be listenable and some not. Those that are listenable are sorted out in step 130'' by taking a second group of samples, determining the averages, and determining the ranges of SS and N samples. Step 130'' differs from step 130 in that, since this is a scanner tuner and the duration of a scan is somewhat irrelevant, step

130'' collects samples over a 64ms period rather than a 16ms period. In step 132 the offset of the average AFT is determined, followed by decision step 134, in which these values of SS, N and AFT offset are compared with criteria indicated. If any criteria are not met, step 93 initiates the next channel being tuned in, via repeating the previously described procedure starting at step 88. If a channel meets all of the criteria of decision step 134, the station is recorded via step 160 in the tuning display list along with the SS and N values. If the QF is calculated via step 136, it is compared with the QF determined by position of the city driving/country driving switch in decision step 138. If the QF is below that selected, step 93 is addressed, but if it is acceptable, step 160 is addressed.

One difference with the flowchart of Fig. 8, compared to that of Fig. 15, is that in step 232 of Fig. 15 an indication is made in memory as to whether any station that has been found to be very listenable or listenable is transmitting data in addition to the audio signal. Next, decision step 146 determines whether all channels of the band have been analyzed. If not, a loopback is made to step 88. Ignoring for the moment the phantom steps, in step 162 the display 212 is refreshed with any new listenable channels, and formerly listenable channels that are now unlistenable are deleted. In addition, in step 162 appropriate indicators for SS, N, and QF are produced for each listenable and very listenable channel.

The scanner tuner 186 is now in state 7 and ready for the data monitoring cycle shown in the flowchart of Fig 15A. The next station marked with a data flag in step 232 is tuned in via step 234. The action is independent of the channel to which the listening tuner is tuned so that any channel could be selected. The broadcast data from this station is collected in step 236, and data for each channel is stored in a display buffer for that channel via step 238. Old data is deleted. In step 240, the display 212 is updated with any relevant information or special indicators from the channel tuned in. This information could indicate the type of material being broadcast. Decision step 242 checks to see if all channels have been examined. If not, step 234 is readdressed, but if so, the system loops to the state 8.

Additional embodiments of the invention described in the phantom blocks 126, 136, 244, 253, 254, and diamond decision step 138 of Fig. 15 will now be discussed in greater detail. The first of these is step 244 in which an average of the current QF and SS with values obtained during previous cycles is attained in order to present more stable values in the display 212. There are, of course, many ways for deriving a weighted average, but the one illustrated in Fig. 15B has been found to be useful. First, all but the current and two previous values of SS and QF are deleted in step 245. Next, in step 246 the current measurement is multiplied by 1.00, the first previous measurement by .5, and the second previous measurement by 0.25. The products are summed in step 248, and the multipliers are summed in step 250, to produce 1.75. In step 252, the sum of the products is divided by the sum of the multipliers, and the more stable value is shown in the display 212 via step 254. A similar mathematical process could be applied to obtain a weighted average for any number of measurements instead of just the three measurements indicated in step 244. As noted, this averaging can be used for both SS and QF, as well as N or AFT.

In step 253 of Fig. 15, the strongest of the stations recorded at the step 160 are loaded into memory locations associated with best station memory buttons if provided, and the display 212 is updated so as to indicate the memory button number associated with each station's indicator in the display illustrated in Fig. 32.

A phantom block 254 in Fig. 15 suggests that indications be made on the display 212 as to whether a channel indicated as listenable is increasing or decreasing in SS and for QF, as illustrated in Fig. 32A. Fig. 15C is a flowchart of an embodiment of the invention indicating one way in which this may be accomplished. The weighted average of SS or QF determined in Fig. 15B for the current scan of the FM band is compared with the respective weighted average for the next previous scan of the FM band via step 256. At decision step 258 it is determined whether a difference is less than some given percentage, therein shown as being 10%, for example. If so, step 260 provides for displaying a standard station indicator bar. If not, decision step 262 determines if the later average value is greater than the previous average value. If it is, step 264 causes an upward pointing arrow to be displayed. If it is not, step 266 causes a downward pointing arrow to be displayed as illustrated by station indicators 517 in Fig. 32A.

During a first scan of the band of channels in accordance with Fig. 15, a reference value of AFT is determined by the initialization procedure of Fig. 2 in making its decisions as to the listenability of each channel, but after the procedure of Fig. 15 or of Fig. 15A, if the latter is used, the procedure of Fig. 16 is used to update the reference value of AFT to be used in the next scan of the band of channels. Fig. 16 is state 8 and terminates by returning to state 6 (Fig. 15) and is substantially the same as the procedure for finding a reference value of AFT in the listening tuner as set forth in Fig. 13. In Fig. 13, there is, as indicated by the step 115, no calibration of AFT, if no valid station is found in the loop of steps 102, 104, 226 and 228 and if there is no previous calibrated value as indicated in the step 106. If this occurs in Fig. 16, however, the range of acceptable AFT values used is increased, step 231, in order to accommodate variations in temperature and other factors.

<u>Alternative Way to Find Reference AFT</u>

Reference is made to Figs. 17, 18, 19, and 19A for an explanation of a way of determining the nominal or reference value of AFT in going from state 1 to state 2 in Figs. 6-8 and 10, as well as variations in the SS threshold and N limit on the basis of ambient temperature rather than using the AFT voltage of a very listenable station. Another approach would be to combine the AFT ambient temperature adjustment along with the calibration of AFT on a very listenable station, by the simple combination of the procedures outlined in this application, as illustrated in Fig. 19A. In addition, the threshold for SS and/or the rejection limit of N may also be varied in accordance with temperature. In the circuit of Fig. 17, the ambient temperature is determined by the voltage at the junction 266 of a resistor 268 and a temperature sensor 270, which may be an LM135, that are connected in series in the order named between a point 272 of regulated DC. voltage $+V_{?}$ = 9 v and ground. An ADC 274 converts this voltage to a digital value, and the CPU 198 of Fig. 11 provides the value of AFT voltage to be used from the illustrative look-up table of Fig. 18. The percentage variation in the SS threshold and the limit of N can also be provided in the same way.

The procedure for making these determinations is set forth in the flowchart of Fig. 19. At a decision step 276 a determination is made as to whether there has been more than a given change, such as the suggested .05v, at the junction 266 since the last reading. If not, the procedure terminates via step 278, but if so, in step 280 the temperature sensor voltage at the junction 266 is looked up in a stored table illustrated in Fig. 18 to find the value of AFT voltage and the percent change in the SS threshold or the N limit that should be used. In step 282, the AFT voltage is assigned as the value to be used in deriving the AFT offsets. In an alternative system that incorporated both ambient temperature and very listenable station methods for determining AFT, step 282 of Fig. 19 would instead describe a procedure for adjusting the Nominal AFT derived from a station by an amount specified in a table similar to Fig. 18. This alternative procedure is identified in step 282' in Fig. 19A, which is otherwise the same as Fig. 19. If desired, step 284 provides for deriving the SS threshold from the table of Fig. 18, for use in the various flowcharts. If it is also desired to adjust the N limit used in the flowcharts, this is done in accordance with step 286 and the table of Fig. 18.

Adjustment of Noise Limit

Instead of using a manufacturer's suggested noise limit or the limit determined from temperature in the manner just described, the limit may be calculated in accordance with an aspect of this invention on the basis of the noisiest channel. If implemented at the points in the procedures of Figs. 2 and 5 indicated by a step 98 shown in dashed lines, noise voltage found can be substituted for the 0.1 volt in the subsequent step 104 so as to raise or lower the noise limit curve of Fig. 4. Although the step 98 is not shown in Figs. 6, 7, 7A, 8 and 10, it could be used at such a point in these procedures as to supply the maximum value for the noise limit curves of Figs. 3 and 4 wherever they are used, e.g. in steps 128, 134 and 154, wherever they appear. In the flowchart for this procedure shown in Fig. 20, the highest average value of samples N during a scan is determined via step 288, and the limit of N for the 5 TC value in Fig. 3 is set at an arbitrary percentage such as the 25% less than this value as suggested in step 290. In step 292, the noise rejection limits for the other time constant periods used in the flowcharts are based on an appropriate proportional value multiplied by the new noise rejection limit. For example, a measurement taken at two time constants would use a noise rejection level of 86% of the new noise rejection limit.

A noise limit can also be calibrated in accordance with another aspect of this invention by measuring the noise with the associated antenna clamped to ground so as to exclude received signals. In a circuit of Fig. 21 for making this calibration, an antenna 294 supplies RF signals to a tuner 296 that is coupled to an IF amplifier 298. A switching device such as a relay or transistor 300 (relay is shown) that is connected from the antenna 294 to a point 302 at ground potential is shown as being operated in response to a voltage produced by an address decoding logic 306 under the control of a CPU 308 that is coupled both to the tuner 296, and the IF amplifier 298.

Fig. 22 is a flowchart indicating the manner in which the CPU 308 of Fig. 21 operates to derive a calibrated noise value. As indicated in step 310, the switch 300 is closed so that the only noise in the receiver is thermally generated. Next, in step 312, samples are taken of the voltage across the N capacitor 26 after a brief delay, and their average is computed. The average is multiplied by the inverse of the percentage of full charge occurring at the end of the time of sampling. By way of example, if the end of the sampling occurs at 1 TC, the capacitor will be 63% charged, and the inverse of this is 1.6. At the time of system design, in step 314 a base level for receiver generated noise is set and a noise rejection limit suggested. In step 316, the average noise measured with the antenna 294 grounded is subtracted from the base level. The difference is added to the base noise level to obtain the noise rejection limit via step 318. Thus, the noise rejection limit is adjusted in accordance with the actual thermal noise generated by the receiver. If the thermal noise is greater than the base level, the noise limit is increased and vice versa. The new noise rejection limit is used in place of the base level in all of the associated flowcharts or methods of the invention. The switch 300 is then opened via step 322.

Circuit Parameters

Reference is now made to Figs 23 and 24 that show the circuit parameters coupled to the major components including the tuner 4, the phase locked loop 6, the radio system 12, and the ADC 36 of Fig. 1. All parameters except those coupled to the SS, N and AFT output pins, respectively, are suggested by the manufacturer, or are not material to the discussion, and need not be discussed in detail, but for convenience their values or identification are set forth below in Table 3. It will be understood that this is only one embodiment of the invention so that the parameter values as well as the SS threshold, the limit of N and the AFT range may be different in an embodiment using different major components.

TABLE 3

R 328 -	270 ohms	C 332 -	.01 uf
R 330 -	27 ohms	C 334 -	.01 uf
R 338 -	68 ohms	C 336 -	.01 uf
R 344 -	3.3 kΩ	Quad Coil	TOKO K596
R 354/356 -	7.5 kΩ	C 346 -	10 uf
R 360 -	470 kΩ	C 352 -	.01 uf
R 372 -	220 ohms	C 364 -	470 pf
R 376 -	4.7 kΩ	C 366 -	30 pf
R 378 -	100 kΩ	Xtal 362 -	4 Mhz
R 380 -	8.2 kΩ	C 368 -	100 pf
R 384 -	22 kΩ	C 370 -	.01 uf
R 386 -	4.7 kΩ	C 374	1 uf

Ceramic Filter 324	TOKO SK107M2-AO-00
Ceramic Filter 326	TOKO SK207M2-AO-00
AMP 382	LM324

In the SS, N and AFT circuits that are respectively coupled to the PLL 6 of the illustrated radio system, the component values used as well as the values suggested by the manufacturer are as follows in Table 4:

TABLE 4

	Actual	Mfg's Suggested
C 24 (SS)	2.2 uf	10 uf
R 30 (SS)	10 kΩ	10 kΩ
C 26 (N)	1 uf	2.2 uf
R 32 (N)	22 kΩ	22 kΩ
C 28 (AFT)	4.7 uf	5.0 uf
R 34 (AFT)	2.7 kΩ	5.0 kΩ

The actual values of the SS, N and AFT capacitors C24, C26 and C28 and resistor R34 are less than those suggested by the manufacturer because the averaging of samples in the manner previously explained permits smaller values to be used. In the prior art, unwanted signals such as the audio in the AFT circuit are attenuated by the filtering action of the capacitors so that the capacitors have to be larger.

In Fig. 24, resistors 388, 390, and 391 of 4.7 kΩ are respectively connected in series with the base leads of the transistors 46, 48 and 50 and form the enable circuit that clamps capacitors 24, 26, and 28 on channel changes.

The CPU 38 of Fig. 1 controls the entire radio system via connections to the phase lock loop 6, the display 44, and the ADC 36. The interconnections between these components use standard microprocessor interface design methodologies and are not detailed herein since anyone skilled in the art could develop a suitable design. The essence of the design of this radio is that the CPU 38 effects channel changes by sending a serial digital message via lead Dϕ of data bus 399 of Fig. 23 and Fig. 24 to PLL 6 which will cause PLL 6 to output a tuning voltage to FM tuner 4 such as to cause FM tuner 4 to tune to the desired channel. The CPU 38 implements clamping capacitors 24, 26, and 28 on channel changes by sending either a second or third digital message to PLL 6 which will cause PLL 6 to activate or deactivate, respectively, an output lead 395 which is used to turn transistors 46 and 48 on or off, and output lead 395′ which is used to turn transistor 50 on or off, as desired. The CPU 38 reads SS, N, and AFT signal values by activating ADC 36 to receive data over data bus 399 via applying certain combination of values to leads 398, 402, and 406 through intermediate interface logic. Once ADC 36 is prepared in such a manner, CPU 38 sends a digital message to ADC 36 via data bus 399 commanding the ADC 36 to sample a specific one of its input leads. Alternatively the CPU 38 will apply another combination of values to leads 398, 402, and 406 which will cause ADC 36 to output the digital value of the sample it has just taken on data bus 399, which will be read by CPU 38.

Fig. 25 illustrates the application of momentarily clamping AGC capacitors 418, 420, and a stop threshold capacitor 422 of an AM receiver so as to charge them to neutral values at the initiation of each channel change and thereby save time in tuning from one channel to another, in accordance with one aspect of this invention. Listenable channels can be shown in a display 405.

In the AM receiver shown in Fig. 25, an antenna 406 supplies RF signals to a receiver system 408, herein indicated as being a solid state chip LM1863. The LM1863 also requires additional external components such as coils, resistors, and capacitors according to standard design practices as recommended by the manufacturer, and are not shown. A CPU 410 controls a phase locked loop frequency synthesizer 412 so as to produce a tuning voltage at receiver 408 that causes a local oscillator (not shown), to generate the frequency required to tune in the selected station, and the loop is completed by coupling the local oscillator output "LO Out" to the PLL 412.

Upon activation of a seek or scan mode, the acceptability of the next channel tuned in is determined on the basis of its signal strength as indicated by a meter out pin 15 of receiver 408, and the presence of a correct IF frequency as indicated by a tuned resonator circuit, not shown. When a desired combination exists, a stop detection circuit stops the tuning action and produces a voltage at pin 8 that is coupled to the CPU 410 via a latch 414. A signal indicative of the signal strength SS appears at a pin 15 and is placed in digital form by an ADC 416 before being applied to the CPU 410. In this particular embodiment, external capacitors 418 and 420 respectively connected to pins 1 and 4 form part of an AGC filter that is necessary to eliminate audio signals from the AGC voltage.

In going from one channel to the next, enough time must be allowed to permit the capacitors 418 and 420 to discharge. Otherwise, the stop action circuit may stop tuning on the next channel in response to the voltage stored on the capacitors 418 and 420 in response to the previous channel. The capacitors must be of adequate size to properly filter the AGC signal to prevent the AGC system from attempting to track the IF signal modulation envelope, which would cause high audio Total Harmonic Distortion (THD). Prior art design is therefore a compromise between tuning speed, which is slow for large value AGC filter capacitors, and THD. A delay of as much as 50 ms is typically provided to permit the discharging to take place.

In accordance with this invention, the delay is avoided by discharging the capacitors 418 and 420 with NPN transistors 422 and 424, respectively, in this example. This is accomplished by the CPU 410 sending an appropriate signal to the bases of the transistors 422, 424 via an address decoding logic network 426, and coupling resistors 428 and 430. A low value resistor 419 is in series with capacitor 418 and transistor 422 to prevent damage to the LM1863 chip which has no internal resistance at output pin 1. Using the capacitor discharge design specified by this invention, the capacitors may be optimized to perform the filtering function and minimize THD in a system with very fast tuning.

The stop output circuit also requires a filter capacitor 431, in parallel with a resistor 432, in a threshold circuit that is connected to pin 5 of radio system 408, in order to prevent intermittent operation of the stop detector circuit in the presence of modulation peaks which may have passed through the limiting amplifier. Time is also required to discharge this capacitor.

In accordance with the invention, therefore, a PNP transistor 436 is connected between capacitor 431 and a point 438 of regulated DC. voltage V_{reg}. A resistor 434 is connected in series with the main current path of transistor 436 to aid in achieving the desired voltage pre-charge, to be discussed immediately. When a channel change is initiated in a seek or scan mode, the CPU 410 sends a signal via the Address Decoding Logic 426 and a resistor 440 so as to cause the transistor 436 to conduct and establish the voltage on the capacitor 431 at the voltage at the junction of the resistors 432 and 434. The value of the regulated voltage at the point 438 and the values of the resistors 432 and 434 are such that the voltage at pin 5 is forced to its minimum stop indication voltage when the transistor 436 conducts. If the new channel being analyzed is strong, the stop detector voltage will increase rapidly to a high level so as to trip the stop output station detector on pin 8. If the strength of the new channel is at or just above the stop indicator voltage, the voltage in the capacitor 431 increases rapidly to a point above the minimum stop level and maintains a steady state. If, however, the signal strength of the new channel is below the minimum stop level, only a short delay is required for the capacitor 431 to discharge through the resistor 432.

Reference is now made to the flowchart of Fig. 26 for an explanation of the operation of the AM receiver tuning system of Fig. 25 when a single tuner is used and no display is provided. At a block step 450, a user activates a seek, scan or best station memory scanning button, and at a step 452, the audio is turned off. The transistors 422, 424 and 436 are momentarily made conductive so as to discharge the capacitors 418 and 420 to ground potential, and to charge or discharge the capacitor 431 to the voltage at the junction of the resistors 432 and 434. The receiver 408 is then tuned to the next channel. After a delay such as 10ms to permit the stop threshold circuit to stabilize via step 454, it is then determined at a decision step 456 whether the voltage at the stop output pin 8 indicates that the station tuned to is listenable. If not, the procedure loops back to step 452. If so, a sample is taken of SS voltage at the pin 15 via step 458. Next, at decision step 460 it is determined whether a seek or scan button has been activated or whether a best station memory scanning button has been activated. If the seek or scan button was activated, the receiver remains tuned to the present channel. If, however, the best station memory button was activated, the channel is loaded into a tuning list along with its SS via step 462. It is determined at decision step 464 whether the entire AM band has been scanned. If not, the procedure returns to step 452. If so, the stations having the greatest values of SS are associated with the memory buttons via step 466.

The flowchart of Fig. 27 is for an AM receiver having a single tuner and a display, such as 405, of listenable stations. It is very much the same as the flowchart of Fig. 26 except for the following. At decision step 468, a determination is made as to whether a given time like 30 seconds has transpired since the last activation of the display refresh button. If not, the next listenable station on the tuning/display list is tuned in and the audio tuned on via step 470. The receiver then enters a state 3A in which the station is monitored as shown by the flowchart of Fig. 27A. In Fig. 27A, a sample of the SS is taken after a brief delay via step 471, and the SS indicator of the tuned in channel is updated via step 473. The process is continuously repeated. Returning now to Fig. 27, step 450' includes a display refresh button rather than a best station memory button. Instead of associating the stronger listenable stations with a few memory buttons, as in step 466 of Fig. 26, the display 405 is refreshed with all listenable stations and their respective signal strengths via step 472. If at a diamond decision step 474 it is determined that a seek or scan button has been activated, the next listenable station on the tuning list, and hence in the display 405, is tuned in and its audio tuned on via step 476. The system then enters a state 3A in which the signal strength is monitored. If at decision step 474 it is determined that the display refresh button was activated, the audio is turned on and then the system proceeds to the monitoring state 3A.

For simplicity of explanation the systems described in this application have not specifically been described as having both best station memory buttons and a display, however systems designed in accordance with this invention may incorporate both of these features.

Dual Tuner AM Tuning System

Fig. 28 is a flowchart for the operation of the listening tuner 184 in a dual tuner system incorporating the invention. When a user actuates a seek or scan button, the audio is turned off via step 480, and the next listenable channel on the tuning/display list developed by a scanner tuner 186 is tuned in and the audio turned on via step 482. The channel is then monitored in a state 3A as illustrated in Fig. 27A.

Fig. 29 is a flowchart for the scanner tuner 184 of a dual tuner AM tuning system incorporating the invention. Refreshing the tuner/display list may be done whenever desired, because the scanner tuner 184 is not providing the audio signal, and would normally proceed on a continuous basis. When the refresh procedure as initiated via start step 484, the same procedure is followed as indicated by steps 452', 454, 458, 462' and 472, and decision steps 456 and 464, of Fig. 27, except that step 452' does not specify turning off the audio since this is a scanner tuner which would not normally have a connection to the audio output. After the AM band has been scanned for listenable stations and the display 212 has been refreshed, the procedure returns via step 486 to start step 484.

Additional Procedures

The following additional procedures are indicated by phantom blocks in Fig. 29. In step 488, a more stable indication may be made of the signal strength of the stations shown in the display by averaging a number of SS samples as, for example, in Fig. 15B. Step 490 indicates that stronger listenable stations are loaded into memory locations associated with channel or memory buttons, and the display updated to show the button number associated with a particular station as will be discussed in connection with Fig. 32. Step 492 then calls for indicating in the display whether the SS of a channel is increasing or decreasing in a manner illustrated in Fig. 15C.

Displays

There are a number of ways in which pertinent data can be shown on a display, and it is thought to be well within the skill of those in the display art to devise means for forming the displays to be described.

In the display illustrated in Fig. 30, the channels having listenable stations are indicated by vertical lines 495 at the frequency of the channel, for example. The number of listenable stations will vary depending upon the sensitivity of the tuner. The height of a line is proportional to the signal strength, SS, of the station, and the station being listened to such as the one at 103.5Mhz (megahertz), is differentiated from the other stations in any suitable manner such as, for example, by its being pulsated on or off or by a different color. Stations which have considerable noise may be indicated by a dashed vertical line 494 or differentiated in some other way. RDS data indicating the type of programming for each listenable station may be derived by the scanning tuner 186 as in Fig. 15A and displayed, step 240, for example, by placing coded indices in circles 493 at the tops of the lines 495. For example, stations broadcasting news, weather, or sports could have codes of N, W, or S, respectively, indicated in association with the station's indicator bar 495. RDS data pertinent to the tuned in station can be derived as at step 218 of Fig. 12 or step 175 of Fig. 9 and shown as at 496 in the top section, and real time RDS data may be shown in the bottom section 498. A menu system, such as that described subsequently in Fig. 36, could be used to select the types of RDS data to be displayed, e.g. to display indicators just for stations broadcasting the news and sports, or perhaps just stations broadcasting jazz, etc. The menu system could be controlled by standard keyboard mechanisms as indicated by item 42 of Fig. 1, or could be controlled by either a touch entry system or voice response system as described by Fig. 39 to be discussed later. In a similar vein, station indicators could be displayed only for stations of the selected types of program material based upon the RDS digital data transmitted by each station.

Fig. 30A illustrates the radio scanner and display system working in conjunction with radio paging services broadcasting on commercial radio stations via SCA or RDS subcarriers, in which the data stream indicated by 498 carries the paging message.

Fig. 30B illustrates an alternative display mode for displaying listenable stations broadcasting a selected type of program material based upon the RDS digital data broadcast by each station.

In Fig. 31, a horizontal line 500 illustrates the adjustable threshold value of SS. Channels having lesser SS than the threshold value cannot be tuned in. As indicated at 507 the vertical line for the station tuned in is in the form of a hollow rectangle that is wider than the other vertical lines, and the degree to which it is filled in from the bottom, as at 504, may represent its SS. An enlarged view is presented as indicated at 505. Various frequencies of the band may be shown as at 506 and the frequency of the station tuned in, 508, may also be shown. In the lower portion 510, display information as to the values of SS, N, AFT and QF may be shown. A color code may be used to indicate the QF of the tuned in station, as indicated at 511. The display may also indicate that a station is drifting in accordance with step 173 of Fig. 9 by, for example, displaying the words "Drifting" or similar notation at the site of 511. When a station exhibits virtually no noise as determined via decision step 128 in Figs 7, 8 and 10, a special indication, such as a green color or a solid indicator line, can be made at the vertical SS line for that station.

In Fig. 32, the numbers of the memory buttons 512 are formed at the vertical line representing the SS of a listenable station. For example, the station to which the receiver is tuned is the one corresponding to the memory button M3.

Fig. 32A illustrates a display which utilizes station indicator bars formed as upward pointing arrows 514 or downward pointing arrows 516 to denote stations that are increasing of decreasing in SS according to steps 264 or 266 of Fig. 15C

Fig. 33 illustrates displays of listenable stations in both the FM and AM bands.

Fig. 34 illustrates another way of designating channels with listenable stations along with their values of SS. Instead of vertical lines, spots of light having a brightness or color proportional to SS are formed.

In Fig. 35, the lines are formed by an LCD, whereas other portions of the display may have been printed on the radio's faceplate. The height of the lines on the LCD or their brightness can indicate the value of SS.

Fig. 36 illustrates a display menu that may be brought up on the display 44 of Fig. 1 by depressing the menu key of the keyboard 42. A cursor, indicating which item of the menu will be activated, is indicated by an asterisk *. When the * is opposite FM-SCAN, an image like Fig. 31 is displayed without the values of SS, N, AFT and QF, but they can be displayed if the * is moved down one line. If the * is opposite Plot/Scan, Fig. 37 is displayed in which plots of SS, N and AFT are made as time goes on. From Fig. 37 it can be seen that there is a correlation between N and SS. The actual values of SS, N, AFT and QF are presented in sequence at the lower left, and the height of a lighted area 505 at the right corresponds to SS, as also shown on Fig. 31. In addition, the quality factor QF is indicated in script at the lower right. Yellow is shown as being displayed. In a color display, the actual color could be indicated. Toggling the Enter key causes Fig. 38 to be displayed alternately with Fig. 37 so as to prevent statistics of a tuned in station such as the average values of SS, N and AFT, their respective lows and highs, and their ranges.

Touch Entry and Voice Response Tuning

Fig. 39 illustrates a display screen which is sensitized to fingertip touch, using standardly available products, and arranged such that touching the area on the display where a station's indicator bar is displayed will cause the tuner to tune immediately to that station. Touch entry input devices are available from many manufacturers, and so the operation be described in general terms, as follows, but will not be described in detail. One standard approach to touch entry devices, as illustrated in Fig. 39, is to apply a touch sensitized transparent plate 518, commonly called a touch screen, on top of the display 212. The touch sensitized plate 518 is associated with input translation circuitry 520, typically supplied by the same manufacturer that supplies the touch sensitized plate, which resolves the detected touch into an x-y coordinate. The x-y coordinate data is made available to the CPU 198 via standard hardware and software interfacing techniques. The software designer of the system creates a translation table that converts the x-y coordinates into the frequency of the station being displayed at the selected site. The CPU 198 then would use standard procedures for tuning to that station.

Fig. 39 also illustrates an alternative voice response tuning arrangement in which a microphone 522 accepts spoken commands, which are translated into machine understandable format by the input translation unit 520, and are then supplied to CPU 198 for action.

Although various embodiments of the invention have been shown and described herein, they are not meant to be limiting. Those of skill in the art may recognize modifications to these embodiments, which modifications are meant to be covered by the spirit and scope of the appended claims.

What Is Claimed Is:

1. A tuning system for a radio receiver comprising:

means for deriving signals indicative of listenable stations in a band;

means responsive to said signals for producing displays at respective locations of listenable stations in the band; and

means for tuning the radio receiver to a selected one of the displayed stations.

2. A tuning system as set forth in claim 1, wherein said means for deriving signals indicative of listenable stations includes:

means for controlling said tuning system so that it tunes in the channels of the band in sequence;

means for providing at least one of SS (signal strength), N (noise) and AFT (automatic fine tuning) signals for each channel; and

means responsive to said SS, N and AFT signals for deriving the signals indicative of listenable stations in the band.

3. A tuning system as set forth in claim 1, wherein said tuning system further comprises:

a scanner tuner including said means for deriving signals indicative of listenable stations in a band;

a listening tuner which includes said means for tuning the radio receiver to a selected one of the displayed stations; and means for controlling said scanner tuner so that it repetitively scans the channels of the band in sequence.

4. A tuning system as set forth in claim 2, further comprising:

means for modifying said displays so that they illustrate the SS of each listenable station.

5. A tuning system as set forth in claim 2, further comprising:

means for modifying said displays so that they illustrate the N of each listenable station.

6. A tuning system as set forth in claim 2, further comprising:

means for deriving from said SS, N and AFT signals a measure QF (quality factor) of the quality of each listenable channel; and

means for modifying said displays so that they illustrate the QF of each listenable station.

7. A tuning system as set forth in claim 2, wherein said means responsive to at least one of said SS, N and AFT signals for deriving signals indicative of listenable stations is adjustable by the listener.

8. A tuning system as set forth in claim 2, further comprising:

means for deriving digital data broadcast by a channel; and

means for presenting said digital data on the display means.

9. A tuning system as set forth in claim 2, further comprising:

a unitized controller means for providing a CPU (central processing unit) function, a PLL (phase lock loop) function, an ADC (analog-to-digital) function, and a display control function.

10. A radio as set forth in claim 2, further comprising:

means for deriving the ranges of SS in two groups of samples, the samples being such that the effect of artifacts on their average is reduced; and

means for indicating that a station is not a reliable source of AFT reference voltage, if the ranges differ by more than a given percentage.

11. A tuning system as set forth in claim 2, wherein said means for tuning the radio receiver to a selected one of the displayed stations may be effected by touching said display means at the respective displayed location of the selected station.

12. A tuning system as set forth in claim 2, wherein said means for tuning the radio receiver to a selected one of the displayed stations may be effected by spoken commands.

13. A tuning system as set forth in claim 6, wherein said means for deriving signals indicative of listenable stations is responsive to QF.

14. A tuning system as set forth in claim 13, wherein said means for deriving signals indicative of listenable stations being responsive to QF is adjustable by the listener.

15. A tuning system as set forth in claim 14, wherein the said adjustable means includes a switch.

16. A tuning system as set forth in claim 14, wherein the said adjustable means includes a display of a menu of selectable choices.

17. A tuning system as set forth in claim 7, wherein said adjustable means includes a switch.

18. A tuning system as set forth in claim 7, wherein said adjustable means includes a display of a menu of selectable choices.

19. A tuning system as set forth in claim 8, wherein said digital data includes the type of program material or other identifying information being broadcast on a channel, and said tuning system further includes means for presenting an indicator representing said identifying information on the display means in an associative manner with said displays at respective locations of the listenable stations in the band.

20. A tuning system as set forth in claim 19, further comprising:

means for selecting which types of said identifying information indicators may be presented; and

wherein said means for tuning the radio receiver to a selected one of the displayed stations is restricted to tuning to stations associated with said selected types of said identifying information.

21. A tuning system as set forth in claim 19, wherein said means for tuning the radio receiver to a selected one of the displayed stations is controlled by touching said display means at the respective displayed location of said associated identifying information indicator for the selected station.

22. A tuning system as set forth in claim 19, wherein said means for tuning the radio receiver to a selected one of stations associated with a displayed identifying information indicator may be effected by spoken commands.

23. A tuning system as set forth in claim 20, wherein said means for selecting which types of identifying information that may be presented is a displayed menu of selectable choices.

24. A tuning system as set forth in claim 20, wherein the identifying information of the selected types is displayed, and indicators for other listenable stations are not displayed.

25. A tuning system as set forth in claim 23, wherein said selecting of types of identifying information from said menu can be effected by touching the display means at the location of the selected choice.

26. A tuning system as set forth in claim 23, wherein said selecting of types of identifying information from said menu can be effected by spoken commands.

27. A tuning system as set forth in claim 24, wherein the identifying information of the selected types is presented in a menu of selectable choices.

28. A tuning system as set forth in claim 9, wherein said unitized controller means includes an RDS (radio data system) decoder function.

29. A tuning system as set forth in claim 3, further comprising:

means for deriving digital data broadcast by a channel, the digital data including radio paging data;

means for selecting radio paging codes from said radio paging data to monitor;

means for monitoring stations broadcasting radio paging codes;

means for presenting the digital data accompanying said selected radio paging codes on the display means when one of said selected radio paging codes is received; and

means to alert the listener when one of said selected radio paging codes is received.

30. A tuning system as set forth in claim 3, further comprising:

means for determining from SS (signal strength) signals for the listenable stations on successive scans of the band by the scanner tuner, whether the SS for each listenable station is increasing or decreasing; and

means responsive to said determining means, for modifying the displays for the listenable channels so as to indicate whether their SS is increasing or decreasing.

31. A tuning system as set forth in claim 3, further comprising:

a unitized tuner stage comprising both the listening tuner stage and the scanner tuner stage.

32. A tuning system as set forth in claim 3, further comprising:

a unitized IF (intermediate frequency) stage comprising both a listening tuner IF stage and a scanner tuner IF stage.

33. A tuning system as set forth in claim 1, wherein said means for tuning the radio receiver to a selected one of the displayed stations may be effected by touching said display means at the respective displayed location of the selected station.

34. A tuning system as set forth in claim 1, wherein said means for tuning the radio receiver to a selected one of the displayed stations may be effected by spoken commands.

35. A tuning system including:

means for providing a voltage representing a characteristic of the reception for each channel tuned to;

an integration or filter circuit including a capacitor coupled to said voltage; and

means for momentarily charging said capacitor to a neutral value when the system operates to tune from a first channel to a second channel.

36. A tuning system as set forth in claim 35, further comprising:

means for deriving one or more samples of the voltage on said capacitor after said momentary charging and before said capacitor becomes fully charged; and

means for determining if a characteristic is acceptable by comparing the value of the sample or the average of multiple samples with the voltage that would be across the capacitor at the time of the samples if a voltage corresponding to a limit for the characteristic were applied to the integration or filter circuit.

37. A radio including:

means for applying a voltage to a capacitor corresponding to a characteristic of signals received in a channel;

means for obtaining samples of the voltage across the capacitor at such times that the effect of artifacts on the average value of said samples is reduced; and

means for deriving said average value.

38. A radio as set forth in claim 37, wherein the voltage across the capacitor represents signal strength (SS).

39. A radio as set forth in claim 37, wherein the voltage across the capacitor corresponds to a noise (N) signal.

40. A radio as set forth in Claim 37, wherein the voltage on the capacitor corresponds to automatic fine tuning (AFT), and the artifact is the effect of audio frequencies.

41. In a radio receiver that supplies at least one of signal strength (SS), noise (N), and automatic fine tuner (AFT) signals to associated capacitors, respectively, for integration or filtering of said signals, said capacitors being connected in a circuit with respective resistors so as to have predetermined respective charging time constants, apparatus for deriving the final integrated or filtered values comprising:

means for indicating the times at which the charging of said capacitors begins;

means for obtaining sample voltages across the respective capacitors at given times after the time when charging begins and before the capacitors are fully charged; and

means for processing the sample voltages so as to obtain via extrapolation indications of the voltages that would appear on the capacitors when they are fully charged.

42. A system for determining whether the signals received by an FM receiver are unlistenable, comprising:

means for deriving a reference value of an automatic fine tuning (AFT) signal of a listenable signal;

means for deriving an AFT signal produced by another station signal;

means for finding the absolute difference between the AFT signal of the listenable signal, and the AFT produced by said another station signal; and

means for identifying the another station signal as being unlistenable if said absolute difference exceeds a predetermined amount.

43. A method for finding a channel having a value of AFT that can be used as a reference value in identifying the listenability of channels in an FM receiver including a tuner, wherein SS (signal strength), N (noise) and AFT (automatic fine tuning) voltages are produced on respective capacitors, comprising the steps of:

tuning the tuner to a channel in the band;

clamping the voltages across the capacitors to neutral values of voltage;

unclamping the capacitors;

obtaining a first group of samples of the voltage on each capacitor and calculating their respective averages;

rejecting a channel for which the average voltage of the SS samples is less than a given threshold or the average of the N samples is greater than a given limit or the average of the AFT samples lies outside a range of values;

tuning in the next channel and repeating the procedure if the channel is rejected;

obtaining second and third groups of samples of SS, N and AFT;

calculating the voltage averages of each of the second and third group of samples of SS, N and AFT, respectively;

determining the voltage ranges of the samples of SS in each of said second and third groups; and

accepting a channel for the purpose of providing a reference value of AFT, if the voltage averages of said second and third groups of SS samples are both greater than a predetermined threshold value, the voltage ranges of SS values of the samples in said second and third groups are within a given percentage of each other, the voltage averages of the samples of N for both groups are less than a given limit and the difference between the voltage averages of the AFT samples of both groups is less than a given voltage, which is less than said given value with which the first group of AFT samples is compared.

44. A method for finding a channel having a value of AFT that can be used as a reference value as set forth in claim 43, wherein the second and third groups of samples are obtained from the strongest station by the addition of the following steps prior to obtaining the second and third groups of samples:

recording a channel in memory along with the average voltage of its SS samples if it is not rejected;

checking to see if all channels of the band have been subjected to the procedure;

tuning to the channel having a station with the greatest average voltage of the SS samples; and tuning to the channel with the next greatest average voltage of the SS samples and repeating the procedure if the channel is not accepted.

45. A method wherein the reference value of AFT is determined by the steps including:

obtaining an indication of the ambient temperature; and

deriving the reference value of AFT from a table of temperatures and corresponding values of AFT.

46. A method for identifying a channel having a listenable station in an FM receiver having capacitors that are charged by voltages in its tuner for SS (signal strength), N (noise) and AFT (automatic fine tuning) there being respective time constants for the charging of each capacitor, comprising the steps of:

providing a reference value of AFT;

momentarily clamping said capacitors for SS, N and AFT to respective neutral voltage values at a change in channel;

obtaining the value of a first group of individual samples or the average of a first group of multiple samples of the voltage of each of said capacitors so as to obtain an SS average, an N average, and an AFT average;

computing the offset between the reference value of AFT and the AFT value or average; and

rejecting a channel as not having a listenable station if the SS value or average is less than a given threshold, the N value or average is greater than a first limit, or its AFT offset exceeds a given range, the remaining channels being accepted as listenable.

47. A method for identifying a channel having a listenable station in an FM receiver having capacitors that are charged by voltages in its tuner for SS (signal strength), N (noise) and AFT (automatic fine tuning) there being respective time constants for the charging of each capacitor, comprising the steps of:

providing a reference value of AFT;

momentarily clamping said capacitors for SS, N and AFT to respective neutral voltage values at a change in channel;

obtaining the value of a first group of individual samples or the average of a first group of multiple samples of the voltage of each of said capacitors so as to obtain an SS average, an N average, and an AFT average;

computing the offset between the reference value of AFT and the AFT value or average; and

rejecting a channel as not having a listenable station if the SS value or average is less than a given threshold, the N value or average is greater than a first limit, or its AFT offset exceeds a given range, the remaining channels being accepted as potentially listenable.

48. A method as set forth in claim 47, wherein an accepted channel is identified as very listenable if its N value or average is below a second limit that is less than said first

limit so as to indicate that it has virtually no noise, the remaining channels being accepted as potentially listenable.

49. A method as set forth in claim 47, wherein a channel that has been accepted as potentially listenable is accepted as listenable by:

obtaining the average of a second group of samples of the voltage of each of said capacitors so as to obtain a second SS average, a second N average, and a second AFT average;

computing the AFT offset between the reference value of AFT and the second AFT average; and

identifying said channel as having a listenable station if the second SS average is greater than a threshold value, the second N average is less than a third limit, and the AFT offset less than a given voltage, the remaining channels being rejected.

50. A method as set forth in claim 47, wherein a channel that has been accepted as potentially listenable is accepted as listenable by:

obtaining the average of a second group of samples of the voltage of each of said capacitors so as to obtain a second SS average, a second N average, and a second AFT average;

computing the AFT offset between the reference value of AFT and the second AFT average;

obtaining the quality factor, QF, for a given channel that was rejected in said accepting step; and accepting said channel if it has a quality factor greater than a predetermined value, the remaining channels being rejected.

51. A method as set forth in claim 47 wherein a channel identified as unlistenable therein is re-examined by:

determining if its identification as unlistenable was only due to noise;

taking another sample of the voltage on the N capacitor if this is the case; and

identifying the channel as being listenable if the voltage of this last sample is not greater than it would be at the time of said another sample if the signal for N were at its maximum value.

52. A method as set forth in claim 47, further comprising the step of:

stopping the procedure on an accepted channel if a seek or scan button has been activated.

53. A method as set forth in claim 47, further comprising the steps of:

recording any channel accepted in said accepting step along with its averages of SS and N samples of the first group;

repeating the procedure until all channels of the band have been analyzed; and refreshing a display with recorded channels and their respective averages of voltage from the SS and N capacitors if a display refresh button is activated.

54. A method as set forth in claim 47 wherein said display refreshing is effected if the system is a scanner tuner of a dual tuner system.

55. A method as set forth in claim 47, wherein the reference value of AFT is determined by the steps including:

obtaining an indication of the ambient temperature; and

deriving the reference value of AFT from a table of temperatures and corresponding values of AFT.

56. A method as set forth in claim 47, wherein the reference value of AFT is further determined by the steps including:

obtaining an indication of the ambient temperature;

deriving an adjustment value of AFT from a table of temperatures and corresponding values of AFT; and

adding the adjustment value of AFT from the reference value of AFT to arrive at an adjusted reference value of AFT.

57. A method as set forth in claim 47, wherein the first noise limit is adjusted by the steps including:

obtaining an indication of the ambient temperature; and changing the noise limits by a percentage in a table of temperatures and corresponding percentages.

58. A method as set forth in claim 47, wherein the SS threshold is adjusted by the steps including:

obtaining an indication of the ambient temperature; and

changing the SS thresholds by a percentage in a table of temperatures and corresponding percentages.

59. A method as set forth in claim 47, wherein said first noise limit is the voltage that would appear on the N capacitor at the time of the first group of samples if the charging voltage is determined by steps including:

clamping an antenna of a receiver to ground;

sampling the voltage across the noise capacitor at a given point during its charging;

obtaining an average of any samples;

multiplying the average by a factor such as to attain the fully charged voltage of the noise capacitor;

obtaining the difference between the fully charged voltage and the baseline level for noise of the receiver design; and

adding the difference to the baseline level to derive the charging voltage.

60. A method as set forth in claim 47, further comprising the steps of:

recording accepted channels on a tuning list;

repeating the procedure beginning with the step of momentarily clamping the capacitors to neutral voltages until all channels of the band have been subjected to the procedure; and

respectively associating the channels having the largest average values of SS with memory buttons if a best station memory scanning button has been activated.

61. A method for identifying channels in an FM band having stations that are listenable on an FM receiver having SS (signal strength), N (noise) and AFT (automatic fine tuning) capacitors, respectively, on which SS, N and AFT voltages are produced comprising the steps of:

providing a reference value of AFT;

momentarily clamping said capacitors to respective neutral values;

applying for a given channel the associated SS, N, and AFT signals to said capacitors, respectively;

taking a first group of one or more samples of the voltages of each of said SS, N and AFT capacitors before they are fully charged;

computing the averages of the samples for each capacitor;

computing the AFT offset between the average value of AFT samples and the reference value;

identifying a channel as not having a listenable channel if it fails to meet given criteria for the AFT offset, and for the averages of the samples for the SS and N capacitors;

identifying and recording in memory as very listenable those of the remaining channels have virtually no noise on the basis of the average of the samples of the N capacitor;

repeating the procedure until all channels of a band have been analyzed;

identifying as unlistenable channels adjacent to a channel that has not been identified as not having a listenable station if the SS of both is less than a given percentage of the SS of the channel to which they are adjacent;

tuning to each of the remaining channels not yet identified as very listenable or unlistenable, each in sequence until all of the remaining channels have been analyzed;

while tuned to each channel, taking a second group of samples of the voltages of the SS, N and AFT capacitors;

computing the respective averages of the second group of samples;

computing the offset of the average of the AFT samples from the reference value of AFT; and

identifying a channel as having a listenable station if it passes criteria as to the AFT offset and the averages of the second groups of the SS and N samples.

62. A method as set forth in claim 61, further comprising the steps of:

computing the ranges for the second set of samples of SS and N;

computing a quality factor QF; and

accepting a channel as having a listenable station if the QF equals or exceeds a given value.

63. A method for rapidly identifying channels of an FM band having listenable stations on a receiver providing SS (signal strength), N (noise), and AFT (automatic fine tuning) voltages on respective capacitors, comprising the steps of:

providing a reference voltage of AFT;

momentarily clamping the capacitors to neutral voltages;

applying for a given channel associated SS, N, and AFT signals to said capacitors, respectively;

obtaining the averages of a first group of one or more samples of each of the SS, N and AFT voltages;

computing the offset between the average of the AFT samples from the reference value of AFT;

rejecting on the basis of the averages of SS and N and the AFT offset not meeting first criteria those channels not having a station that is even marginally listenable;

repeating the procedure beginning with the sampling until all channels of the band have been analyzed;

identifying the non-rejected channels as being very listenable if they have virtually no noise;

obtaining the averages of a second group of samples of each of the SS, N and AFT voltages for the channels that have not been rejected or identified as being very listenable;

computing the AFT offset of the average of the second samples with respect to the AFT reference voltage; and

identifying as having at least marginally listenable stations those channels having SS and N averages and an AFT offset that meet second criteria.

64. A method for rapidly identifying the listenability of channels in an FM band comprising the steps of:-

rejecting channels that are clearly not listenable;

analyzing the remaining channels to identify those that are very listenable; and

analyzing the remaining channels to see if they are at least marginally listenable.

65. In a tuning system for a receiver in which channels of a band are identified as listenable or unlistenable by comparing the strength of the received signal with a threshold value and wherein a city/highway driving switch is provided, the method of comprising the steps of:

determining whether said switch is in the city or in the highway position; and

setting the signal strength threshold at a higher value when said switch is in the highway position than when it is in the city position.

66. A method as set forth in claim 65, wherein the switch is a city/country switch, said method further including the step of:

setting the signal strength threshold at a lower value when said switch is in the country position than when it is in the city position.

67. In a tuning system for a receiver in which channels of a band are identified as listenable or unlistenable by comparing the quality factor with a minimum value and wherein a city/highway driving switch is provided, the method comprising the steps of:

determining whether the switch is in the city or highway driving position; and

setting the minimum value of the quality factor at a higher level when the switch is in the highway position than when it is in the city position.

68. A method as set forth in claim 67, wherein the switch is a city/country switch, and further including the step of:

setting the minimum value of the quality factor at a lower level when said switch is in the country position than when it is in the city position.

69. In a tuning system that repeatedly scans the channels in a band and identifies them in each scan as being listenable if they meet criteria including signal strength, a method of

indicating the channels that are listenable comprising the steps of:

deriving averages of the signal strength of each listenable channel on a current scan with its signal strength in at least one previous scan, and

forming a display at respective locations of the average signal strength of the listenable channels.

70. In a tuning system that repeatedly scans channels in a band and identifies them in each scan as being listenable if they have at least a given quality factor, a method of indicating the channels that are listenable comprising the steps of:

deriving averages of the quality factor of each listenable channel on a current scan with its quality factors on at least one previous scan; and

forming a display of said averages.

71. A method for operating a tuner comprising the steps of:

tuning in the channels of a band and deriving indications as to which are listenable;

forming in response to said indications a display of listenable channels;

tuning the tuner to a desired channel;

periodically monitoring data that may be transmitted on that channel in addition to an audio program; and

forming said data in said display.

72. A method of operation of a receiver having a listening tuner and a scanner tuner comprising the steps of:

repeatedly tuning said scanning tuner across a band of channels;

providing first indications as to which channels are listenable and second indications as to channels that contain data different from the audio signal;

forming a display in response to said first indication of all listenable channels;

forming a display in response to said second indications illustrating the content thereof;

tuning said listening tuner to a desired channel; and

forming a display for this channel of data received therein in addition to the audio information.

73. A tuning system comprising;

a tuner;

means for successively tuning said tuner to each channel in a band;

said tuner having means for providing voltages indicative of the reception characteristics of the received signal of the channel to which it is tuned;

means responsive to said voltages for indicating the channels that are unlistenable; and

means for identifying which of these other channels are very listenable.

74. In a tuning system for a receiver that identifies channels of a band as being listenable or unlistenable on a basis including a noise limit, a method for a deriving voltage for said noise limit comprising the steps of:

tuning the receiver across the band and recording a voltage corresponding to the noise level of each channel;

determining which channel is noisiest; and

deriving the value of the noise limit from the noise voltage for the noisiest channel.

75. In a tuning system for a receiver that identifies channels of a band as being listenable or unlistenable by comparing noise voltage built up on a noise capacitor at each channel change with a noise limit voltage, a method for deriving a noise limit voltage comprising the steps of:

clamping the antenna of the receiver to ground;

sampling the voltage across the noise capacitor before it is fully charged;

obtaining an average of the samples;

multiplying the average by a factor such as to attain the value of voltage the capacitor will have when fully charged;

providing a voltage corresponding to the baseline level of noise for the receiver;

obtaining the difference between the fully charged voltage and the voltage corresponding to baseline noise; and

adding the difference to the voltage for the baseline noise so as to provide the noise limit voltage.

76. In a tuning system where channels are identified as being listenable or unlistenable on the basis of the difference between their AFT voltage and a reference AFT voltage, a method for finding a reference AFT voltage comprising the steps of:

tuning the system across a band of channels;

finding the strongest channel; and

using the AFT voltage of the strongest channel as the reference AFT voltage.

77. In a tuning system where channels are identified as being listenable or unlistenable on the basis of the difference between their AFT voltage and a reference AFT voltage, a method for finding a reference AFT voltage comprising the steps of:

tuning the system across a band of channels;

finding a very listenable channel; and

using the AFT voltage of said very listenable channel as the reference AFT voltage.

78. In a dual tuner radio system, a method of balancing the measurements of SS (signal strength) and N (noise) between the two tuners, comprising the steps of:

calibrating AFT with both tuners upon power up;

subtracting the SS measurement of the calibration station made by the first tuner from the SS measurement of the calibration station made by the second tuner to arrive at an SS balancing factor;

adding said SS balancing factor to all subsequent SS measurements made by said first tuner;

subtracting the N measurement of the calibration station made by the first tuner from the N measurement of the calibration station made by the second tuner to arrive at an N balancing factor; and

adding said N balancing factor to all subsequent N measurements made by said first tuner.

79. In a tuning system for a radio, a method of determining a Quality Factor QF of a channel comprising the steps of:

obtaining samples of N (noise) and AFT (automatic fine tuning);

taking the averages of said samples;

obtaining a reference value of AFT;

subtracting the AFT average from the reference value to obtain an AFT offset; and,

computing a QF as a factor of N, and AFT offset that is representative of the listenability of the received signal.

80. In the method for a tuning system as set forth in claim 79, wherein said step of QF computation includes the steps of:

taking the square root of N average times AFT offset; and

adding thereto the N range divided by two.

81. In a tuning system as set forth in claim 79, said method further including the steps of:

obtaining samples of signal strength (SS);

taking the average of said SS samples; and

including SS as a factor in the step of computing QF.

82. A method for identifying the listenability of channels in an FM receiver including a city/highway driving switch, a display, and a tuner, wherein SS (signal strength), N (noise) and AFT (automatic fine tuning) voltages are produced on respective capacitors, comprising the steps of:

determining whether said switch is in the city or in the highway position;

setting respective signal strength thresholds at higher values when said switch is in the highway position than when it is in the city position;

tuning the tuner to a channel in the band;

clamping the voltages across the capacitors to neutral values of voltage;

unclamping the capacitors;

obtaining a first group of samples of the voltage on each capacitor and calculating their respective averages;

rejecting a channel for the purpose of providing a reference value of AFT if the voltage average of SS samples are below a predetermined threshold value, or if the voltage average of N samples are greater than a given limit, or if the AFT voltage average is less than a given value;

tuning in the next channel and repeating the procedure if the channel is rejected;

obtaining second and third groups of samples of SS, N, and AFT;

accepting a channel for the purpose of providing a reference value of AFT, if the voltage averages of said second and third groups of SS samples are both greater than a predetermined threshold value, the voltage ranges of SS values of the samples in said second and third groups are within a given percentage of each other, the voltage averages of the samples of N for both groups are less than a given limit and the difference between the voltage averages of the AFT samples of both groups is less than a given voltage, which is less than said given value with which the first group of AFT samples is compared;

accepting the average of the combined averages of the second and third groups of AFT voltages as the AFT reference value;

tuning in the next channel and repeating the procedure of obtaining a first group of samples of SS, N, and AFT and calculating their voltage averages;

rejecting a channel as definitely not listenable, for which the average voltage of the SS samples is less than a given threshold, or the average of the N samples is greater than a given limit, or the average of the AFT samples are offset from the reference value of AFT by more than a predetermined amount;

tuning in the next channel and repeating the procedure if the channel is rejected;

obtaining second and third groups of samples of SS, N, and AFT;

calculating the voltage averages of each of the second and third group of samples of SS, N, and AFT, respectively;

determining the voltage ranges of the samples of SS in each of said second and third groups; and

analyzing the remaining channels to identify those that are very listenable;

analyzing the remaining channels to see if they are at least marginally listenable; and

forming a display at respective locations of the average signal strength of the listenable channels.

83. In a tuning system for a receiver in which channels of a band are identified as listenable or unlistenable by comparing the strength of the received signal with a threshold value and wherein a city/highway driving switch is provided, said tuning system comprising:

means for determining whether said switch is in the city or in the highway position;

means for setting signal strength thresholds at higher values when said switch is in the highway position than when it is in the city position;

means for momentarily charging a capacitor to a neutral value when the system operates to tune from a first channel to a second channel;

means for applying a voltage to said capacitor corresponding to a characteristic of signals received in a channel;

an integration or filter circuit including said capacitor couple to said voltage;

means for obtaining samples of the voltage across the capacitor at such times that the effect of artifacts on the average value of said samples is reduced;

means for deriving said average value;

means for identifying if a channel is listenable by determining if a characteristic is acceptable by comparing the value of the sample or the average of multiple samples with the voltage that would be across the capacitor at the time of the samples if a voltage corresponding to a limit for the characteristic were applied to the integration or filter circuit;

means responsive to said signals for producing displays at respective locations of identified listenable stations in the band; and

means for tuning the radio receiver to a selected one of the displayed stations.

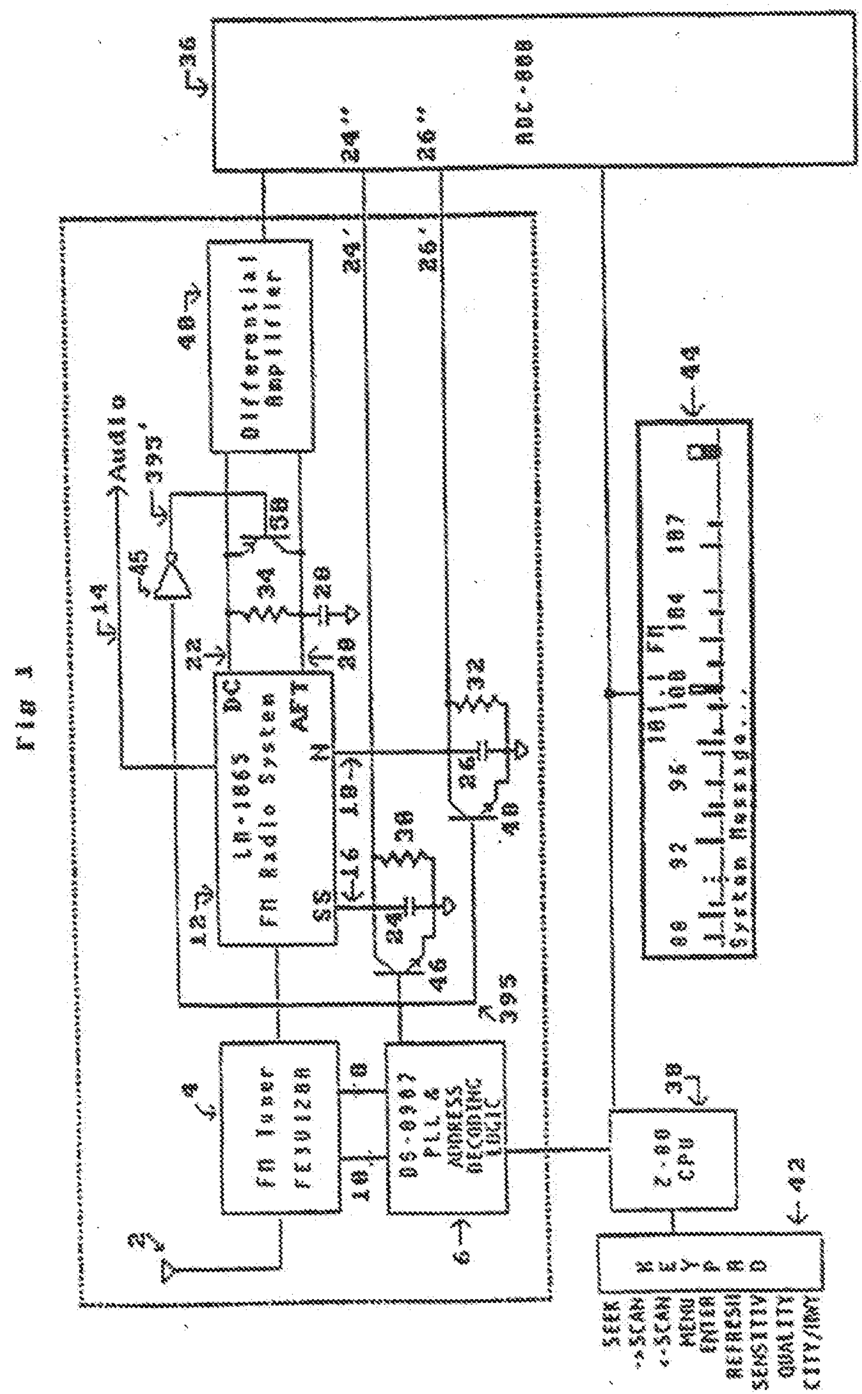

ADC-808
Differential Amplifier
Audio
FM Radio System
Z-80 CPU
KEYPAD
SEEK
MENU
ENTER
REFRESH
QUALITY
System Message

Fig 1

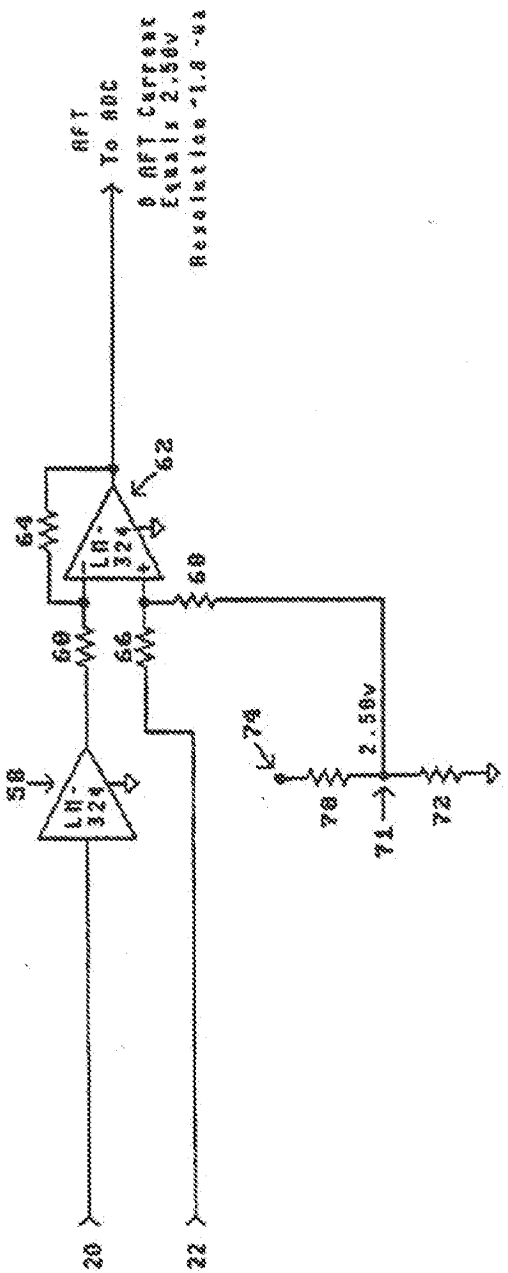


Fig 1A
Differential
Amplifier

Fig. 2

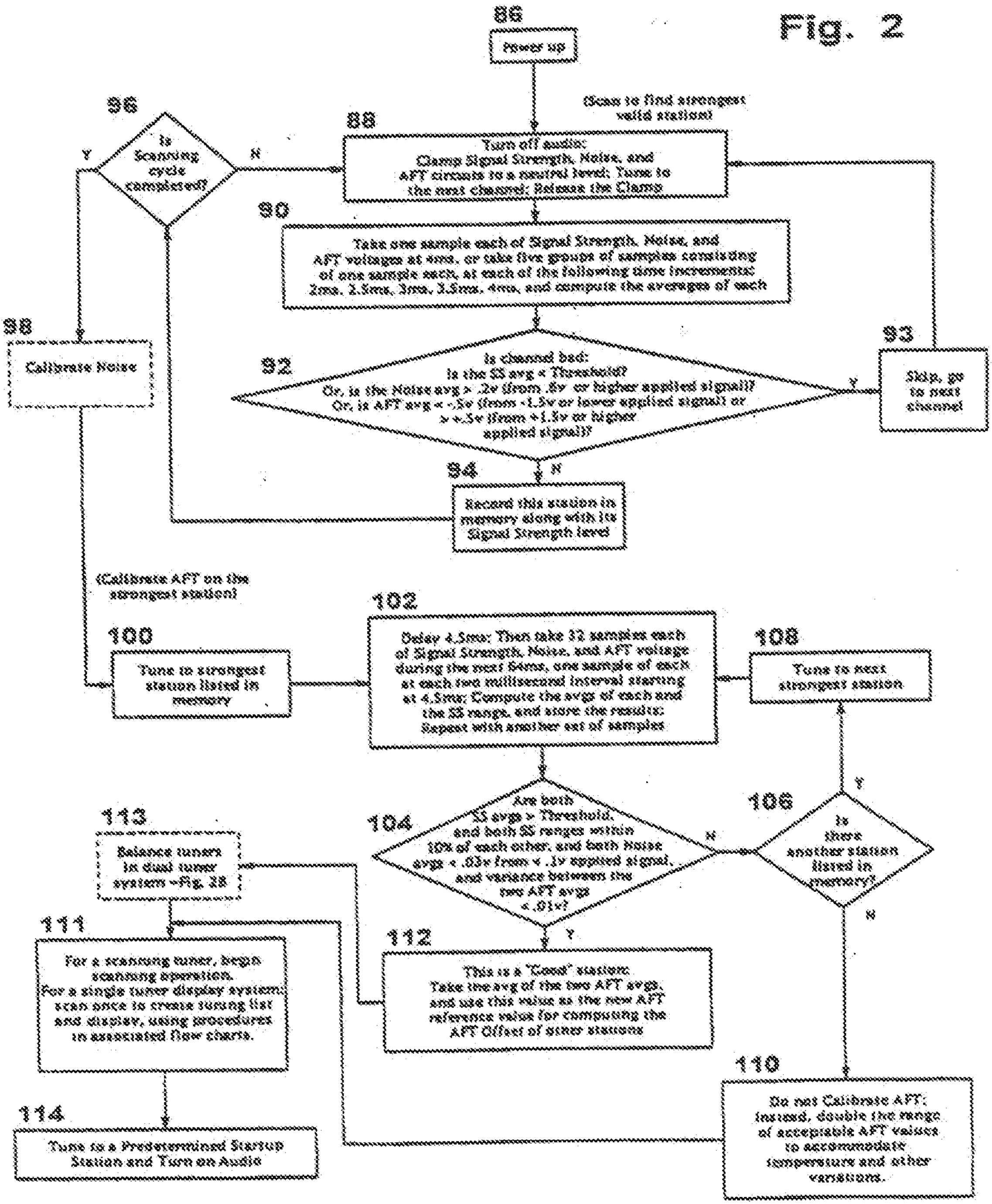

86
Power up
(Scan to find strongest valid station)
88
Turn off audio; Clamp Signal Strength, Noise, and AFT circuits to a neutral level; Tune to the next channel; Release the Clamp
96
Is Scanning cycle completed?
90
Take one sample each of Signal Strength, Noise, and AFT voltages at 4ms, or take five groups of samples consisting of one sample each, at each of the following time increments: 2ms, 2.5ms, 3ms, 3.5ms, 4ms, and compute the averages of each
92
Is channel bad: Is the SS avg < Threshold? Or, is the Noise avg > .2v (from .8v or higher applied signal)? Or, is AFT avg < -.5v (from -1.5v or lower applied signal) or > +.5v (from +1.5v or higher applied signal)?
93
Skip, go to next channel
94
Record this station in memory along with its Signal Strength level
98
Calibrate Noise
(Calibrate AFT on the strongest station)
100
Tune to strongest station listed in memory
102
Delay 4.5ms; Then take 32 samples each of Signal Strength, Noise, and AFT voltage during the next 64ms, one sample of each at each two millisecond interval starting at 4.5ms; Compute the avgs of each and the SS range, and store the results; Repeat with another set of samples
108
Tune to next strongest station
104
Are both SS avgs > Threshold, and both SS ranges within 10% of each other, and both Noise avgs < .03v from < .1v applied signal, and variance between the two AFT avgs < .01v?
106
Is there another station listed in memory?
113
Balance tuners in dual tuner system - Fig. 28
111
For a scanning tuner, begin scanning operation. For a single tuner display system: scan once to create tuning list and display, using procedures in associated flow charts.
112
This is a "Good" station: Take the avg of the two AFT avgs, and use this value as the new AFT reference value for computing the AFT Offset of other stations
110
Do not Calibrate AFT; instead, double the range of acceptable AFT values to accommodate temperature and other variations.
114
Tune to a Predetermined Startup Station and Turn on Audio
Y
N

Fig. 2A

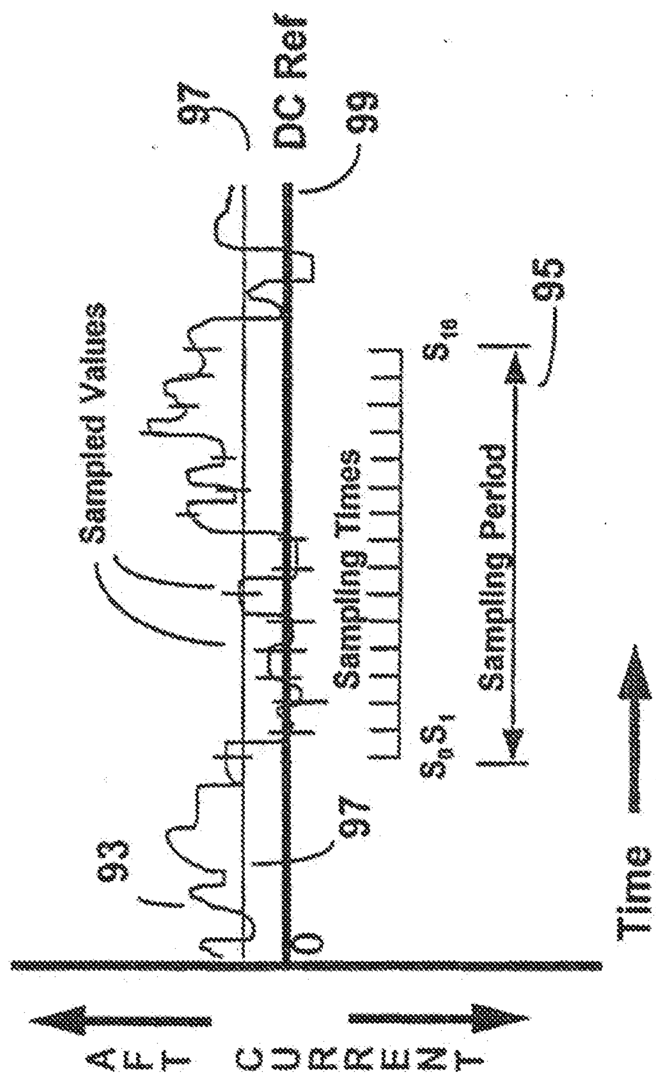
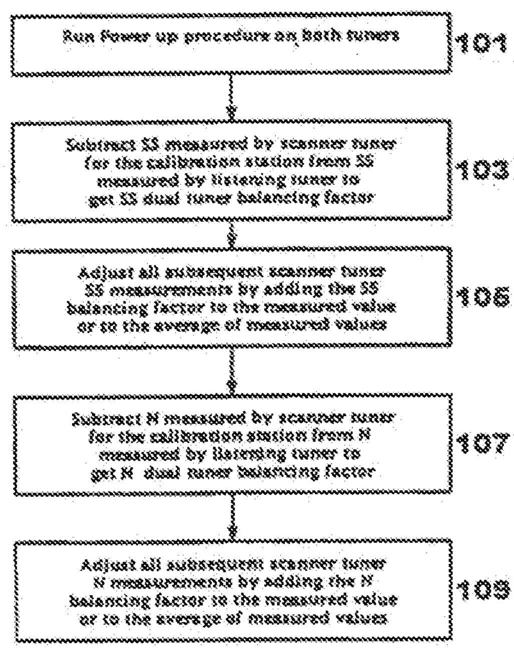

DC Ref
97
99
Sampled Values
93
97
0
Sampling Times
S_0S_1
S_{18}
Sampling Period
95
Time
AFT CURRENT

Fig. 2B


Run Power up procedure on both tuners
101
Subtract SS measured by scanner tuner for the calibration station from SS measured by listening tuner to get SS dual tuner balancing factor
103
Adjust all subsequent scanner tuner SS measurements by adding the SS balancing factor to the measured value or to the average of measured values
105
Subtract N measured by scanner tuner for the calibration station from N measured by listening tuner to get N dual tuner balancing factor
107
Adjust all subsequent scanner tuner N measurements by adding the N balancing factor to the measured value or to the average of measured values
109

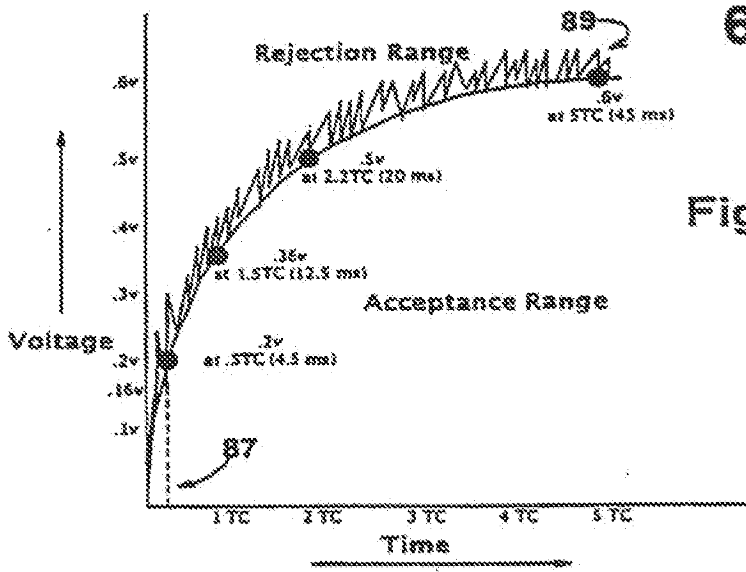

89
Rejection Range
.6v
.5v
.4v
.3v
.2v
.16v
.1v
Voltage
.6v
at 5TC (45 ms)
.5v
at 2.2TC (20 ms)
.36v
at 1.5TC (12.5 ms)
.2v
at .5TC (4.5 ms)
Acceptance Range
87
1 TC
2 TC
3 TC
4 TC
5 TC
Time

Fig. 3

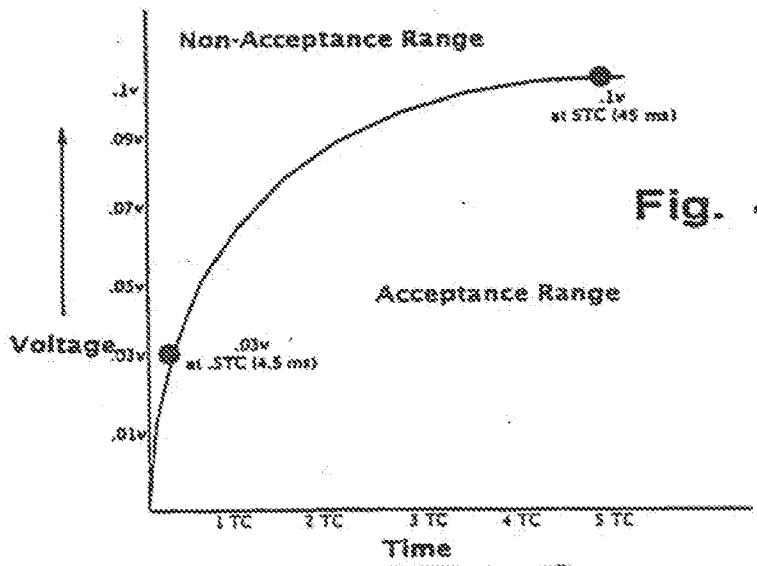

Non-Acceptance Range
.1v
.09v
.07v
.05v
.03v
.01v
Voltage
.1v
at 5TC (45 ms)
.03v
at .5TC (4.5 ms)
Acceptance Range
1 TC
2 TC
3 TC
4 TC
5 TC
Time

Fig. 4

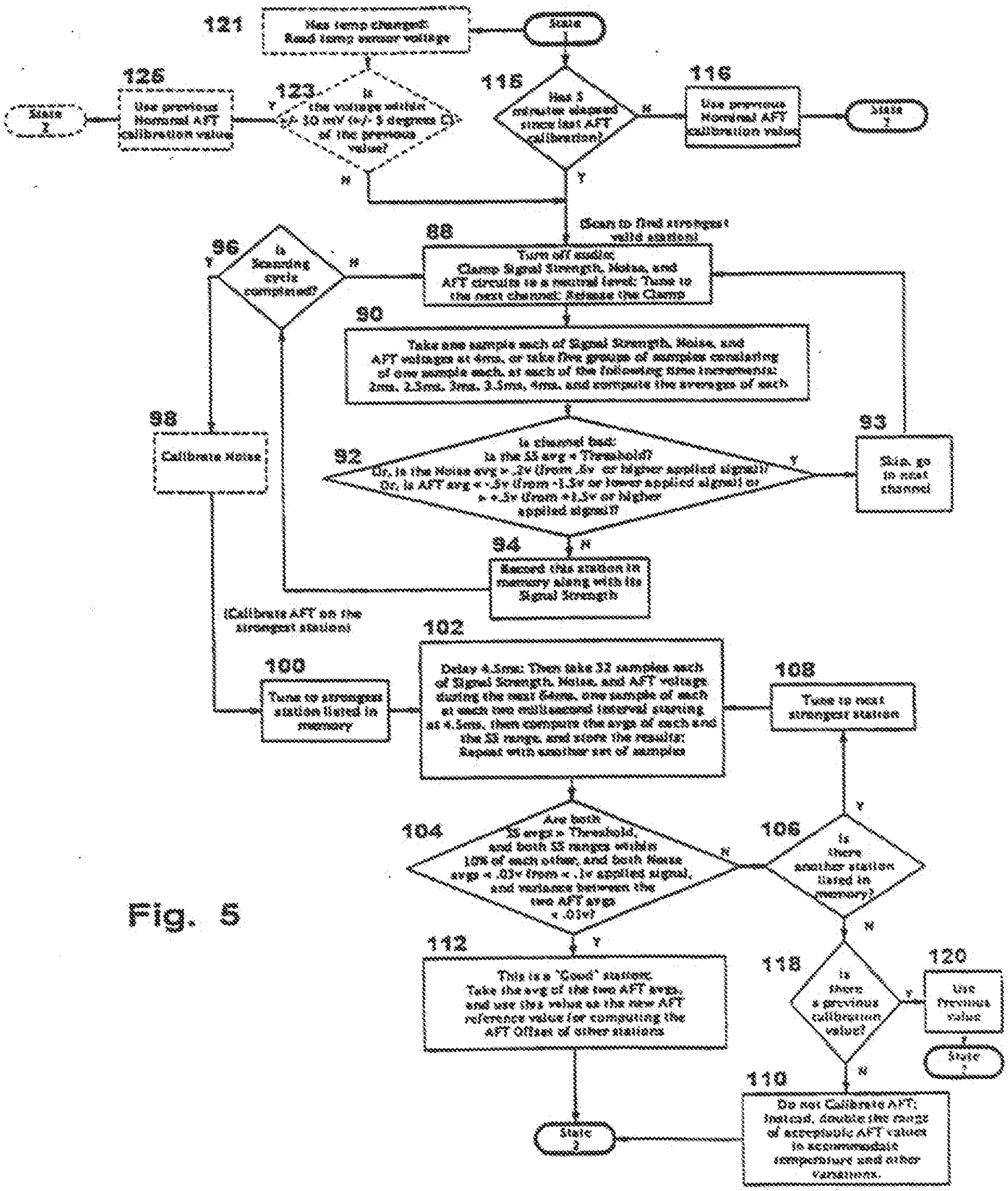

121 Has temp changed: Read temp sensor voltage
Start
126 Use previous Nominal AFT calibration value
State 2
123 Is the voltage within +/- 30 mV (+/- 5 degrees C) of the previous value?
115 Has 5 minutes elapsed since last AFT calibration?
116 Use previous Nominal AFT calibration value
State 2
(Scan to find strongest valid station)
88 Turn off audio; Clamp Signal Strength, Noise, and AFT circuits to a neutral level; Tune to the next channel; Release the Clamp
96 Is Scanning cycle completed?
90 Take one sample each of Signal Strength, Noise, and AFT voltages at 4ms, or take five groups of samples consisting of one sample each, at each of the following time increments: 2ms, 2.5ms, 3ms, 3.5ms, 4ms, and compute the averages of each
98 Calibrate Noise
92 Is channel bad: Is the SS avg < Threshold? Or, is the Noise avg > .2v (from .6v or higher applied signal)? Or, is AFT avg < -.3v (from -1.3v or lower applied signal) or > +.3v (from +1.3v or higher applied signal)?
93 Skip, go to next channel
94 Record this station in memory along with its Signal Strength
(Calibrate AFT on the strongest station)
100 Tune to strongest station listed in memory
102 Delay 4.5ms; Then take 32 samples each of Signal Strength, Noise, and AFT voltage during the next 64ms, one sample of each at each two millisecond interval starting at 4.5ms, then compute the avgs of each and the SS range, and store the results; Repeat with another set of samples
108 Tune to next strongest station
104 Are both SS avgs > Threshold, and both SS ranges within 10% of each other, and both Noise avgs < .03v from < .1v applied signal, and variance between the two AFT avgs < .01v?
106 Is there another station listed in memory?
112 This is a "Good" station; Take the avg of the two AFT avgs, and use this value as the new AFT reference value for computing the AFT Offset of other stations
118 Is there a previous calibration value?
120 Use Previous value
State 2
110 Do not Calibrate AFT; Instead, double the range of acceptable AFT values to accommodate temperature and other variations.
State 2
Y
N

Fig. 5

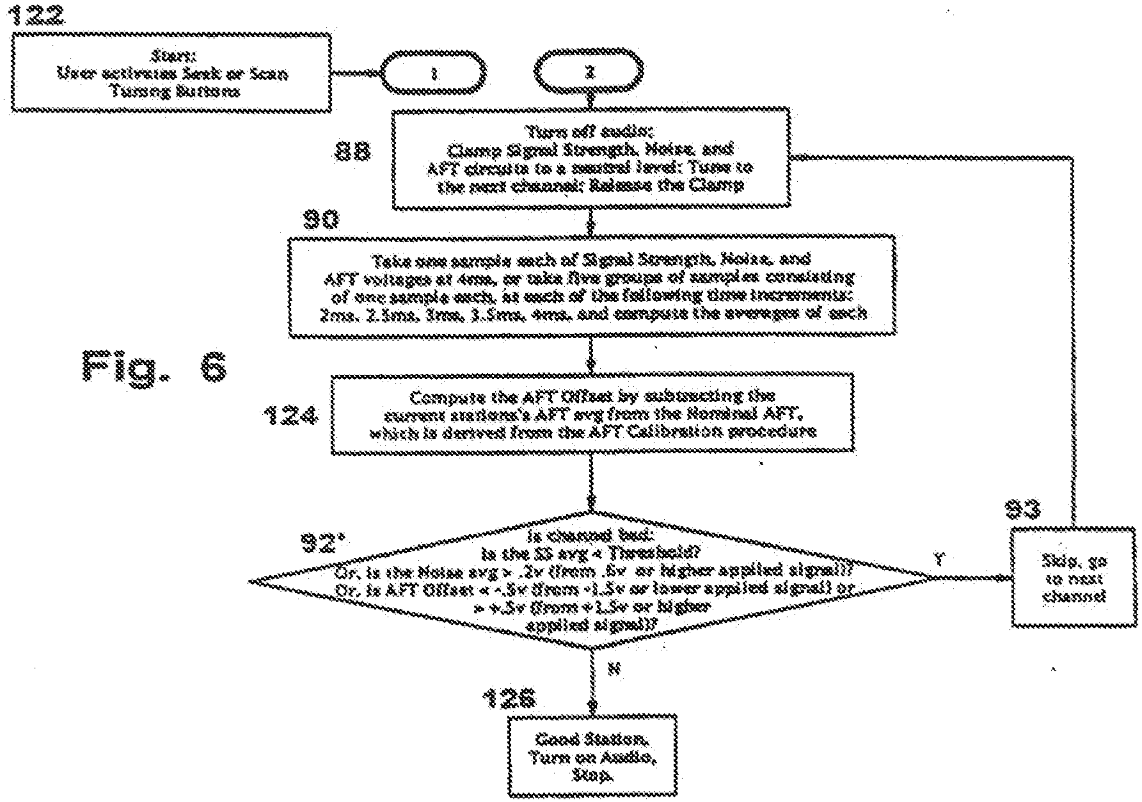

122
Start:
User activates Seek or Scan
Tuning Buttons
1
2
88
Turn off audio;
Clamp Signal Strength, Noise, and
AFT circuits to a neutral level; Tune to
the next channel; Release the Clamp
90
Take one sample each of Signal Strength, Noise, and
AFT voltages at 4ms, or take five groups of samples consisting
of one sample each, at each of the following time increments:
2ms, 2.5ms, 3ms, 3.5ms, 4ms, and compute the averages of each
124
Compute the AFT Offset by subtracting the
current stations's AFT avg from the Nominal AFT,
which is derived from the AFT Calibration procedure
92'
Is channel bad:
Is the SS avg < Threshold?
Or, is the Noise avg > .2v (from .5v or higher applied signal)?
Or, is AFT Offset < -.5v (from -1.5v or lower applied signal) or
> +.5v (from +1.5v or higher
applied signal)?
Y
93
Skip, go
to next
channel
N
126
Good Station,
Turn on Audio,
Stop.

Fig. 6

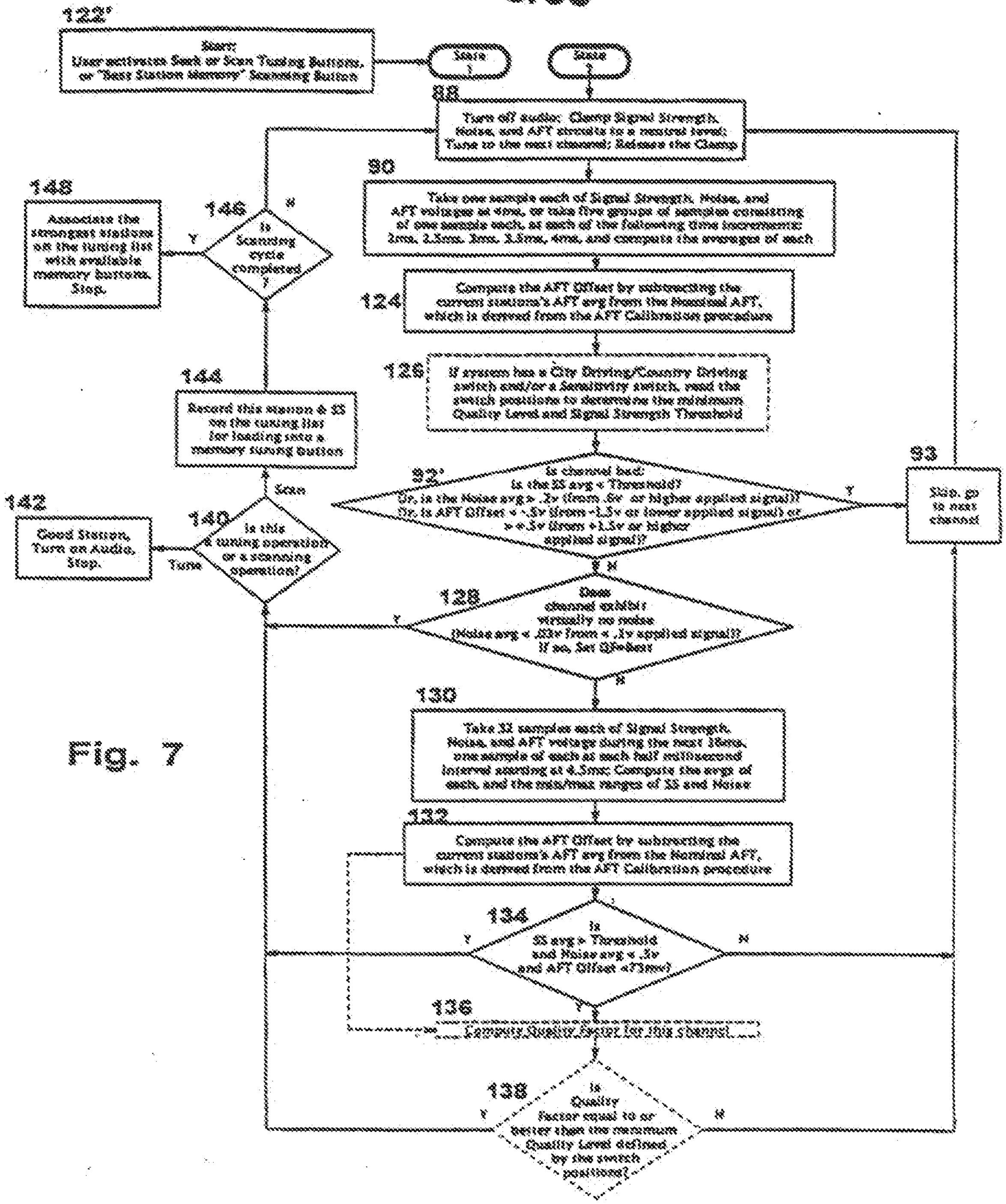

122'
Start: User activates Seek or Scan Tuning Buttons, or "Best Station Memory" Scanning Button
State 1
State 2
88
Turn off audio; Clamp Signal Strength, Noise, and AFT circuits to a neutral level; Tune to the next channel; Release the Clamp
90
Take one sample each of Signal Strength, Noise, and AFT voltages at 4ms, or take five groups of samples consisting of one sample each, at each of the following time increments: 2ms, 2.5ms, 3ms, 3.5ms, 4ms, and compute the averages of each
124
Compute the AFT Offset by subtracting the current station's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
126
If system has a City Driving/Country Driving switch and/or a Sensitivity switch, read the switch positions to determine the minimum Quality Level and Signal Strength Threshold
92'
Is channel bad: Is the SS avg < Threshold? Or, is the Noise avg > .2v (from .6v or higher applied signal)? Or, is AFT Offset < -.5v (from -1.5v or lower applied signal) or > +.5v (from +1.5v or higher applied signal)?
93
Skip, go to next channel
128
Does channel exhibit virtually no noise (Noise avg < .03v from < .1v applied signal)? If so, Set QF=best
130
Take 32 samples each of Signal Strength, Noise, and AFT voltage during the next 16ms, one sample of each at each half millisecond interval starting at 4.5ms; Compute the avgs of each, and the min/max ranges of SS and Noise
132
Compute the AFT Offset by subtracting the current station's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
134
Is SS avg > Threshold and Noise avg < .3v and AFT Offset < 73mv?
136
Compute Quality Factor for this channel
138
Is Quality Factor equal to or better than the minimum Quality Level defined by the switch positions?
140
Is this a tuning operation or a scanning operation?
Scan
Tune
142
Good Station, Turn on Audio, Stop.
144
Record this station & SS on the tuning list for loading into a memory tuning button
146
Is Scanning cycle completed?
148
Associate the strongest stations on the tuning list with available memory buttons. Stop.
Y
N

Fig. 7

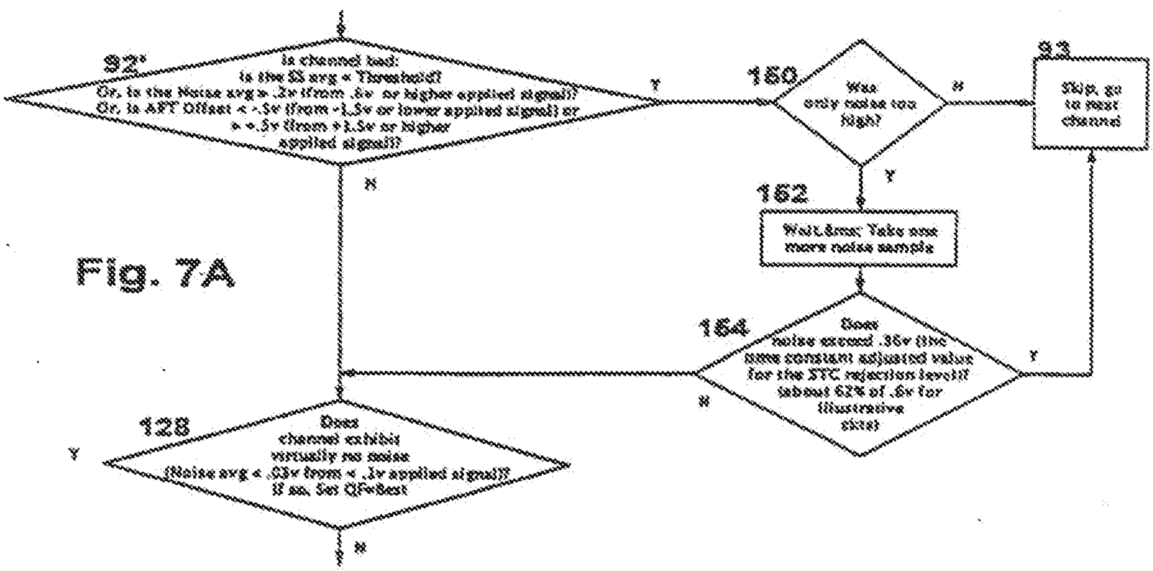

92'
Is channel bad:
Y
N
160
Was only noise too high?
N
Y
93
Skip, go to next channel
162
Wait; Take one more noise sample
164
Y
N
128
Does channel exhibit virtually no noise
Y
N

Fig. 7A

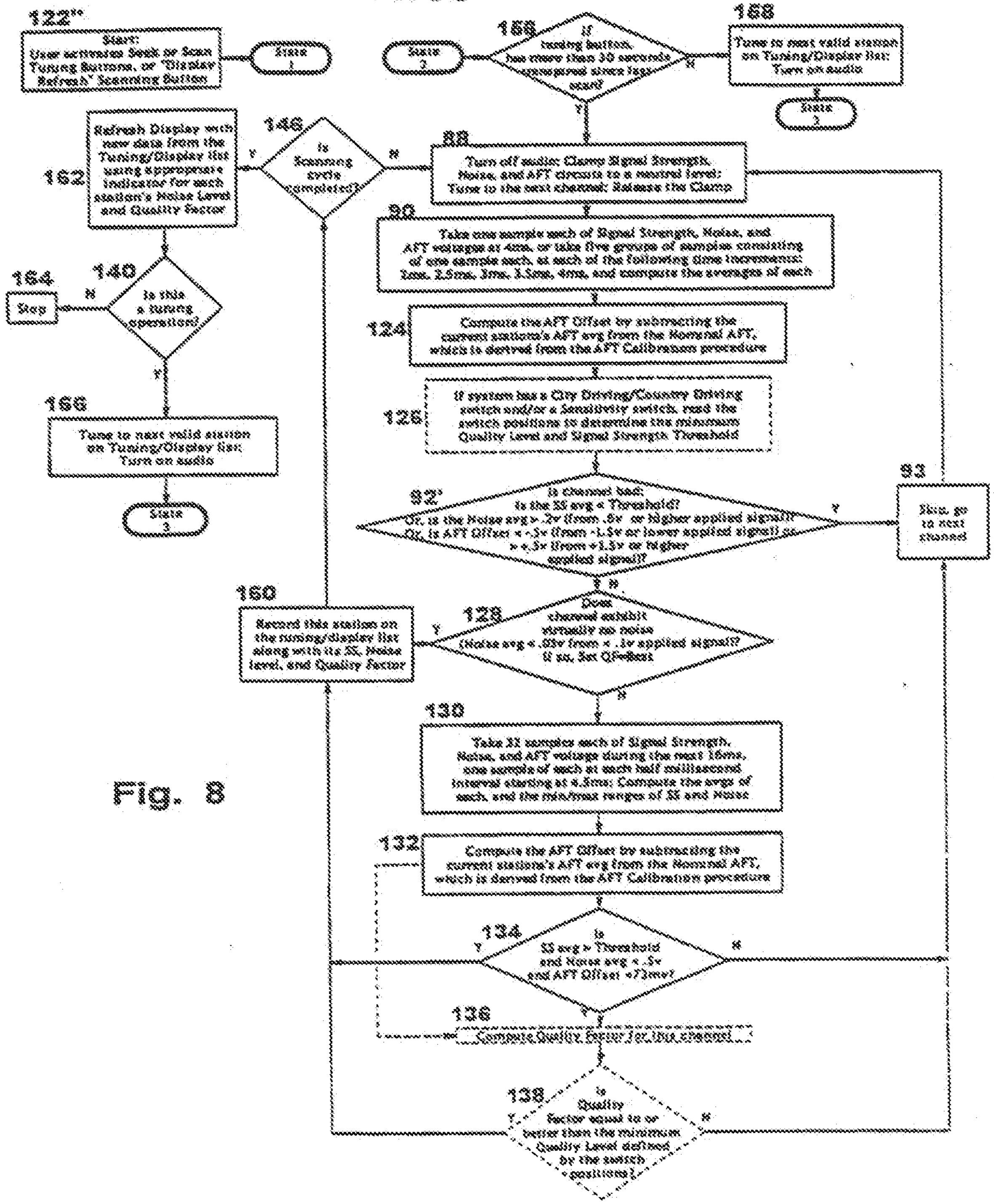
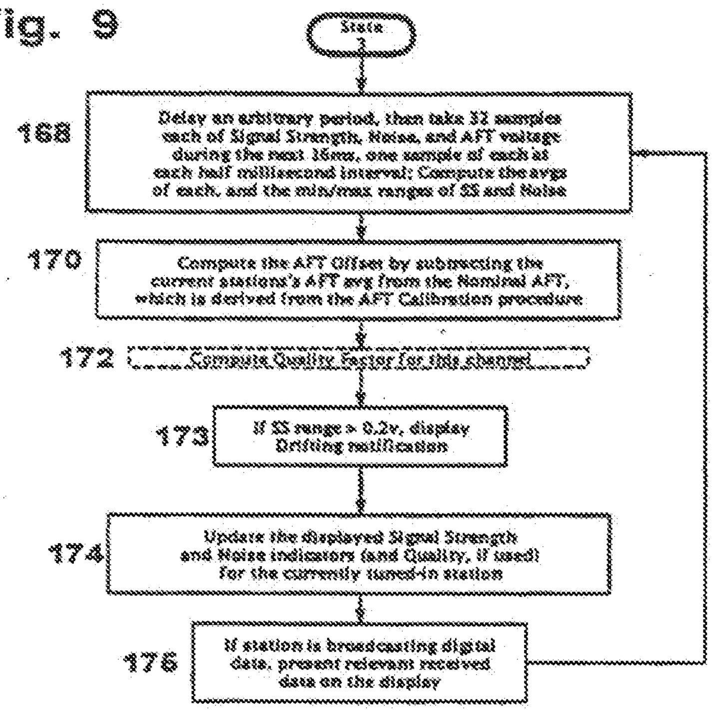

122''
Start: User activates Seek or Scan Tuning Buttons, or "Display Refresh" Scanning Button
State 1
158
If tuning button, has more than 30 seconds elapsed since last scan?
State 2
168
Tune to next valid station on Tuning/Display list: Turn on audio
State 3
162
Refresh Display with new data from the Tuning/Display list using appropriate indicator for each station's Noise Level and Quality Factor
146
Is Scanning cycle completed?
88
Turn off audio: Clamp Signal Strength, Noise, and AFT circuits to a neutral level; Tune to the next channel; Release the Clamp
90
Take one sample each of Signal Strength, Noise, and AFT voltages at 4ms, or take five groups of samples consisting of one sample each, at each of the following time increments: 1ms, 2.5ms, 3ms, 3.5ms, 4ms, and compute the averages of each
164
Stop
140
Is this a tuning operation?
124
Compute the AFT Offset by subtracting the current station's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
126
If system has a City Driving/Country Driving switch and/or a Sensitivity switch, read the switch positions to determine the minimum Quality Level and Signal Strength Threshold
166
Tune to next valid station on Tuning/Display list; Turn on audio
State 3
92'
Is channel bad: Is the SS avg < Threshold? Or, is the Noise avg > .2v (from .6v or higher applied signal)? Or, is AFT Offset < -.5v (from -1.5v or lower applied signal) or > +.5v (from +1.5v or higher applied signal)?
93
Skip, go to next channel
160
Record this station on the tuning/display list along with its SS, Noise level, and Quality factor
128
Does channel exhibit virtually no noise (Noise avg < .03v from < .1v applied signal)? If so, Set QF=Best
130
Take 33 samples each of Signal Strength, Noise, and AFT voltage during the next 16ms, one sample of each at each half millisecond interval starting at 4.5ms; Compute the avgs of each, and the min/max ranges of SS and Noise
132
Compute the AFT Offset by subtracting the current station's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
134
Is SS avg > Threshold and Noise avg < .5v and AFT Offset <73mv?
136
Compute Quality factor for this channel
138
Is Quality factor equal to or better than the minimum Quality Level defined by the switch positions?
Y
N

Fig. 8

Fig. 9


State 3
168
Delay an arbitrary period, then take 32 samples each of Signal Strength, Noise, and AFT voltage during the next 16ms, one sample of each at each half millisecond interval; Compute the avgs of each, and the min/max ranges of SS and Noise
170
Compute the AFT Offset by subtracting the current stations's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
172
Compute Quality Factor for this channel
173
If SS range > 0.2v, display Drifting notification
174
Update the displayed Signal Strength and Noise indicators (and Quality, if used) for the currently tuned-in station
176
If station is broadcasting digital data, present relevant received data on the display

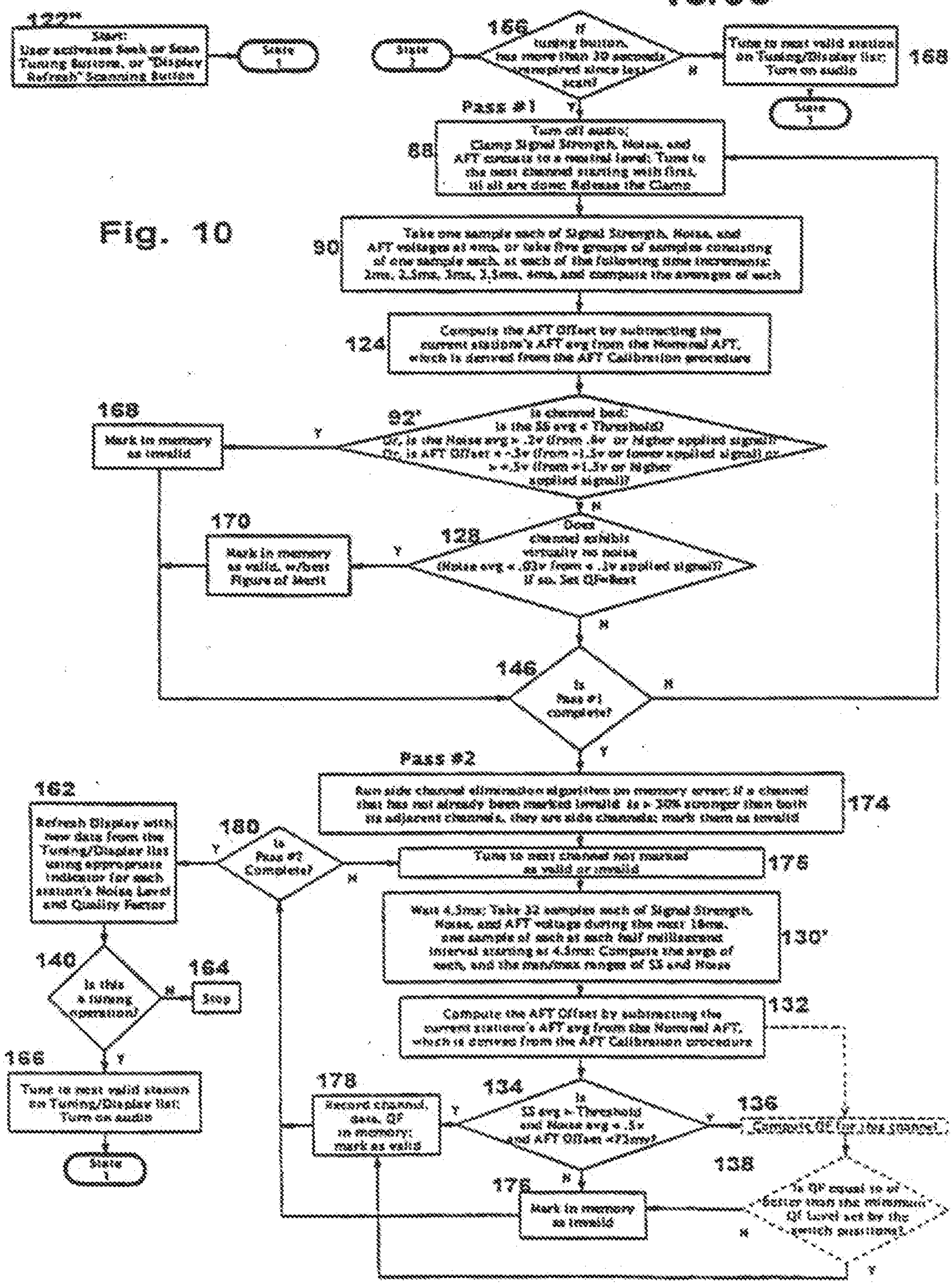

Pass #1
Pass #2
88
90
124
92'
166
168
170
128
146
174
175
130'
132
134
136
138
176
178
180
162
140
164

Fig. 10

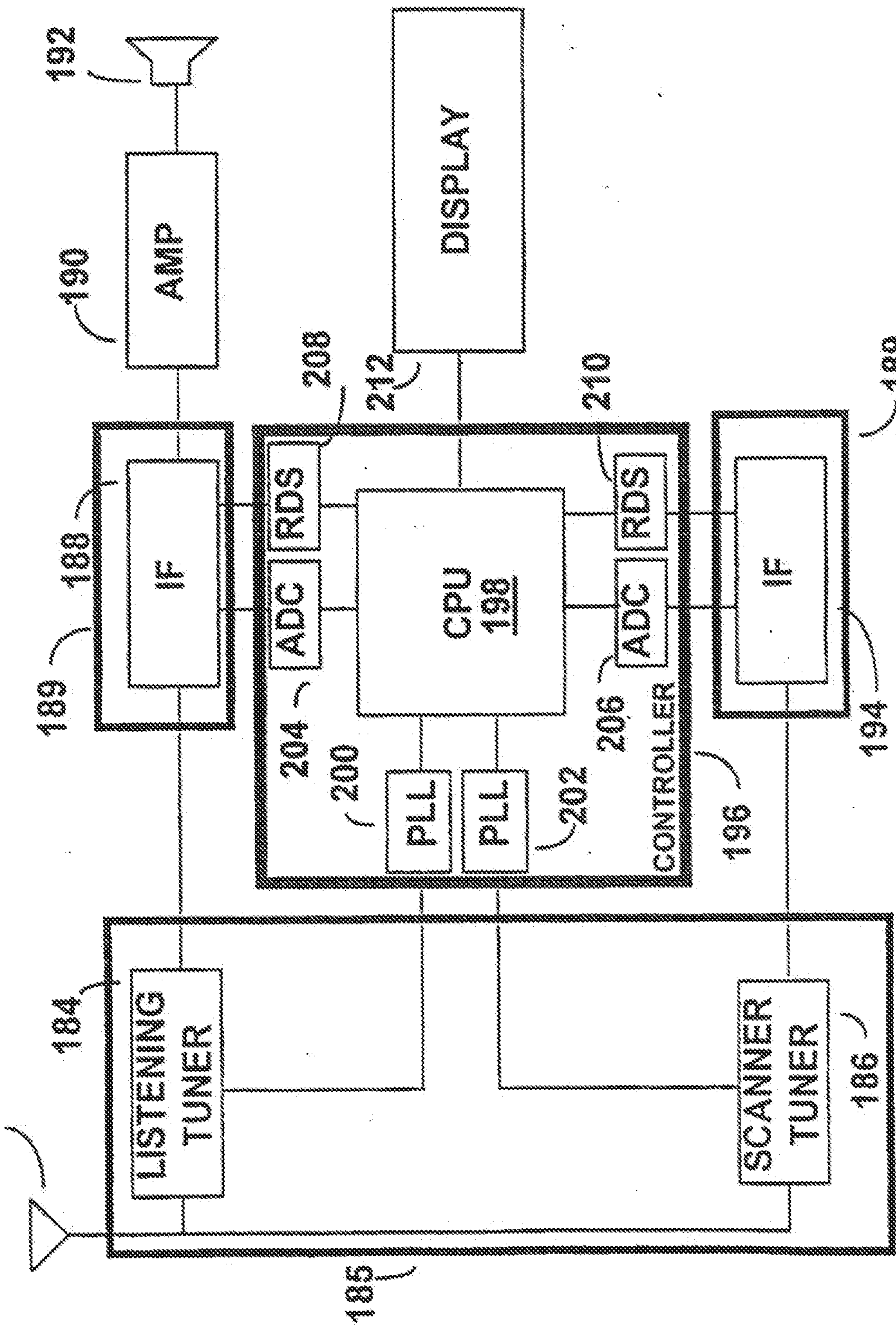

192
190
AMP
DISPLAY
208
212
210
189
188
IF
RDS
ADC
CPU
198
189
204
200
PLL
202
206
CONTROLLER
196
194
184
LISTENING
TUNER
SCANNER
TUNER
186
182
185

Fig. 11

Fig. 12

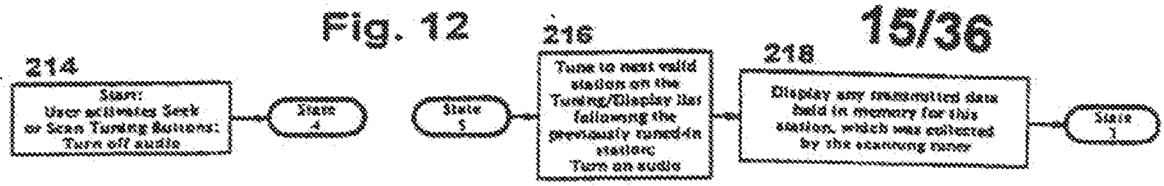

214
Start:
User activates Seek
or Scan Tuning Buttons:
Turn off audio
State
4
State
5
216
Tune to next valid
station on the
Tuning/Display list
following the
previously tuned-in
station;
Turn on audio
218
Display any transmitted data
held in memory for this
station, which was collected
by the scanning tuner
State
1

Fig. 13

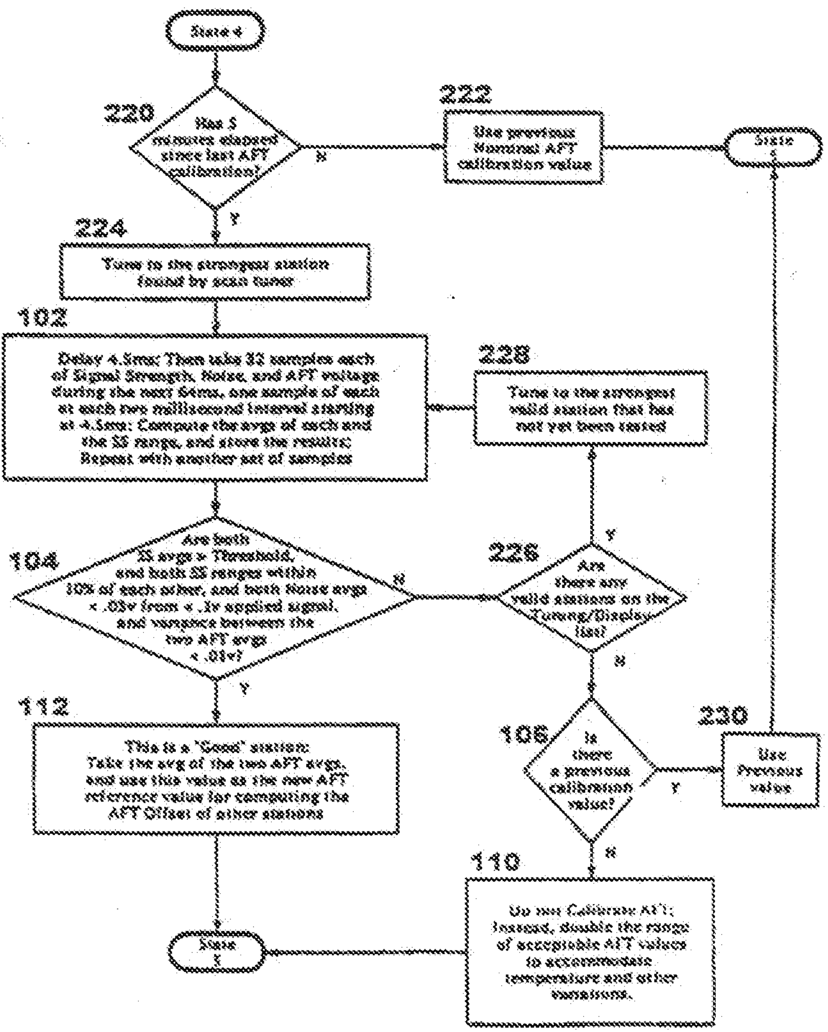
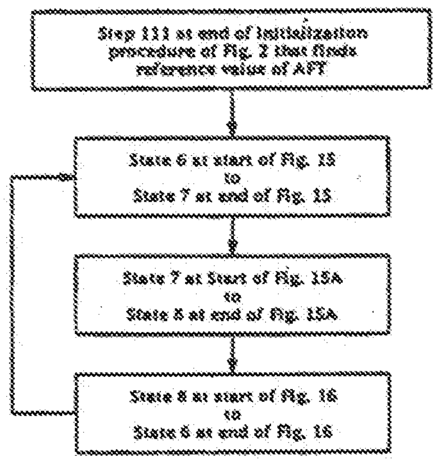

State 4
220
Has 5
minutes elapsed
since last AFT
calibration?
N
Y
222
Use previous
Nominal AFT
calibration value
State
1
224
Tune to the strongest station
found by scan tuner
102
Delay 4.5ms; Then take 32 samples each
of Signal Strength, Noise, and AFT voltage
during the next 64ms, one sample of each
at each two millisecond interval starting
at 4.5ms; Compute the avgs of each and
the SS range, and store the results;
Repeat with another set of samples
228
Tune to the strongest
valid station that has
not yet been tested
104
Are both
SS avgs > Threshold,
and both SS ranges within
10% of each other, and both Noise avgs
< .03v from < .1v applied signal,
and variance between the
two AFT avgs
< .01v?
N
Y
226
Are
there any
valid stations on the
Tuning/Display
list?
Y
N
112
This is a "Good" station:
Take the avg of the two AFT avgs,
and use this value as the new AFT
reference value for computing the
AFT Offset of other stations
106
Is
there
a previous
calibration
value?
Y
N
230
Use
Previous
value
110
Do not Calibrate AFT;
Instead, double the range
of acceptable AFT values
to accommodate
temperature and other
variations.
State
1

Fig. 14


Step 111 at end of initialization procedure of Fig. 2 that finds reference value of AFT
State 6 at start of Fig. 15 to State 7 at end of Fig. 15
State 7 at Start of Fig. 15A to State 8 at end of Fig. 15A
State 8 at start of Fig. 16 to State 6 at end of Fig. 16

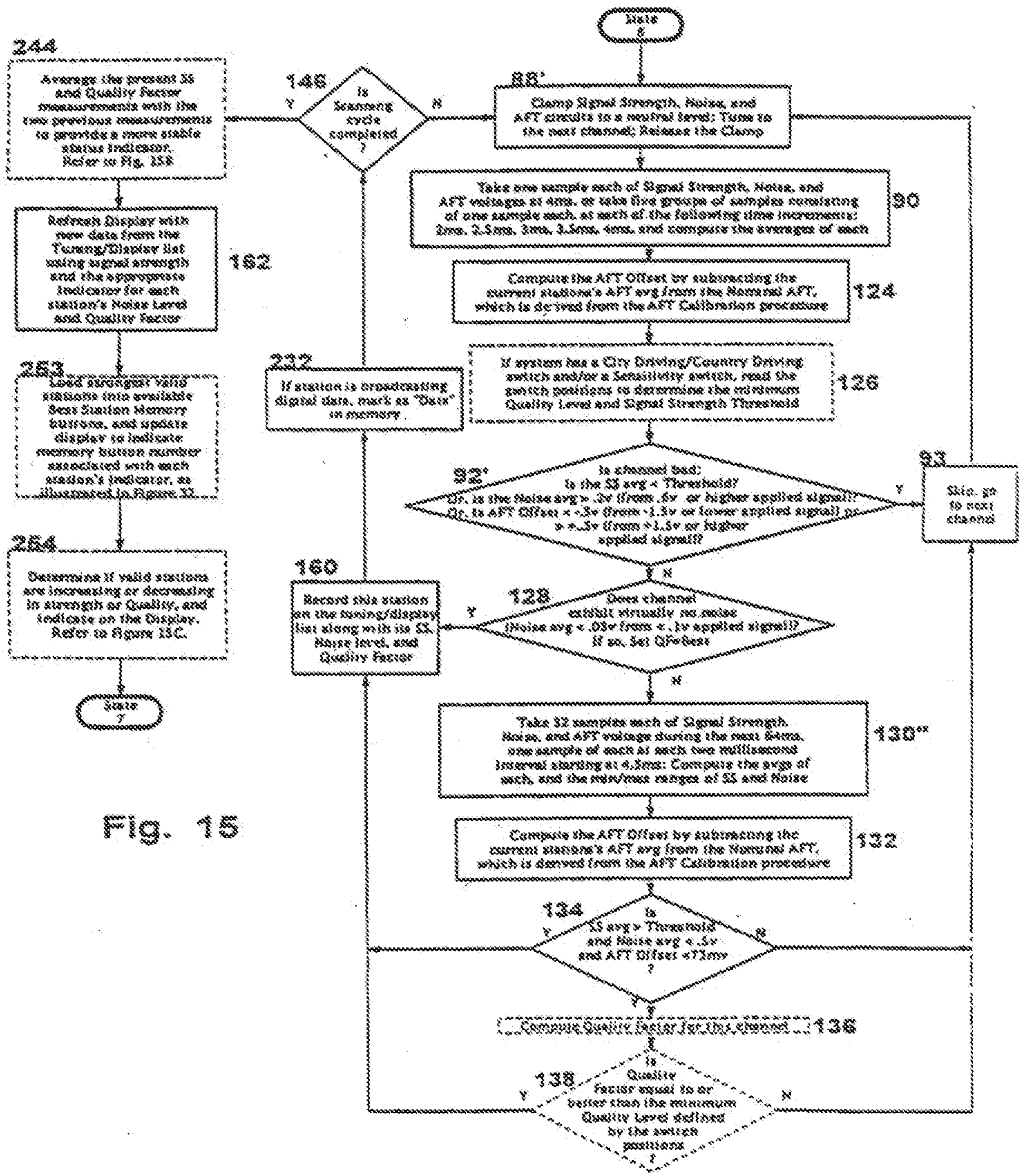
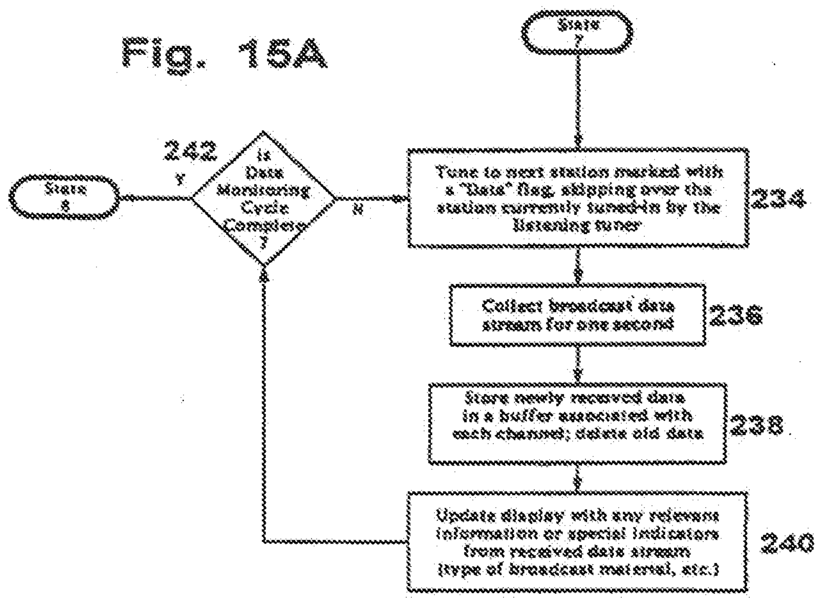

State 6
244
Average the present SS and Quality Factor measurements with the two previous measurements to provide a more stable status indicator. Refer to Fig. 15B
146
Is Scanning cycle completed ?
88'
Clamp Signal Strength, Noise, and AFT circuits to a neutral level; Tune to the next channel; Release the Clamp
Take one sample each of Signal Strength, Noise, and AFT voltages at 4ms. or take five groups of samples consisting of one sample each, at each of the following time increments: 2ms, 2.5ms, 3ms, 3.5ms, 4ms, and compute the averages of each
90
Refresh Display with new data from the Tuning/Display list using signal strength and the appropriate indicator for each station's Noise Level and Quality Factor
162
Compute the AFT Offset by subtracting the current station's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
124
253
Load strongest valid stations into available Best Station Memory buttons, and update display to indicate memory button number associated with each station's indicator, as illustrated in Figure 32.
232
If station is broadcasting digital data, mark as "Data" in memory
If system has a City Driving/Country Driving switch and/or a Sensitivity switch, read the switch positions to determine the minimum Quality Level and Signal Strength Threshold
126
92'
Is channel bad; Is the SS avg < Threshold? Or, is the Noise avg > .2v (from .6v or higher applied signal)? Or, is AFT Offset < -.3v (from -1.3v or lower applied signal) or > +.3v (from +1.3v or higher applied signal)?
93
Skip, go to next channel
254
Determine if valid stations are increasing or decreasing in strength or Quality, and indicate on the Display. Refer to figure 15C.
160
Record this station on the tuning/display list along with its SS, Noise level, and Quality Factor
128
Does channel exhibit virtually no noise (Noise avg < .03v from < .1v applied signal)? If so, Set QF=Best
State 7
Take 32 samples each of Signal Strength, Noise, and AFT voltage during the next 64ms, one sample of each at each two millisecond interval starting at 4.5ms; Compute the avgs of each, and the min/max ranges of SS and Noise
130''
Compute the AFT Offset by subtracting the current station's AFT avg from the Nominal AFT, which is derived from the AFT Calibration procedure
132
134
Is SS avg > Threshold and Noise avg < .5v and AFT Offset <75mv ?
Compute Quality Factor for this channel
136
138
Is Quality Factor equal to or better than the minimum Quality Level defined by the switch positions ?
Y
N

Fig. 15

Fig. 15A


State 7
242
Is Data Monitoring Cycle Complete ?
Y
N
State 8
Tune to next station marked with a "Data" flag, skipping over the station currently tuned-in by the listening tuner
234
Collect broadcast data stream for one second
236
Store newly received data in a buffer associated with each channel; delete old data
238
Update display with any relevant information or special indicators from received data stream (type of broadcast material, etc.)
240

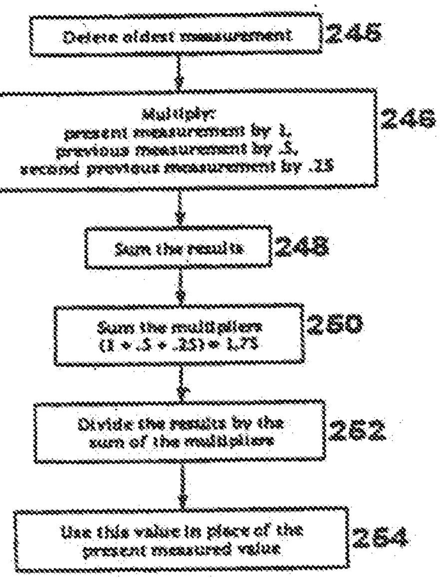


Fig. 15B

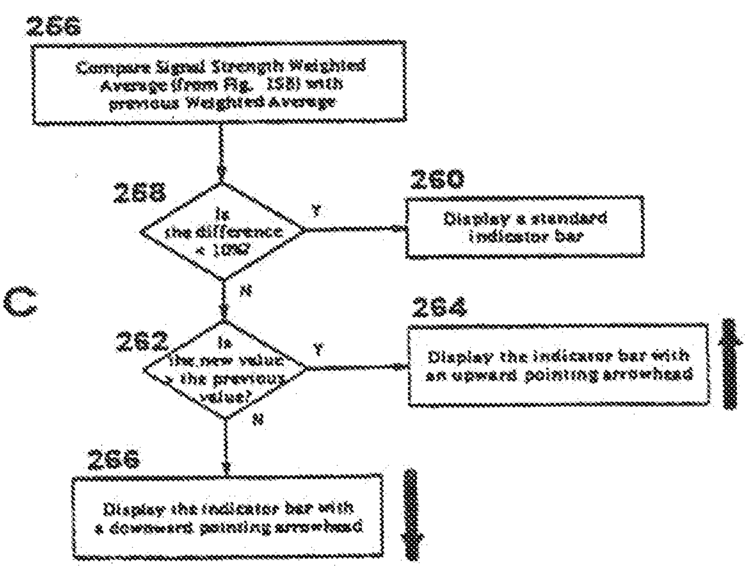


Fig. 15C

Fig. 16

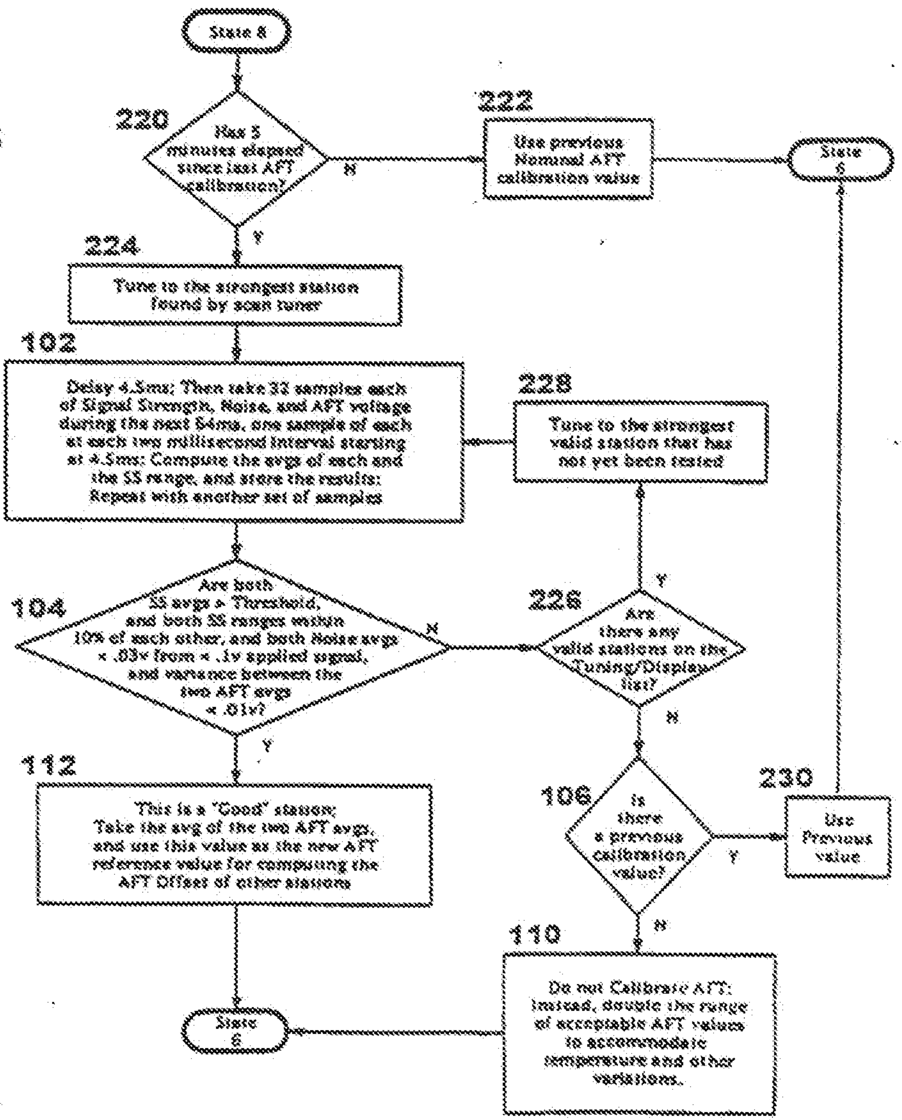
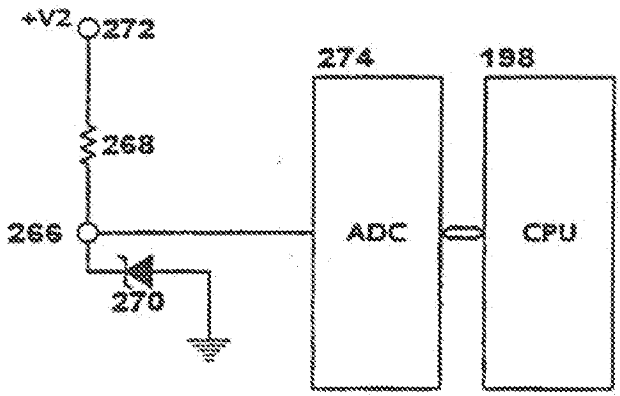

State 8
220
Has 5 minutes elapsed since last AFT calibration?
N
222
Use previous Nominal AFT calibration value
State 6
Y
224
Tune to the strongest station found by scan tuner
102
Delay 4.5ms; Then take 32 samples each of Signal Strength, Noise, and AFT voltage during the next 64ms, one sample of each at each two millisecond interval starting at 4.5ms; Compute the avgs of each and the SS range, and store the results; Repeat with another set of samples
228
Tune to the strongest valid station that has not yet been tested
104
Are both SS avgs > Threshold, and both SS ranges within 10% of each other, and both Noise avgs < .03v from < .1v applied signal, and variance between the two AFT avgs < .01v?
N
226
Are there any valid stations on the Tuning/Display list?
Y
N
Y
112
This is a "Good" station; Take the avg of the two AFT avgs, and use this value as the new AFT reference value for computing the AFT Offset of other stations
106
Is there a previous calibration value?
Y
230
Use Previous value
N
110
Do not Calibrate AFT; instead, double the range of acceptable AFT values to accommodate temperature and other variations.
State 6

Fig. 17



ILLUSTRATIVE TABLE OF TEMP SENSOR VOLTAGE TO AFT DEVIATION VOLTAGE, SIGNAL STRENGTH THRESHOLD and NOISE REJECTION LIMIT

T. Sensor (V)	Temp	AFT	SS	NOISE
2.80V	5C	-.216V	-12%	-12%
2.85V	10C	-.162V	-9%	-9%
2.9V	15C	-.108V	-6%	-6%
2.95V	20C	-.054V	-3%	-3%
3.0V	25C	0V	0%	0%
3.05V	30C	+.054V	+3%	+3%
3.10V	35C	+.108V	+6%	+6%
3.15V	40C	+.162V	+9%	+9%
3.2V	45C	+.216V	+12%	+12%

Fig. 18

Fig. 19

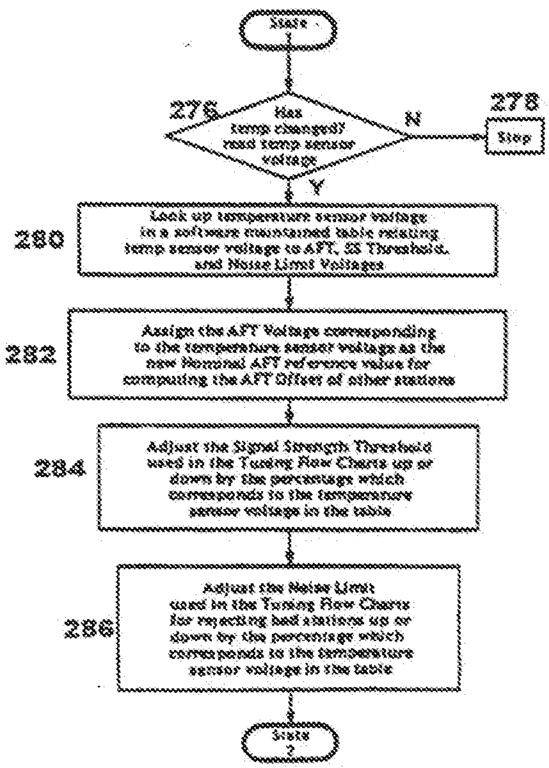


Fig. 19A

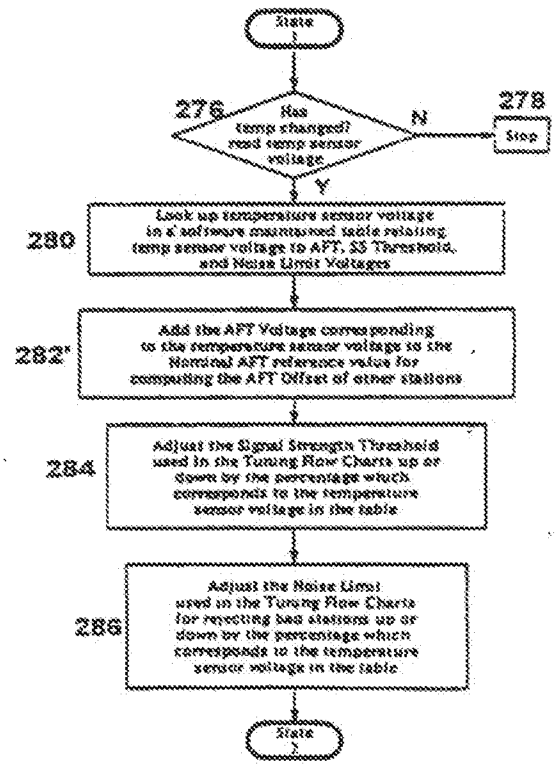


Fig. 20

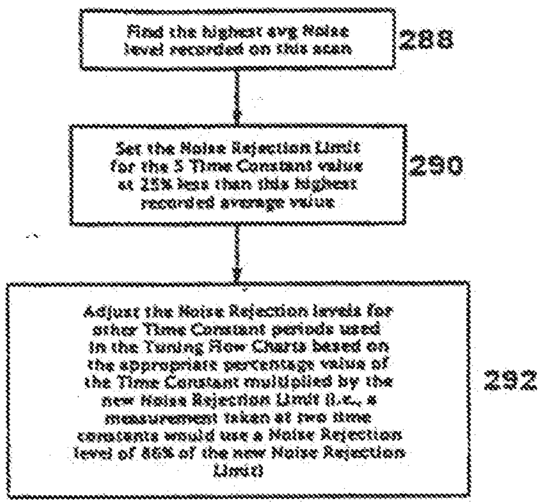
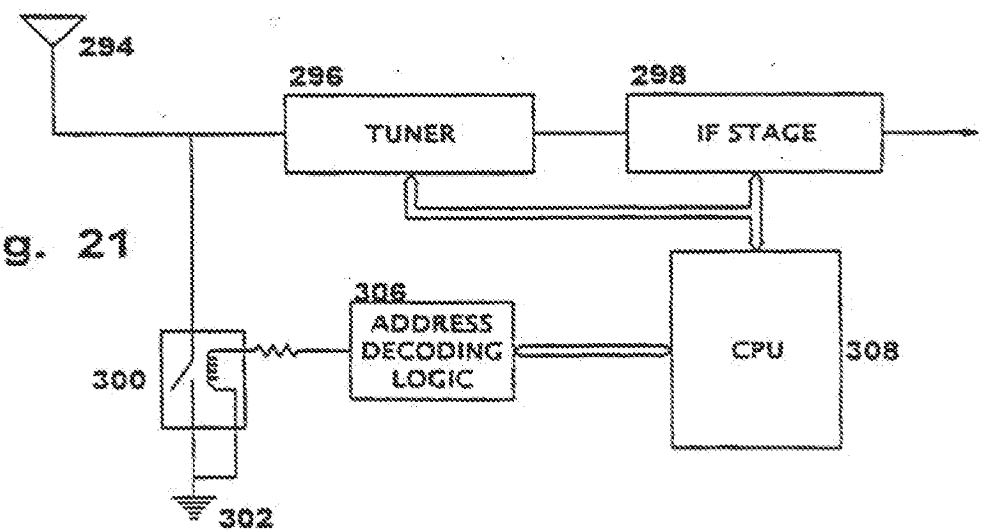

Find the highest avg Noise level recorded on this scan
288
Set the Noise Rejection Limit for the 5 Time Constant value at 25% less than this highest recorded average value
290
Adjust the Noise Rejection levels for other Time Constant periods used in the Tuning Flow Charts based on the appropriate percentage value of the Time Constant multiplied by the new Noise Rejection Limit (i.e., a measurement taken at two time constants would use a Noise Rejection level of 86% of the new Noise Rejection Limit)
292

Fig. 21


294
296
TUNER
298
IF STAGE
306
ADDRESS DECODING LOGIC
CPU
308
300
302

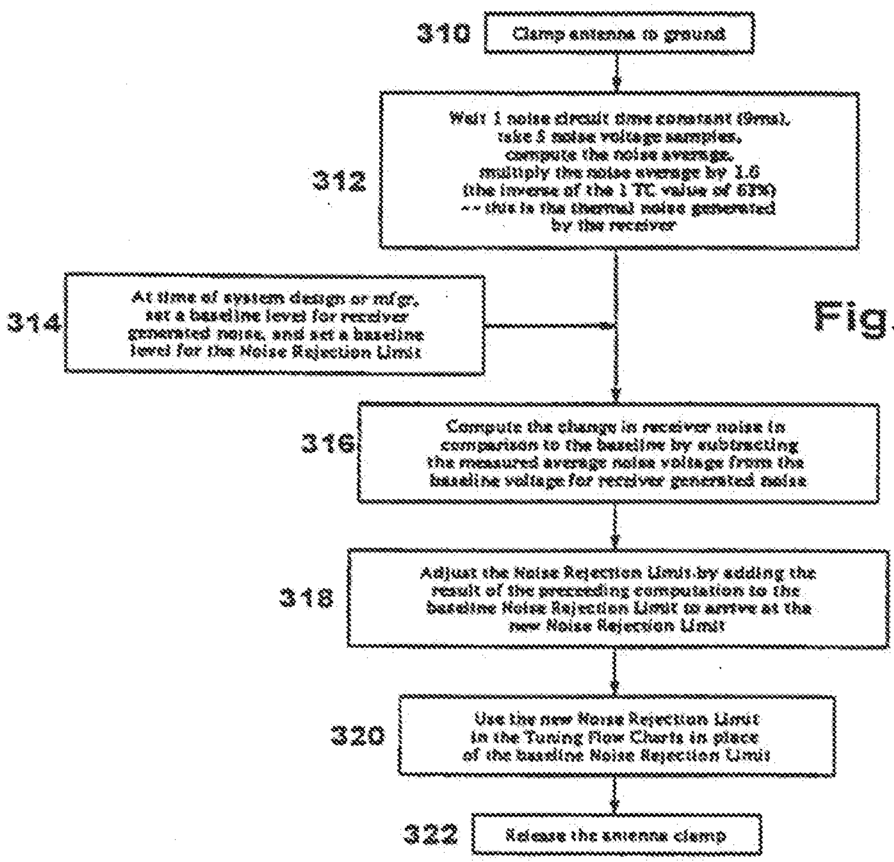

310
Clamp antenna to ground
312
Wait 1 noise circuit time constant (9ms),
take 5 noise voltage samples,
compute the noise average,
multiply the noise average by 1.6
(the inverse of the 1 TC value of 63%)
~~ this is the thermal noise generated
by the receiver
314
At time of system design or mfgr,
set a baseline level for receiver
generated noise, and set a baseline
level for the Noise Rejection Limit
316
Compute the change in receiver noise in
comparison to the baseline by subtracting
the measured average noise voltage from the
baseline voltage for receiver generated noise
318
Adjust the Noise Rejection Limit by adding the
result of the preceding computation to the
baseline Noise Rejection Limit to arrive at the
new Noise Rejection Limit
320
Use the new Noise Rejection Limit
in the Tuning Flow Charts in place
of the baseline Noise Rejection Limit
322
Release the antenna clamp

Fig. 22

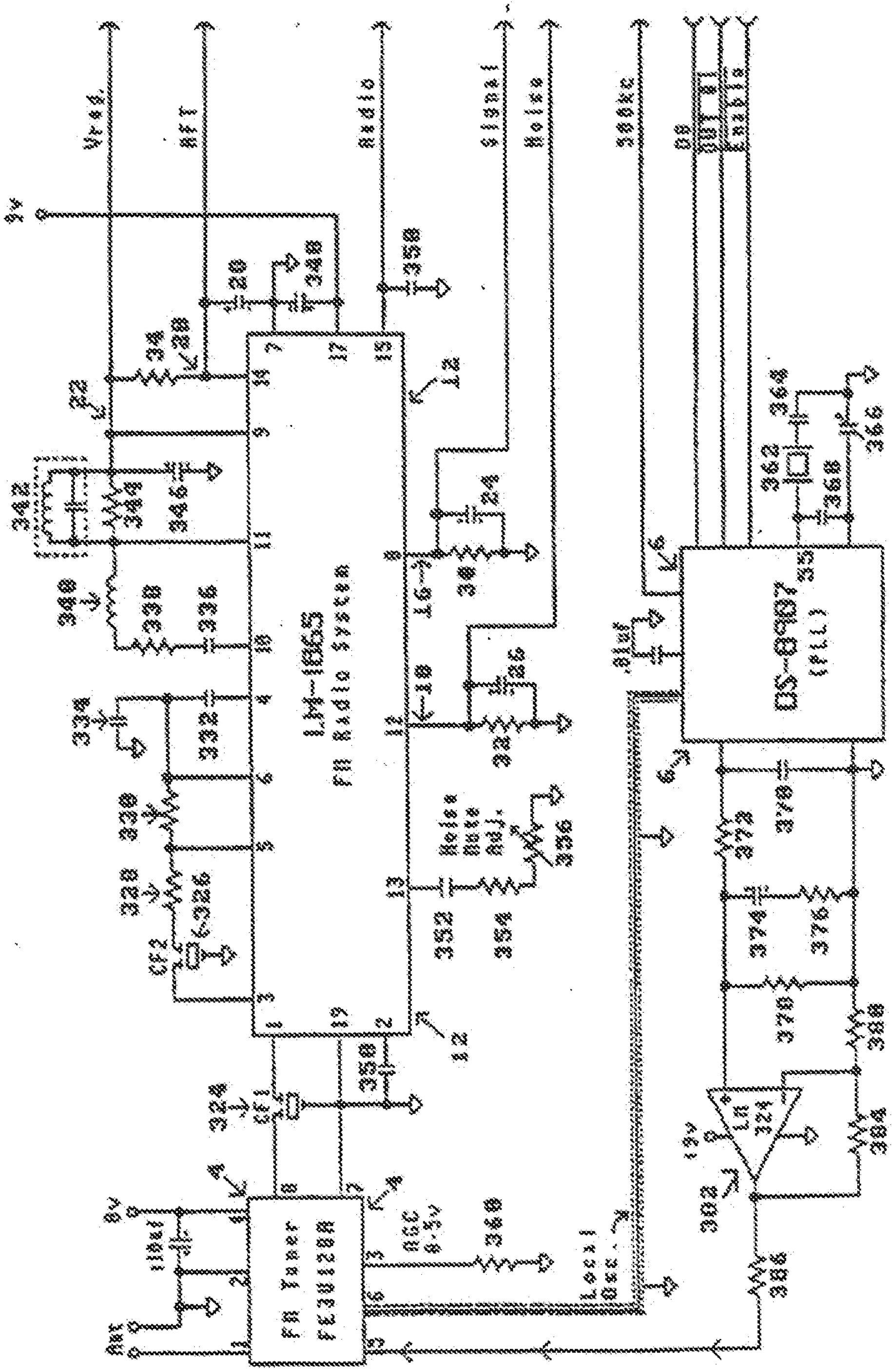

LM-1865
FM Radio System
DS-8907
(PLL)
FM Tuner
Vref.
Radio
Signal
Noise
Local Osc.
AGC

Fig. 23

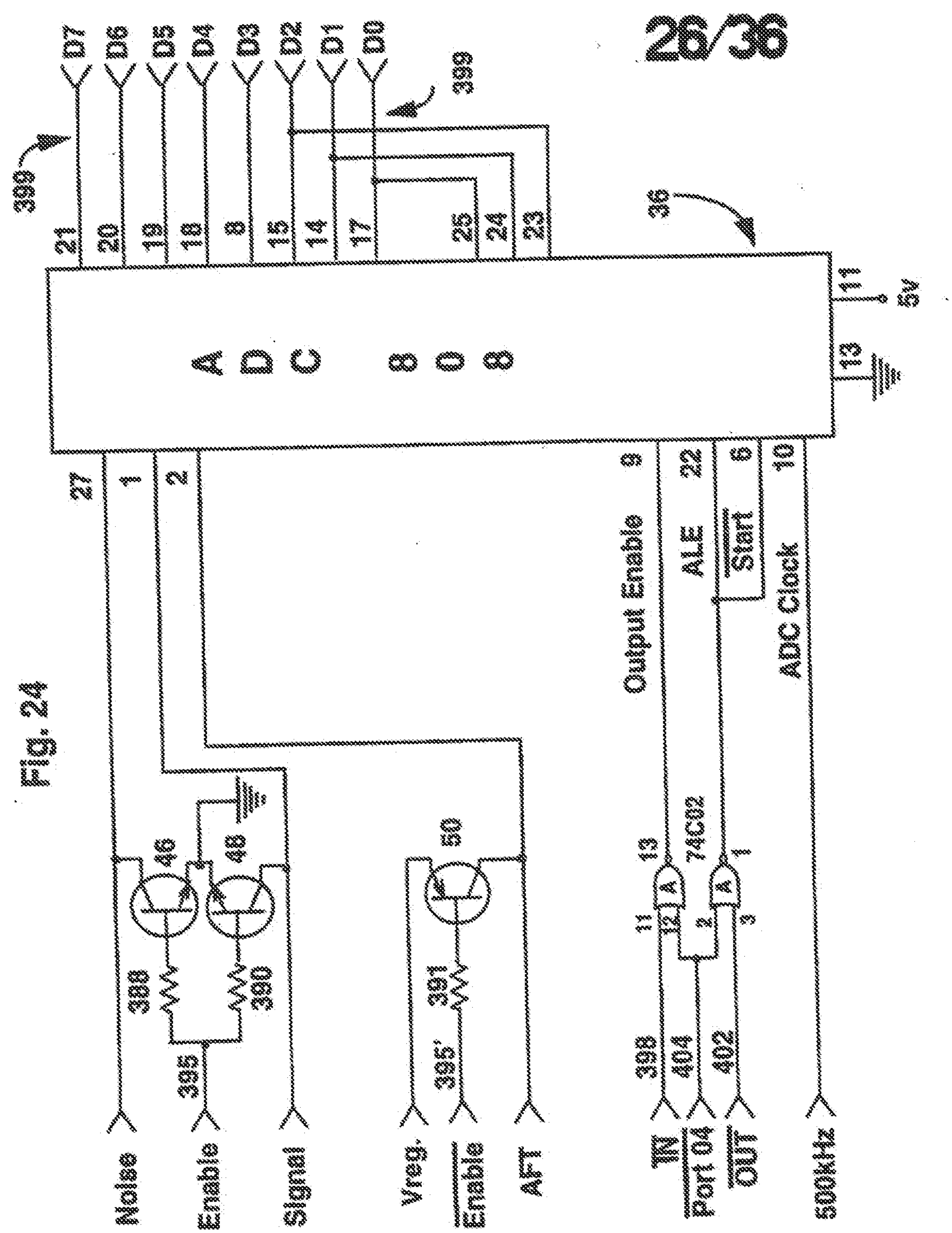
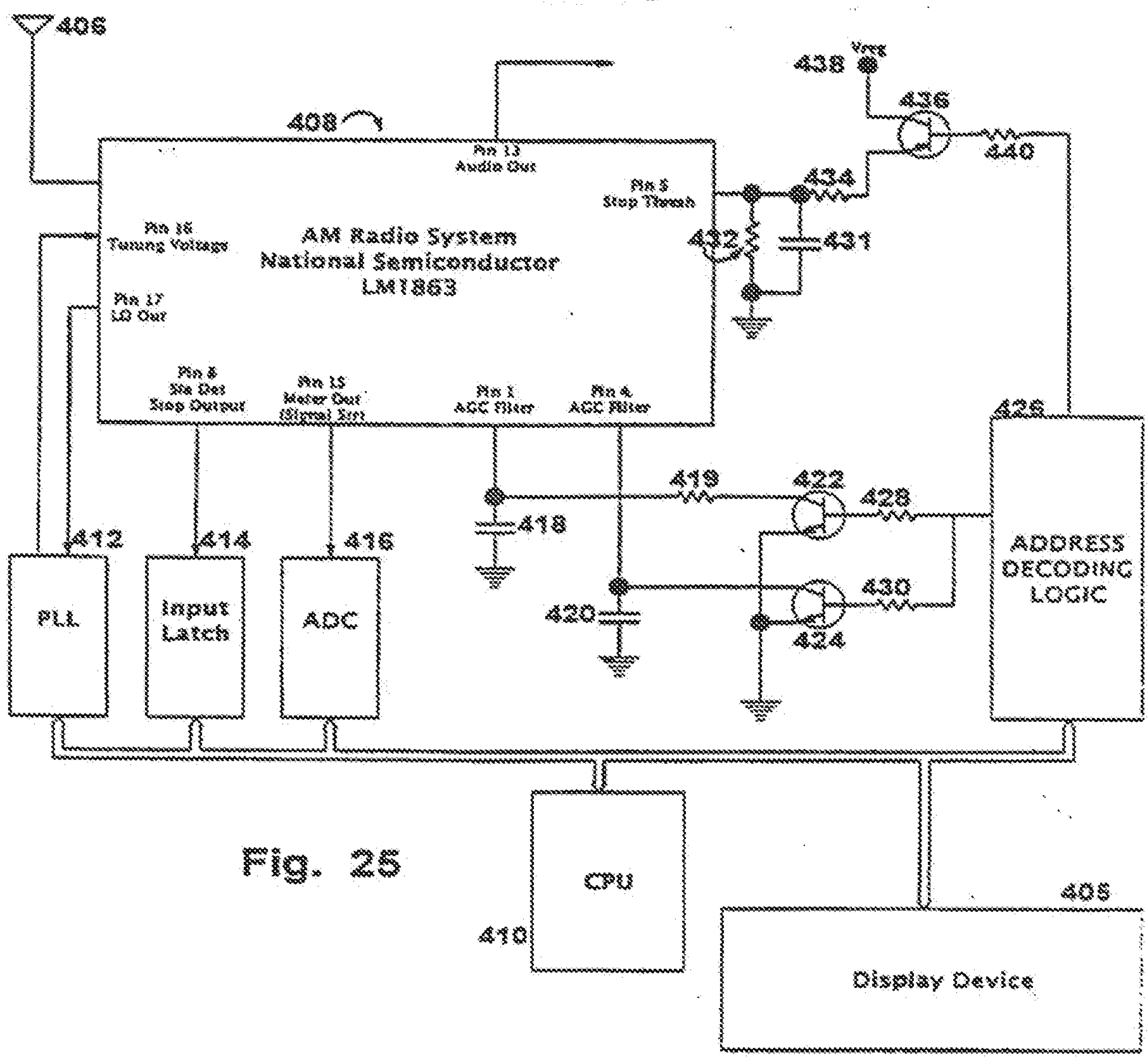
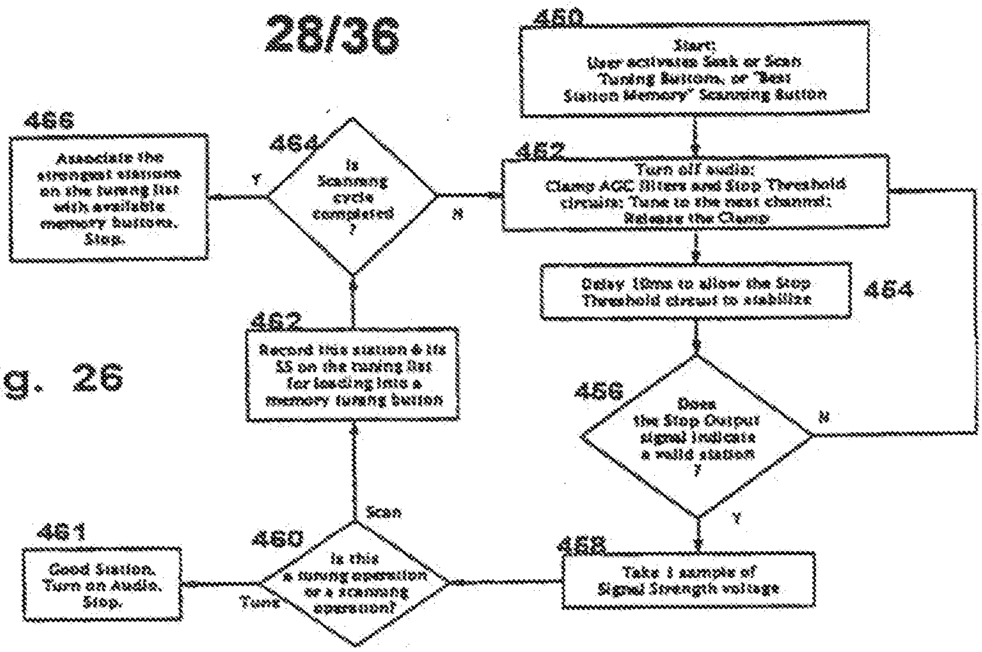

D7
D6
D5
D4
D3
D2
D1
D0
399
399
21
20
19
18
8
15
14
17
25
24
23
36
ADC 808
11
5v
13
27
1
2
9
22
6
10
Output Enable
ALE
Start
ADC Clock
46
48
50
388
390
391
395
395'
13
74C02
1
11
12
2
3
398
404
402
Noise
Enable
Signal
Vreg.
Enable
AFT
TIN
Port 04
OUT
500kHz

Fig. 24



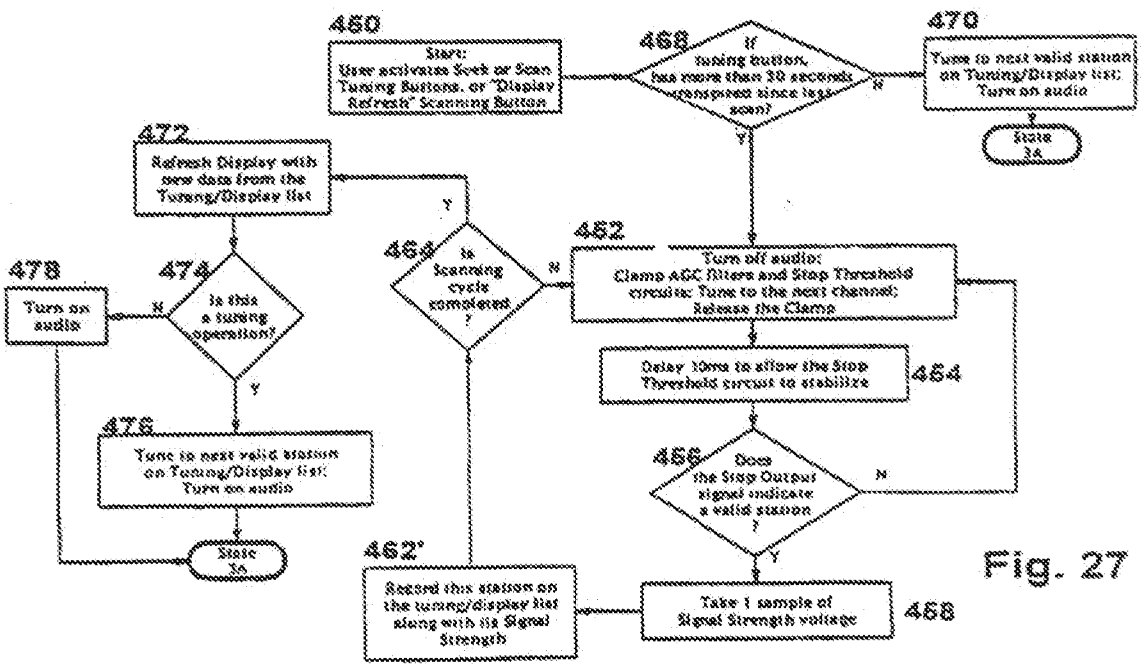
406
408
Pin 13 Audio Out
Pin 5 Stop Thresh
Pin 16 Tuning Voltage
AM Radio System
National Semiconductor
LM1863
Pin 17 LO Out
Pin 8 Sta Det Stop Output
Pin 15 Meter Out (Signal Str)
Pin 1 AGC Filter
Pin 4 AGC Filter
438
Vreg
436
434
440
432
431
426
419
422
428
412
414
416
418
420
430
424
PLL
Input Latch
ADC
ADDRESS DECODING LOGIC
CPU
410
405
Display Device

Fig. 25



450
Start: User activates Seek or Scan Tuning Buttons, or "Best Station Memory" Scanning Button
452
Turn off audio; Clamp AGC filters and Stop Threshold circuits; Tune to the next channel; Release the Clamp
454
Delay 10ms to allow the Stop Threshold circuit to stabilize
456
Does the Stop Output signal indicate a valid station ?
N
Y
458
Take 1 sample of Signal Strength voltage
460
Is this a tuning operation or a scanning operation?
Scan
Tune
461
Good Station. Turn on Audio. Stop.
462
Record this station & its SS on the tuning list for loading into a memory tuning button
464
Is Scanning cycle completed ?
Y
N
466
Associate the strongest stations on the tuning list with available memory buttons. Stop.

Fig. 26



450
Start: User activates Seek or Scan Tuning Buttons, or "Display Refresh" Scanning Button
468
If tuning button, has more than 30 seconds transpired since last scan?
N
Y
470
Tune to next valid station on Tuning/Display list; Turn on audio
State 3A
452
Turn off audio; Clamp AGC filters and Stop Threshold circuits; Tune to the next channel; Release the Clamp
454
Delay 10ms to allow the Stop Threshold circuit to stabilize
456
Does the Stop Output signal indicate a valid station ?
N
Y
458
Take 1 sample of Signal Strength voltage
462'
Record this station on the tuning/display list along with its Signal Strength
464
Is Scanning cycle completed ?
Y
N
472
Refresh Display with new data from the Tuning/Display list
474
Is this a tuning operation?
N
Y
478
Turn on audio
476
Tune to next valid station on Tuning/Display list; Turn on audio
State 3A

Fig. 27

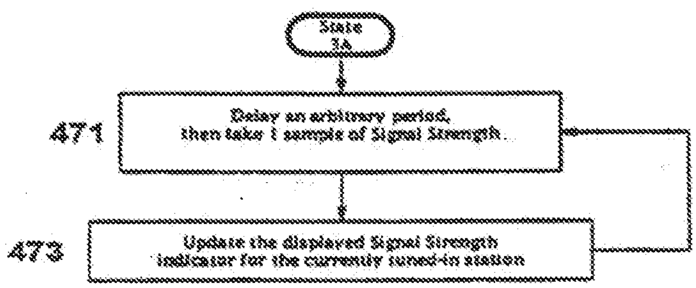

State 3A
471
Delay an arbitrary period, then take 1 sample of Signal Strength.
473
Update the displayed Signal Strength indicator for the currently tuned-in station

Fig. 27A

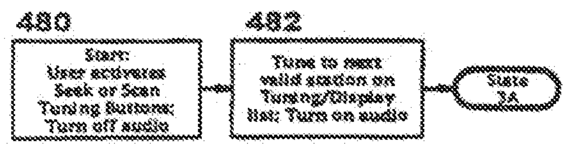

480
Start:
User activates
Seek or Scan
Tuning Buttons;
Turn off audio
482
Tune to next
valid station on
Tuning/Display
list; Turn on audio
State
3A

Fig. 28

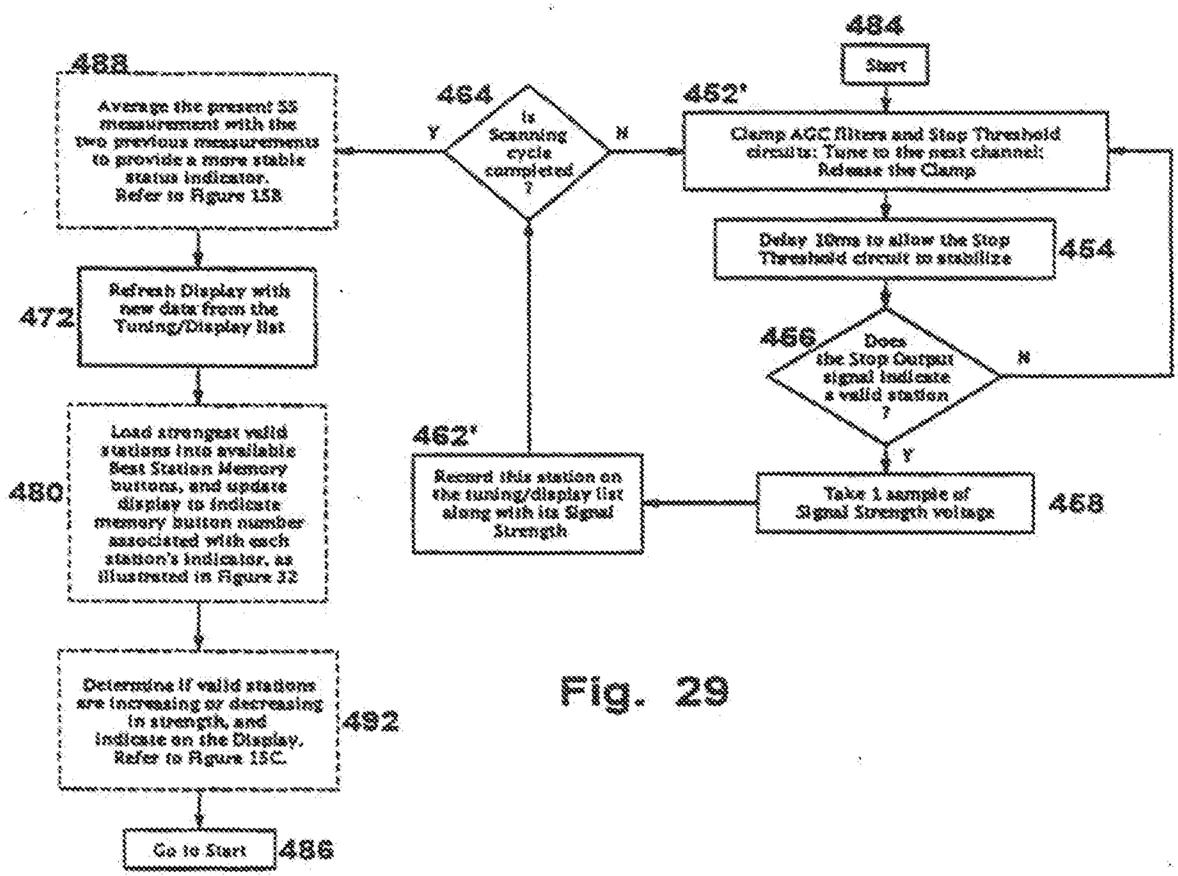

484
Start
452'
Clamp AGC filters and Stop Threshold
circuits; Tune to the next channel;
Release the Clamp
Delay 10ms to allow the Stop
Threshold circuit to stabilize
454
466
Does
the Stop Output
signal indicate
a valid station
?
N
Y
Take 1 sample of
Signal Strength voltage
468
462'
Record this station on
the tuning/display list
along with its Signal
Strength
464
Is
Scanning
cycle
completed
?
Y
N
488
Average the present SS
measurement with the
two previous measurements
to provide a more stable
status indicator.
Refer to Figure 15B
472
Refresh Display with
new data from the
Tuning/Display list
480
Load strongest valid
stations into available
Best Station Memory
buttons, and update
display to indicate
memory button number
associated with each
station's indicator, as
illustrated in Figure 32
Determine if valid stations
are increasing or decreasing
in strength, and
indicate on the Display.
Refer to Figure 15C.
492
Go to Start
486

Fig. 29

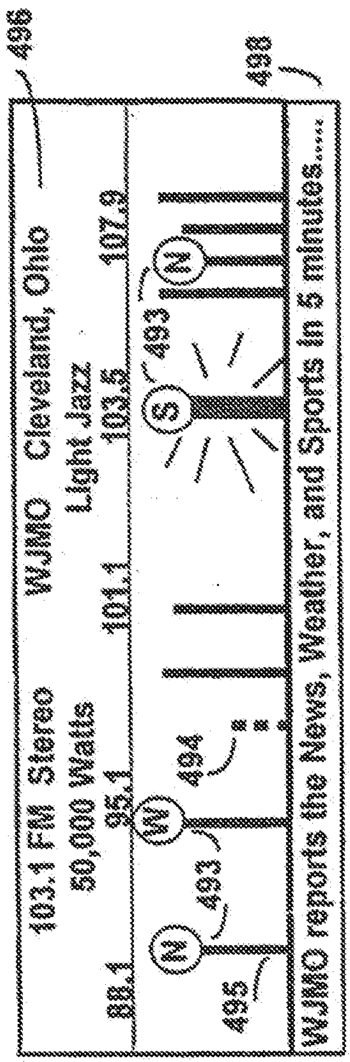


Fig. 30

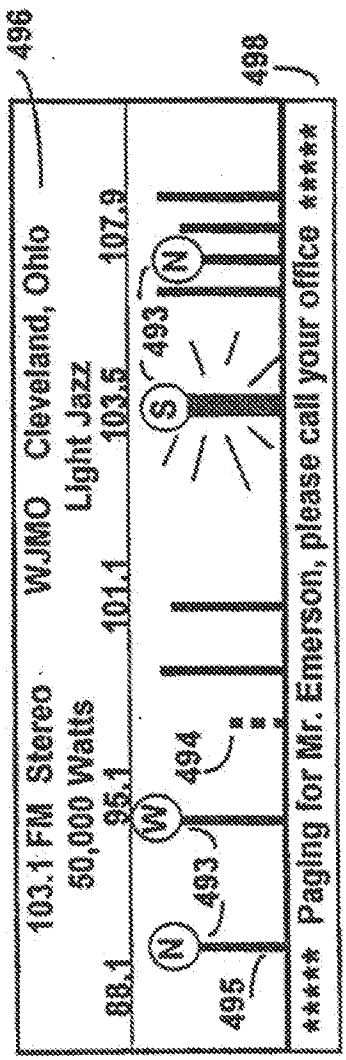


Fig. 30A

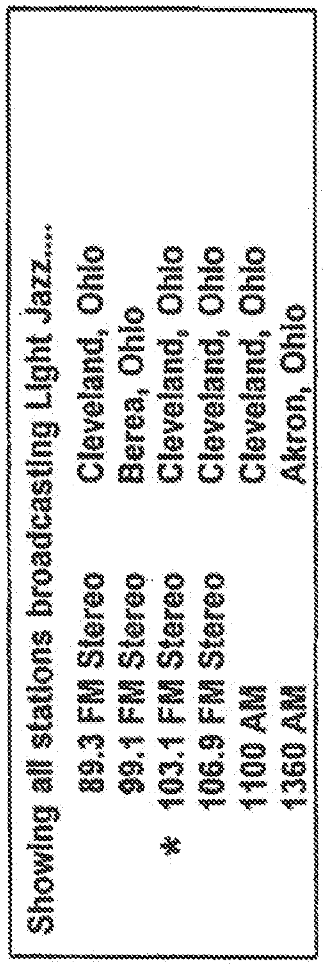


Fig. 30B

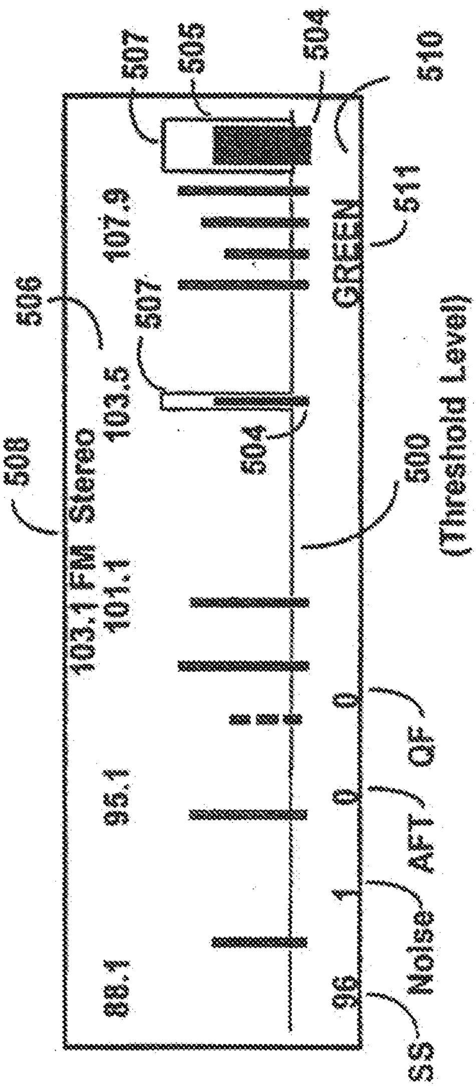


Fig. 31

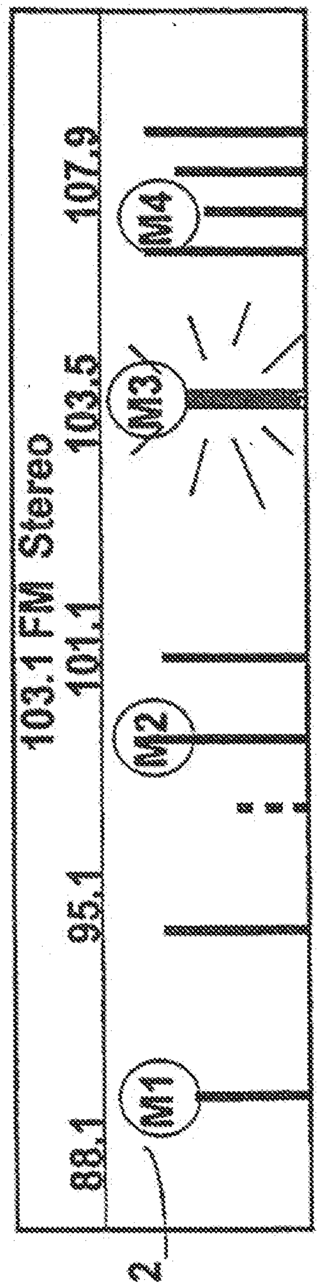


Fig. 32

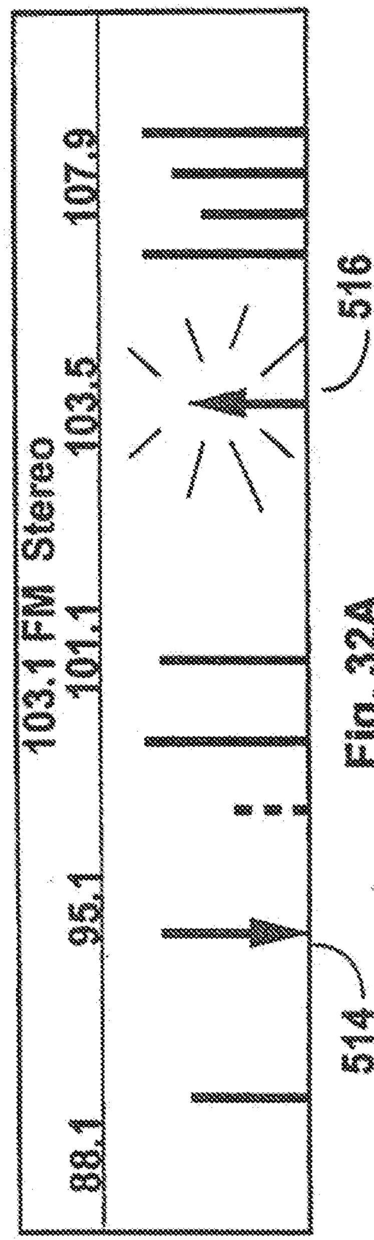


Fig. 32A

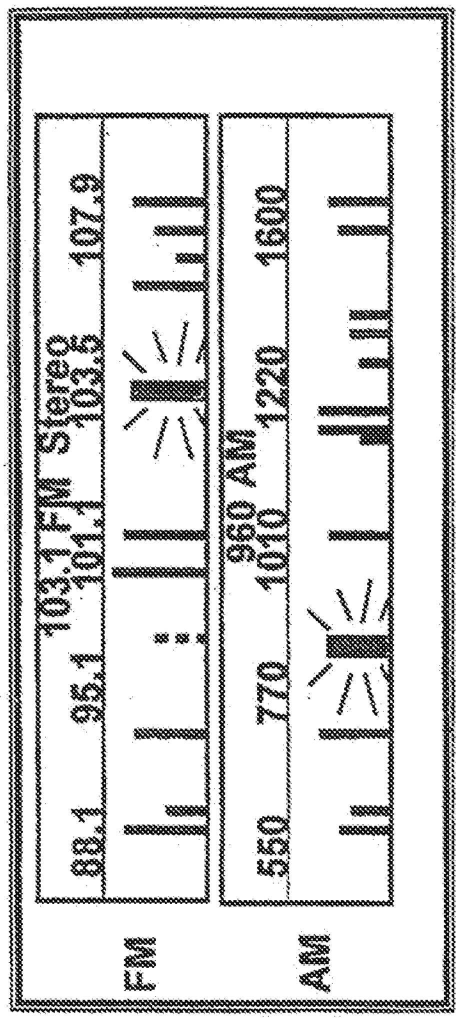


Fig. 33

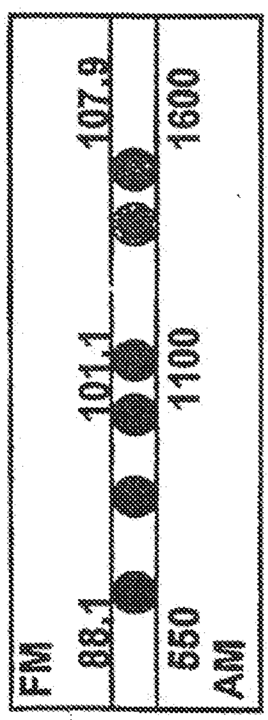


Fig. 34

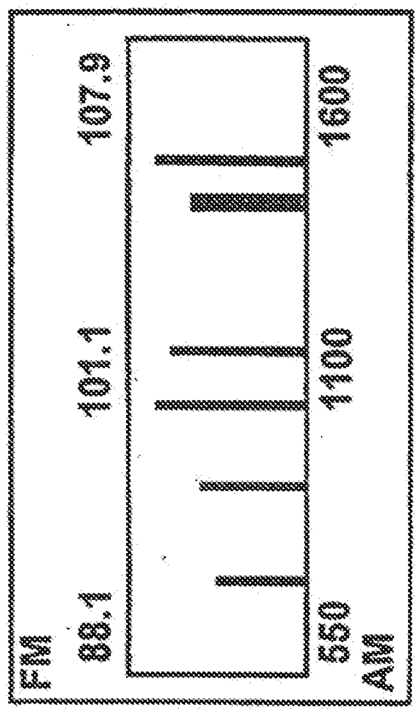


Fig. 35

MENU

* FM-SCAN
FM-SCAN + (Sig/Noise/AFT/QF)
Plot/Stats
Set SS Threshold

Fig. 36

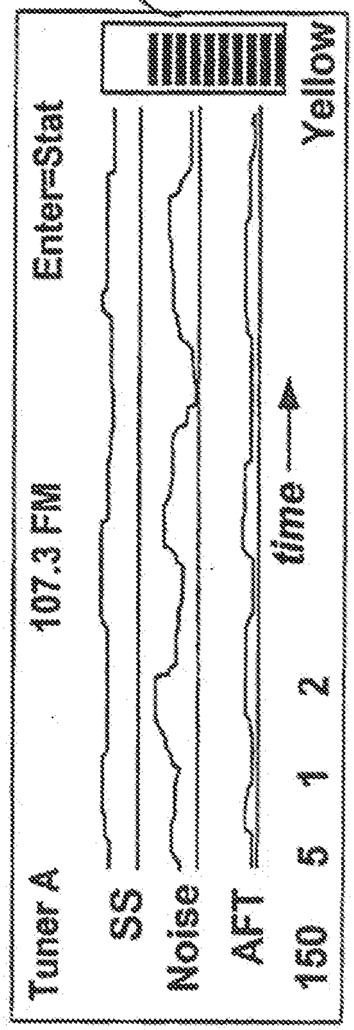


Fig. 37

Tuner A 107.3 FM Enter=Plot

Data	Tuner	Avg	Lo	Hi	Range
SS	A	150	148	151	3
Noise	A	5	4	5	1
AFT	A	1		QF=	2
SS	B	145	143	147	4
Noise	B	6	4	5	2
AFT	B	1		QF=	2

505

Yellow

Fig. 38

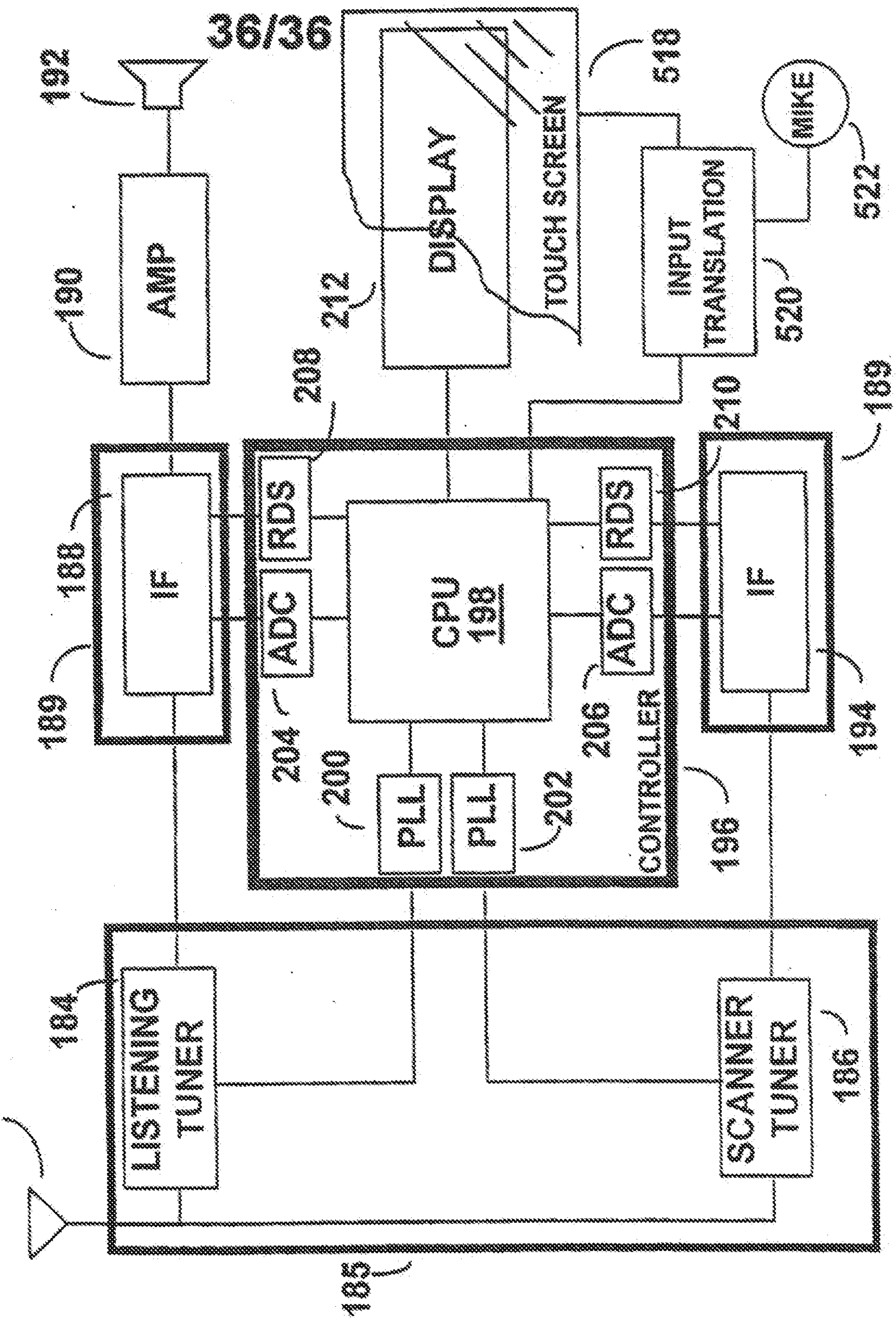

192
AMP
190
DISPLAY
TOUCH SCREEN
212
518
INPUT TRANSLATION
520
MIKE
522
208
240
189
188
IF
189
RDS
ADC
CPU 198
RDS
ADC
IF
194
204
206
200
PLL
PLL
202
CONTROLLER
196
184
LISTENING TUNER
SCANNER TUNER
186
182
185

Fig. 39

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/08987

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 17/02
US CL :Please See Extra Sheet.
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. : Please See Extra Sheet.

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

NONE

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

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 5,268,712 (HILPERT ET AL.) 07 DECEMBER 1993, SEE FIGURE 6.	1 --- 2,3,5,6,7,9,11,12-15,17,33,34,35-39, 69, 70, 71
Y	US, A, 4,598,422 (FELLMAN) 01 JULY 1986, SEE ENTIRE DOCUMENT.	35-39
Y	US, A, 5,280,642 (HIRATA ET AL.) 18 JANUARY 1994, SEE FIGURE 2 AND FIGURE 3A.	1-4, 8, 69-73
Y	US, A, 5,101,508 (OWAKI) 31 MAY 1992, SEE FIGURE 5.	16-18

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

* Special categories of cited documents:

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"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"&" document member of the same patent family

Date of the actual completion of the international search

17 MARCH 1995

Date of mailing of the international search report

06 APR 1995

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/08987

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	JP, A, 52-30302 (MIYATAKE) 09 APRIL 1975, SEE ABSTRACT	1 --- 2-7,9,14,17 ,34-39,69-71
Y	US, A, 4,88,815 (AHLEMEYER ET AL.) 19 DECEMBER 1989, SEE FIGURE 1	65-68
Y	US, A, 5,073,975 (ZARABADI ET AL.) 17 DECEMBER 1991, SEE ENTIRE DOCUMENT.	2, 3, 5, 6, 7,9,
Y	US, A, 5,081,707 (SCHORMAN ET AL.) 14 JANUARY 1992, SEE ENTIRE DOCUMENT14	12-17, 34
Y	US, A, 4,763,356 (DAY, JR. ET AL.) 09 AUGUST 1988, SEE FIGURE 2	11, 16,33
Y	US, A, 4,509,203 (YAMADA) 02 APRIL 1985, SEE ABSTRACT	2-7
Y	US, A, 5,313,651 (KURITA) 17 MAY 1994, SEE FIGURE 1 AND ABSTRACT	2-7
Y	US, A, 4,969,209 (SCHWOB) 06 NOVEMBER 1990, SEE FIGURES 2 AND 3	11,16,33

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/08987

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

I. CLAIMS 1-34, 69-73 AND 76-77, DRAWN TO A TUNER WITH DISPLAY.
II. CLAIMS 35-64, 74-75, 79-81 AND 82-83, DRAWN TO A TUNING SYSTEM.
III. CLAIMS 65-68 AND 82-83 DRAWN TO A TUNING SYSTEM WITH HIGHWAY/CITY SELECTION.
IV. CLAIMS 78 IS DIRECTED TO A DUAL TUNING SYSTEM, WHICH SHOWS DIFFERENT SPECIAL TECHNICAL FEATURES IN RELATION TO EACH GROUP IDENTIFIED.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☒ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1))(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/08987

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

455/154.1, 154.2, 155.1, 157.2, 158.4, 180.1, 182.3, 186.1, 186.2

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

455/154.1, 154.2, 155.1, 157.1, 157.2, 158.1, 158.4, 161.1, 161.2, 161.3, 164.1, 164.2, 178.1, 179.1, 180.1, 180.4, 182.3, 184,1 186.1, 186.2, 197.2; 343/173

Form PCT/ISA/210 (extra sheet)(July 1992)*

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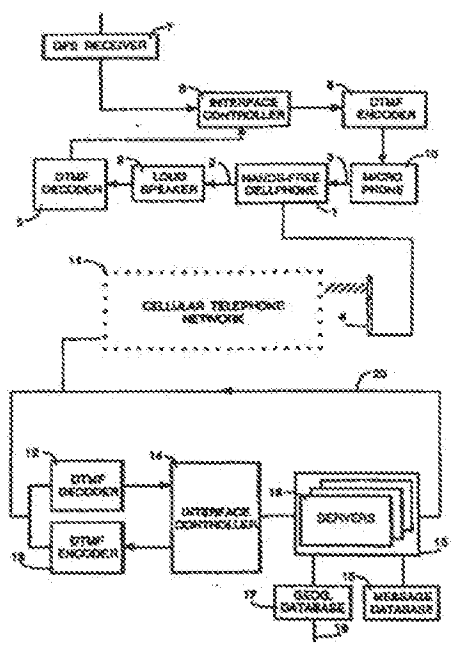
(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).

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: NAVIGATION INFORMATION SYSTEM

(57) Abstract

A navigation information system comprises a communications system having a fixed part (11 to 20) and at least one mobile part (1 to 10), the fixed part including a data storage and processing means (15) for identifying the location of a mobile unit, generating guidance information appropriate to that location and transmitting it to the mobile unit. By locating most of the complexity with the service provider, in particular the navigation computer (15) and geographical database (17), the system can be readily updated and the capital cost of the in-vehicle system, which in its simplest form may be a standard cellular telephone (1), can be minimised. The user makes a request for guidance information, and the system, having determined the user's present location, then transmits instructions to the user. The user's present location can be determined by means such as a Satellite Positioning System (7).



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NAVIGATION INFORMATION SYSTEM

This invention relates to navigation information systems. It is particularly suitable for use in providing users of road vehicles with route guidance, but other applications are possible and are discussed below.

Navigation of a vehicle through an unfamiliar complex road network is a difficult task. Large amounts of fuel and time are wasted as a result of drivers getting lost or using an inefficient route. Accidents can also be caused by drivers attempting to read maps or complex road signs and losing concentration on the road ahead. Moreover, a driver may choose an inefficient route as a result of using an out-of-date map.

An additional problem can occur even if a driver knows a route to his or her destination. That route may be congested or blocked as a result of accidents or maintenance work, so that an alternative route would be more efficient.

Several proposals have been made for navigation guidance systems. In some such proposals a vehicle-borne system has a navigation computer and a geographical information system which is essentially a digitised map stored on a CD-ROM. The system gives the driver information and guidance by screen and/or speech display. These systems would be very expensive. Each vehicle requires a navigation computer and geographical information system. The cost of the complex vehicle-borne equipment involved is estimated to be in the region of £1000. The system is complex to operate, and could only be safely operated by the driver whilst the vehicle is stationary. The geographical information system would require periodic updating, which requires new disks to be distributed to subscribers from time to time.

In some proposed systems of this type real-time data would be broadcast over a radio network to update fixed information held on the geographical information system. Even so, the geographical information system would only be accurate up to its last update. Moreover, a broadcast channel needs to be allocated for the updating service.

It has also been proposed that the guidance service provider collects statistical traffic flow data from which traffic congestion predictions can be made which are fed into the real-time data to be broadcast. The traffic flow data may be collected using roadside sensors, or they may be collected by monitoring the operation of the mobile user equipment. The latter approach can only collect data relating to users of the system, but has a lower capital cost.

In an alternative approach a system of short-range roadside beacons is used to transmit guidance information to passing vehicles equipped with simple transceivers. The beacons transmit information to suitably equipped passing vehicles to give turn instructions appropriate to their chosen destinations. For each beacon the territory to be covered is divided into as many zones as there are exits from the junction the beacon relates to. The zone in which the user's chosen destination falls is determined, and instructions are given appropriate to that zone. At any given beacon all vehicles whose destinations are in the same zone get the same instruction. The definitions of the zones are dependant on the location of the beacons, and each zone comprises the set of destinations which should be reached from the beacon by taking the direction associated with that zone.

Each beacon only gives instructions for reaching the next beacon along the route to the vehicle's destination. For two vehicles starting from the same point for different destinations for which the routes are initially coincident, the beacons along the coincident section of route will each give both users the same instructions, because for those beacons both users are travelling to the same zone. Only for the beacon at the point of divergence are the two users' destinations in different zones, and therefore different instructions are given.

The beacons' programming may be modified from time to time by control signals from a central control station, in a way analogous to remotely controlled adjustable signposts, but in its interactions with the user equipment the beacon is autonomous, identifying which of its zones the user's desired destination is in, and transmitting the appropriate "turn" information to get it to the next beacon on the way. The beacon has no knowledge of the rest of the route.

Each beacon has a detailed map of a small local area (the boundaries of which are, in fact, the adjacent beacons), and if the destination is in this area the beacon gives full information of the route to the destination. The system can therefore provide a user with directions to a destination defined more precisely than the beacon spacing. However, at the beginning of a journey, a user cannot use the system until he encounters a beacon.

This proposed system allows instant updating of the guidance instructions from a central control, and simpler in-vehicle equipment, but requires vast capital expenditure in roadside beacons.

A problem encountered with both the proposed systems described above is that it is difficult for them to provide alternative routings in response to congestion, either current or future, without the risk of creating worse problems on the alternative routes. Although predictions of regularly occurring congestion peaks are relatively simple to programme into the guidance information, and, at least in the beacon system, real-time updates on road congestion can also be fed to the programming of the beacons, the control system does not have any information of vehicle movements from which to predict future congestion. In any case, if the system is in use by a significant fraction of the vehicles, the system will tend to produce congestion on the diversionary routes.

According to a first aspect of the invention, there is provided a navigation information system for providing information to a mobile user dependant on the location of the mobile user, the system comprising a mobile communications system having a fixed part and one or more mobile part for communicating with the fixed part, the one or more mobile part including means for transmitting to the fixed part a request for guidance information and for receiving guidance information from the fixed part, and the fixed part including:

means for determining the location of a mobile part requesting guidance information,

means for generating guidance information according to the location of the mobile part, and

means for transmitting the guidance information so generated to the mobile part,

whereby information dependent on the location of the mobile unit can be transmitted to the mobile unit.

According to a second aspect of the invention, there is provided a navigation information system for providing information to one or more mobile user dependant on the location of the one or more mobile user, the system comprising:

means for determining the location of a mobile unit requesting guidance information,

means for generating guidance information according to the location of the mobile unit,

and a communications system for transmitting the guidance information so generated to the mobile unit,

whereby information dependant on the location of the mobile unit can be transmitted to the mobile unit.

According to a third aspect of the invention there is provided a mobile unit for a navigation information system, comprising means for receiving guidance instruction information over a communications link, and guidance instruction means controllable by the guidance instruction information received over the communications link, whereby guidance can be communicated to the user by means of the guidance instruction means.

According to a fourth aspect of the invention, there is provided a method of providing navigation information to mobile units of a mobile radio system dependant on the locations of the mobile units comprising the steps of storing navigation data in a fixed part, transmitting a request for navigation guidance from a mobile unit to the fixed part, determining the location of the mobile unit, generating guidance information on the basis of the stored data, location information and the request, and transmitting the guidance information from the fixed part to the mobile unit, whereby information relevant to the location of the mobile unit is transmitted to the mobile unit.

This invention has advantages over both the prior art systems discussed above. Considerable improvements can be made over the prior on-board navigation system proposals by putting the intelligence in the fixed part of the system. Firstly, there is no need to distribute maps or updates to subscribers because the data is held centrally. New roads can be added to the system at the instant they are opened. Total capital expenditure is minimised since all users share the same database. Moreover, the computing resources are used more efficiently, because an in-vehicle system spends most of its time inactive but a centralised system can be time-shared.

Moreover, in contrast to the prior art roadside beacon system, the invention can be implemented with little deployment of equipment in the field, thereby offering considerable economies in capital cost and maintenance, and allowing rapid installation and modification of the system to meet changing requirements.

Preferably the system includes means for determining the location of the mobile part in relation to a geographical overlay comprising a plurality of overlay areas, and means for transmitting information associated with an overlay area which includes the location of the mobile part, whereby a mobile part within that overlay area receives information associated with that overlay area. This allows information associated with a particular overlay area to be transmitted to any mobile units in that overlay area. The system may also comprise means for determining when a mobile part enters a predetermined overlay area, and means for transmitting a message, to a user other than the said mobile part, in response to the said mobile part entering the predetermined overlay area. For example, one overlay area may cover part of a road approaching a junction, and the message may be the appropriate instruction to the driver, as he approaches the junction, as to which way he should turn. Each individual overlay area therefore gives navigation instructions specific to that overlay area. The overlay areas may overlap, and may be of any size down to the practical minimum of the resolution of the location determination process. Large overlay areas are suitable for transmitting general information, whilst smaller areas can be used to target information to users in very precise locations, such as individual elements of a complicated road layout. The overlay areas may be delimited in two or three dimensions.

An advantage of this preferred arrangement over the fixed beacon systems is that the geographical overlay can be readily modified. Advantageously, the system includes means for storing a digital representation of the geographical overlay, and means for modifying the stored representation such that the configurations of the overlay areas may be selected to meet changing requirements. The overlay areas can be readily combined or subdivided, or their boundaries otherwise altered to meet changing circumstances without any modification to the hardware, simply by reconfiguring the geographical overlay defined in the central database. Moreover, unlike the prior art beacon system discussed above, there is no major cost in street furniture and supporting infrastructure, because existing cellular mobile communications systems may be used to transmit the instructions from a central database. If the driver enters an overlay area which is not on the route chosen by the system, an error message can be transmitted. Such messages may be transmitted to a user other than the mobile unit, for instance in order to monitor the whereabouts of valuable cargoes or of personnel working away from a base.

The geographical overlay may also be used to operate an access-control system, for example for site security or for levying tolls. In this arrangement, if a user enters an overlay area for which he does not have permission, an alert signal can be sent to a system controller, or to security staff on site who can intercept the interloper. Means may be provided (either in a fixed location or with the mobile user) to store a value associated with the mobile unit, and means arranged to modify the stored value in response to the messages transmitted in accordance with the location of the mobile unit, either to increment the value e.g. for subsequent billing, or to decrement the value e.g. in a prepaid stored-value device.

The fixed part may include means for storing map information or other data for use in providing information, herein referred to as guidance data, means for updating the stored guidance data, means for identifying mobile parts to which the updated data are applicable, and means for transmitting such data over the communications system to the mobile parts so identified. This allows information about changing traffic situations to be transmitted to all users who will be affected, without needing to broadcast the details to other users as would be the case with those prior art systems where updating is possible.

Although the information transmitted to the user is specific to the location, information about the user can be processed centrally. This allows short-term traffic predictions to be made. The guidance data transmitted to the mobile units can therefore be based on the position measurements of a plurality of the mobile parts. If the mobile parts are vehicles, these position measurements will identify the locations of roads, and an indication of their traffic density. As new roads are built or routes are diverted, traffic will move to the new routes. Measuring the position of the traffic will therefore result in the data being updated automatically. To reduce the volume of information transmitted, the fixed part may comprise means for transmitting to the mobile part an expected range of movement information and for receiving from the mobile part movement measurements outside the expected range, and the mobile part comprising means for measuring location and time to derive movement information, means to compare the movement information with the expected range received from a fixed part of the system, and means to automatically report to the fixed system movement measurements outside the expected range. In this way only exceptional traffic conditions are reported.

The fixed part may include means for generating and maintaining guidance data based on vehicle movement data derived from time information and position measurements of a plurality of the mobile parts and/or estimations of future locations of the mobile parts based on the guidance information previously transmitted to the mobile parts. Estimations of future locations of the mobile parts based on the guidance information previously transmitted to the mobile parts can be used to make estimates of future traffic situations.

The data stored in the data storage means may be updated, for example in response to changing traffic conditions, accidents, or highway maintenance. The system may include means for identifying the mobile units to which the updated data are applicable, and transmitting amended instructions over the communications system to said mobile parts. With knowledge of the journeys being planned by a large number of users, a better prediction of demand for particular roads (and hence of congestion on those roads) can be built up. This can be more stable than existing autonomous route-planning systems because the navigation system can take account of the journeys planned for other users.

Advantageously the invention can be implemented using a public cellular radio data service on an individual dial-up basis, providing a simple mechanism for billing and avoiding the need for a separate radio transmission system.

The means for determining the location of the mobile part may comprise means to interrogate a location-identifying means forming part of the mobile part operating for example by means of dead reckoning from a known start point, using an inertial navigation system or distance and direction measuring devices such as a compass and an odometer. Alternatively, the means for locating position may include means for identifying the location of the mobile part in relation to elements of the fixed part of the communications system. The location of the mobile part may be determined by a radio location system associated with the cellular radio system. In another alternative arrangement, a satellite navigation system may be used. In one preferred arrangement the fixed part has means to determine the approximate location of the mobile part, and the location identifying means of the mobile part is arranged to respond to a location request from the interrogation means with a non-unique location signal which, in combination with the approximate location determined by the fixed part, determines a unique location.

In a preferred arrangement, the fixed part and the mobile parts each have a satellite navigation system receiver, and the positions of the mobile parts as measured by the satellite navigation system are compared with those of the fixed part as measured by the satellite navigation system. The position of the fixed part can be known with great accuracy and provides a reference measurement which allows the position of the mobile part to be determined with greater accuracy than is possible by direct measurement using the satellite system alone.

Preferably the fixed part has one or more servers and means for allocating a server to a mobile part only when it requires service. In practice only a very small number of mobile units will require service at any given time, so this allows the computing resources of the fixed part to be used most efficiently, and the system can support many more mobile units in total than it has server capacity for. This is in contrast to the prior art system discussed above, in which each mobile unit requires a dedicated computer carried on board, which is only used for a fraction of the time. Moreover, all the servers can use a common road-use database, which can use the information on routes it has planned for mobile users to build a prediction of future road use status, such as likely congestion points, and build this into its guidance instruction process. For example the system can be arranged such that it does not direct more than a predetermined number of users to use a particular stretch of road at a particular time, and finds alternative routes for any users who would otherwise be directed along that road at that time. In this way the system can predict likely congestion points and take pre-emptive action.

The mobile part may include guidance instruction means controllable by instructions contained in the guidance information transmitted from the fixed part over the communications link, whereby guidance instructions can be communicated to the user by means of the guidance instruction means.

For some applications the vehicle may be controlled directly in response to the guidance information received over the communications link. However, for use on the public highway, it is preferable that the guidance information controls display means, which may be visual or audible or both, to indicate to a driver the direction to take.

The guidance instruction means may be programmable from the fixed part over the communications link, either automatically or by a human operator. The guidance instruction means may include a speech synthesiser, which may be located in the fixed part, transmitting voice messages to the user over the communications system, or may be located in the mobile unit and controlled by data messages from the fixed part. The former arrangement allows the mobile unit to be simplified, whilst the latter arrangement requires a smaller signalling load.

In the described embodiment the mobile part is in a vehicle, but it may be a hand-held device for guiding a pedestrian. In one form, the mobile part may be a conventional mobile cellular radio unit. This allows a basic service to be provide to a user without the need for any dedicated equipment.

Embodiments of the invention will now be described by way of example with reference to the drawings, in which:

Figure 1 shows a mobile part and a fixed part of a navigation information system according to an embodiment of the invention;

Figure 2 illustrates how the invention may be applied to a simple road layout;

Figure 3 illustrates the division of a territory into zones according to the instructions generated by the system;

Figure 4 illustrates an application of the invention to a more complex road layout;

Figures 5a and 5b illustrate the modification of an overlay in response to a change in traffic circumstances; and

Figure 6 illustrates a road network, showing overlay areas defined by the method of the invention in relation to a cellular radio network

According to the embodiment of Figure 1 the navigation system has a fixed part (comprising elements 12 to 19) and a number of mobile parts, of which one only is shown (comprising elements 1 to 10), interconnected by a cellular telephone network 11.

The mobile part comprises a mobile telephone 1 having an audio output 2, an audio input 3 and a radio antenna (transmit/receive) 4. The output 2 is connected to a decoder 5 to translate Dual-Tone Multi-Frequency (DTMF) signals received by the telephone 1 into data which is fed to an interface controller 6. The interface controller 6 also receives input from a GPS (Global Positioning System) satellite receiver 7. The interface controller transmits data to a DTMF encoder 8 which generates tones to be fed to the audio input of the mobile telephone. The audio output 2 and input 3 also include a loudspeaker 9 and microphone 10 respectively, to allow the telephone to be used for speech.

The fixed part comprises an interface with the cellular telephone network 11, connected through a DTMF decoder 12 and encoder 13 and a controller interface 14 to a computer 15. The computer 15 comprises a number of servers 16, one of which is allocated to each active mobile unit. The servers 16 have access to a geographical database 17, and a database of standard messages 18. The geographical database 17 is updateable through updating input 19. The database 17 stores the definitions of a number of overlay areas which together form a geographical overlay to the territory to be covered. Examples of overlays are illustrated in Figures 2, 4, 5a, 5b, and 6, to be described in detail later.

The mobile part obtains location information using the GPS receiver 7 and transmits this information, together with a request for directions to a specified destination, to the fixed part, where a server 16 relates the location information to its geographical database 17 and obtains message information associated with the location from the database 18, and transmits the information back to the mobile part.

The computer 15 may transmit messages in DTMF code, using the encoder 12, or it may generate voice messages which are transmitted through a voice output 20 to the cellular network 11.

DTMF signals are used to transmit the position of the vehicle to the computer 15 which can then offer information and guidance either to the vehicle or to a third party on demand.

In the following discussion, variations on the basic apparatus depicted in Figure 1 will also be described, in which certain elements are modified or replaced.

The system is operated as follows:-

At the start of a journey the driver requests service by activating a pre-dialled control on the telephone 1. This service request is transmitted to the control interface 14 over the telephone network 11. The control interface 14 then allocates a free server 16 to answer the call and interrogate the vehicle GPS receiver 7 to determine its geographical position. The encoder 8 takes the latitude and longitude data and translates the numbers into DTMF tone-pairs, in a manner to be described in more detail below.

The cellular telephone couples this audio signal into its speech input path. This is easy to do with a hands-free vehicle-mounted cellular telephone since the microphone lead is accessible or alternatively, a small transducer can be mounted next to the microphone 10. A DTMF receiver 5 coupled to the loudspeaker 9 (again acoustically or electrically) decodes supervisory data (again in DTMF format) coming back from the server 16 to acknowledge the reception of location messages. If no acknowledgement is received by the DTMF unit then the data message is repeated.

The fixed end of the system comprises a DTMF decoder 12 and encoder 13 coupled to a serial data interface 14 of the server computer 15. This computer, on the one hand, can call the mobile part which will answer automatically and then provide its location using the DTMF signalling system or on the other hand can receive an unsolicited call, which would include the DTMF encoded identity of the mobile unit and would also provide the vehicle location using the DTMF interface 6.

The server 16 then captures the current position of the user, and identifies the overlay area within which that position falls. The server also captures any permanent user-specific information such as the type of vehicle, which may be relevant for the route to be selected e.g. because of height or weight restrictions. The user may encode those requirements which are not permanent, but are specific to the present information request, (in particular his destination) by using the telephone keypad in response to voice prompts. However, in a preferred arrangement the call is presented to a human operator for the capture of this data. This allows the user to obtain assistance in identifying his desired destination to the system, and also allows the driver to speak his requirements, keeping his hands and eyes free for driving.

The operator then remotely programs the in-vehicle interface 6 with system data identifying the vehicle destination, for use in subsequent update processes, and instigates the generation of voice given directions and instructions to the driver by a speech generation subsystem of the computer server 16.

Position fixes may be made at regular intervals, e.g. every two minutes, or every kilometre. Alternatively the fixed part may request the mobile unit to send its next position fix after a specified interval or distance.

As the driver follows the route further instructions can automatically be sent as the driver enters each new overlay area and the driver can be alerted if the route has been left or if any new traffic problems have been detected that will affect the individual driver. The system is arranged such that when the system locates a mobile unit entering an overlay area having a message defined for it, for example the next turn instruction (or an error message if the mobile unit has gone off the selected route), that message is transmitted. The system may also be arranged to transmit messages to users other than the mobile unit in question, for example to monitor the progress of valuable cargoes.

At any time the driver can call the human operator if service requirements change or additional help is needed.

Because a central database is used all vehicle movements can be monitored. Traffic models can be used to optimise traffic flows and reduce journey times. The system can also ensure that it does not itself cause congestion, by limiting the number of vehicles it directs to use the same road at the same time. The control system can use the location data to calculate and record movement vectors from these vehicles.

Using the data collected by this method, it is possible for the central system to derive a digital map of valid routes. The following data could be derived automatically: valid travel lanes; permitted direction(s) of flow; allowable turns;

average travel times; trends in travel times according to time of day and other factors.

The system would automatically update the map to show permanent changes (new road links, changes to one way systems etc.). Temporary lane closures from road works etc. would also be recorded. Manual updating of data would be necessary (for instance to alert the system to a new bypass opening) before the system acquired the information from vehicle flow data, to ensure vehicles are routed over the new road initially. Any approximations in the pre-entered data would automatically be corrected by the system described here.

The system could be further enhanced to include any other information that may be relevant to travellers, by a combination of manual and automated data entry, e.g. location of bus stops, telephone boxes and other street furniture, and proximity to enterprises such as shops, banks or offices.

The variation of transit time trends according to time of day, for each link, could be used to derive a congestion prediction model, as the basis for route guidance. The system may monitor the progress of the mobile units along the routes selected for them, to identify any areas of traffic congestion etc, by comparing actual transit times between predetermined locations. This may be done by the fixed system monitoring the location updates of individual units, or it may be done by the mobile unit, in co-operation with the fixed unit. In this latter case, the fixed part transmits an expected range of transit times within which the mobile is expected to reach a predetermined location. If the mobile unit reaches the location outside this range, it reports the fact to the fixed part. By "reporting by exception" the data processing overhead can be reduced considerably.

However, these systems can become unstable if too many drivers have access to route guidance based on information about current or predicted congestion. To avoid these instabilities route plans are created and updated centrally and passed to individual vehicles. The impact of these vehicles using the suggested routes is then added to the prediction. As more vehicles use the system the prediction produced could become more accurate.

The routes derived can be passed to the vehicles (via a mobile data link, or possibly a short range communications link or other temporary access to a fixed telecommunications network - prior to departure). The vehicle would then operate autonomously, unless the road conditions varied significantly from those predicted.

If the central system detected a problem (from vehicle data or other sources), which had a severe impact on predictions, sufficient to cause a change to advice already given, then the central system could broadcast news of the problem, such that those vehicles affected could automatically call in via a mobile data communications link to receive a new route from its present location to its destination.

If a vehicle system encountered unexpected transit times along its programmed route it would send a report to the central system.

The data flowing though the system will therefore allow it to "learn" more of the road network's characteristic congestion behaviour, e.g. by use of neural net techniques, and to select routes for traffic which avoid using routes at times when they are likely to be congested. In addition, the system can generate digital road maps or other data automatically, based on the position measurements of vehicles using the roads.

A particular advantage of this system is the ability to predict unusual patterns of congestion from the route guidance information requested by the users. Because route guidance is generated centrally, the system can monitor the number of requests for destination information to a given location. By determining the predicted arrival times for each user (which will depend on their starting points, and the time the journey started), a build-up of traffic converging on a particular location at a particular future time (e.g. for a major sporting event) can be detected. Traffic for other destinations, which might have been routed by way of this location, can then be diverted to other routes.

The system described above uses an analogue telecommunications link, in which DTMF codes may be used. For an analogue cellular radio network DTMF is an ideal signalling medium when only short status messages are required to be transmitted. It can survive in the severe signal fading and noise of the mobile environment which frequently precludes the use of fast phase or frequency shift data modulation. Another advantage is the ability to co-exist with speech. For example a DTMF data burst containing vehicle position data could be sent at the start of a call and at intervals during the call. Other simple coded DTMF messages can also be conveyed to indicate emergencies, provide simple driver indications (e.g. illuminated arrows to turn left or right) or trigger synthetic speech generated by another sub-system in the vehicle.

The DTMF coding described above is suitable for an analogue system. In a digital cellular network digitised data can be transmitted over an associated packet data system such as the Short Message Service (SMS) of GSM (Global System for Mobile Communications), or the General Packet Radio Service (GPRS) proposed for GSM.

In the embodiment described above, the speech generation subsystem forms part of the server 16. Alternatively, it can be carried on board the vehicle. In this arrangement the subsystem has various stored speech commands which are controlled from the in-vehicle interface 6 in response to commands transmitted from the fixed part. This arrangement reduces the signalling traffic required over the radio link 11, but increases the complexity of the in-vehicle equipment.

The location-determination system will now be described in greater detail. GPS (Global Positioning System) satellite navigation receivers are now becoming very cheap and are available with a serial data output. These can provide latitude and longitude data to within a tenth of a second of arc (defining position to within 3 metres, which is sufficient to identify which carriageway of a dual carriageway road a user is on).

Satellite positioning systems such as the Global Positioning System (GPS) are prone to small systematic errors, for example as a result of instabilities in the orbits of the satellites. The accuracy of the position measurement may be enhanced by a process known as "Differential GPS" in which a number of fixed reference points are used, whose positions are determined with great precision e.g. using surveying techniques. GPS is used to obtain a measure of the position of one or more of the fixed reference points. This measure is compared with the known, true location to generate a correction value which can be used to correct the position of the mobile unit as measured by GPS.

The position data received from the satellite positioning system may include some redundant data. If the system is only to operate within a limited area of the globe the most significant digits of the position data are redundant, and need not be transmitted from the mobile unit to the fixed part. For example, any point in Germany can be uniquely defined by the units digits of its latitude and of its longitude, as that country lies entirely between 45 and 55 degrees North, and between 5 and 15 degrees East. It is also possible to define any point in the United Kingdom in this way, although in that case a 10 degree offset in longitude has to be applied to avoid duplication of longitudes East and West of the zero meridian.

For larger territories e.g. a pan-European system, or one covering the USA, this simple method of data reduction is impractical. However, it is nevertheless possible to reduce the data requirements by dynamically defining the territory. After an initialisation step using the full location, the system selects as each new location the closest candidate to the previous one. For example, if the mobile unit was last reported at 99 degrees W and the units digit of the longitude is now 0, the user is taken to be at 100 degrees W rather than, for example, 90 degrees or 110 degrees.

If location updates take place sufficiently frequently that the user's position cannot have changed by more than half a degree, the units digit of degrees may also be dispensed with, and the location given only in minutes and seconds of arc. The more frequent the updates, the more digits can be dispensed with.

An alternative method of obtaining the coarse position location is interrogation of the cellular radio system's operating system to identify the cell in which the user is currently located. Cell sizes can be up to about 40km across (although they are often much smaller, so identifying the cell can identify the user's location to within 40km, which identifies latitude to better than half a degree. (1 degree of latitude = 111km). The separation of lines of longitude varies with the cosine of the latitude but even at the Arctic Circle (66 degrees North) a 40km resolution will identify longitude to the nearest whole degree (1 degree of longitude = 111km (cos latitude) = approximately 45km at 66 degrees North).

By left-truncating the position data by omitting the degrees digits a basic position message would therefore consist of 10 decimal digits (minutes, seconds, and tenths of seconds). Altitude data giving altitude in metres would require a further four digits, since all points on the Earth's surface lie within a range of 10,000 metres, but this data can also be left-truncated, as it is unlikely that any multi-level road system would exceed 100 metres in height (or if it did, that a GPS system would work effectively for any receiver on the lower levels). This gives a total of twelve digits, which can be transmitted by DTMF in less than 2 seconds.

If the data is left-truncated as described above, the "coarse" data is added by the interface controller 14 by reference to the previous position or to the cellular radio operating system.

When the computer 15 receives a location message, it stores the location and then searches its database for an overlay area within which that position lies. The overlay areas are defined in the database by co-ordinates of latitude and longitude and have associated attributes which define messages which can be passed to mobile subscribers within the overlay area defined. In some instances height (altitude) information, also available using satellite positioning systems, may be used, for example to distinguish between levels in a multi-level highway intersection. When a DTMF location message has co-ordinates which fall inside an overlay area having an associated message, the message is then transmitted to the mobile part as a computer synthesised speech message, a DTMF coded message (to activate other subsystems) or as a high speed conventional data message.

If the mobile unit fell within the same overlay area at the previous location update, and the message associated with that overlay area is unchanged, the transmission of the message may be suspended.

The frequency at which location updates are requested by the system may be tailored to the size and nature of the current overlay area. For example, an intricate road layout may comprise a large number of small overlay areas, requiring frequent location updates to ensure that a user does not miss an instruction by passing through its associated area between two updates. However, a long stretch of road without junctions may be covered by a single overlay area, so less frequent updates are appropriate. The speed with which a vehicle is likely to be moving, which will differ between urban, rural, and motorway environments may also be used as a factor in determining when the next location update should be requested.

As suggested above, there may be circumstances when a satellite positioning system may be unusable, for example in tunnels or built-up areas where a line-of-sight view of the satellites may be impossible to obtain. Alternative arrangements for identifying and updating the mobile part's location which do not rely on a satellite receiver may be used, either on their own, or to interpolate between points where a satellite system can be used. In one variant, a navigation system based on dead-reckoning may be used. In such systems the user identifies his initial location and the on-board system measures the system's movement e.g. by magnetic bearing measurements, distance counters, and inertial navigation means such as gyrocompasses and accelerometers. Such systems are self-contained, but require knowledge of the starting point. This may be obtained, for example from a satellite positioning system.

In another variant, a method of location may be used which relies on the propagation characteristics of the cellular radio system used for communication with the central control station. Examples of such systems are disclosed in German Patent specifications DE3825661 (Licentia Patent Verwaltungs) and DE 3516357 (Bosch), United States Patent 4210913 (Newhouse), European Patent specification EP0320913 (Nokia), and International Patent applications WO92/13284 (Song) and WO 88/01061 (Ventana). By comparison of signal strength or other characteristics of several cellular base stations, a position fix can be determined. In this arrangement the location measurement may be made directly by the fixed system. This allows the mobile part of the system to be embodied by a conventional cellular telephone, with inputs being provided by speech, or by DTMF tones generated by the keypad, and instructions to the user being transmitted by voice commands.

Examples of the kind of navigation information which may be stored in the database 17 will now be discussed, with reference to Figures 2 to 6. Briefly, Figure 2 shows a junction J having four approach roads 21,22,23, 24; each having associated with it an overlay area 21a, 22a, 23a, 24a respectively. In this figure, and all other figures illustrating road layouts, the roads are shown arranged for left-hand running, as used for example in the UK, Japan, Australia etc. Figure 3 shows part of a road network surrounding the junction J, including towns A, B, C, and a motorway M. Each of the roads 21, 22, 23, 24 has an associated destination zone 21z etc. Figure 4 shows a complex grade-separated junction interlinking four roads N, S, E, W. The junction has superimposed on it an overlay having twelve overlay areas, Na, Ni, Nd, Sa, Si, Sd, Ea, Ei, Ed, Wa, Wi, Wd. Figure 5a shows a small region having a main road 33 and a side road 30. The main road 33 has two associated overlay areas 31, 32. Figure 5b is similar to Figure 5a, but an obstruction X is present on the main road 33, and the overlay area 32 has been subdivided into two overlay areas 32a, 32b, separated by the obstruction. Figure 6 shows an overlay comprising ten overlay areas 40 - 49 superimposed on a cellular radio coverage region comprising five cells 50 - 54.

In greater detail, the road junction J (Figure 2) has four approach roads 21, 22, 23, 24. On each road, at the approach to the junction, an overlay area (21a, 22a, 23a, 24a) is defined. These overlay areas have directional information associated with them, giving turn instructions or other navigational information. As shown in Figure 3, the entire territory covered by the navigation system can be divided into four zones 21z, 22z, 23z, 24z, each comprising the set of all locations for which the corresponding road 21, 22, 23, 24 should be taken from the junction J. In this particular example, road 24 leads directly into town A and is only used for local destinations (zone 24z), road 23 leads to town B (zone 23z), road 22 leads to town D (zone 22z) and road 21 leads to the motorway M, for all other destinations including town C and part of town A. These zones are defined differently for each junction: for example at junction J' different directions are appropriate for towns A and C, so these towns fall in different zones with respect to the overlay areas at that junction. The zones may even be defined differently for different overlay areas at the same junction. For example, if U-turns are not possible at the junction J, any traffic approaching the junction J by road 22 and requiring town D (perhaps as the result of a previous error, or a change of plan) must be routed by way of roads 21, M, and 25. Thus, for overlay area 22a there are only three zones: 24z, 23z and the combined 21z/22z, corresponding to the three permitted exits 21, 23, 24.

The zones may be re-defined according to circumstances. For example, when the motorway M is congested, the best route from junction J to town C may be by way of town B. In such circumstances, zones 21z and 23z are redefined so that town C now falls within zone 23z. It should be noted, however, that the total number of zones remains the number of exit routes from the relevant overlay area.

The overlay areas 21a, 22a, 23a, and 24a should be large enough to ensure that any vehicle approaching the junction gets at least one location update whilst within the relevant overlay area, and is thus sent the relevant turn instruction. As shown in Figure 2, these overlay areas are discrete, and may be considered equivalent to the coverage areas of the beacons of the prior art system discussed above. They may, however, be made contiguous, as shown in Figures 4, 5a, 5b and 6.

Figure 4 shows a more complex, grade-separated junction, in which there are twelve overlay areas. Each road N, E, S, W intersecting at the junction has a corresponding approach overlay area Na, Ea, Sa, Wa, (Wa shown shaded), and a depart overlay area Nd, Ed, Sd, Wd (Ed shown shaded). There are also four intermediate overlay areas Ni, Ei, Si, Wi (Si shown shaded). In the vicinity of the flyover F height (altitude) information obtainable from the GPS system can be used to determine which level, and therefore which overlay area, the user is currently in.

The approach and intermediate overlay areas each end at a decision point P1 to P8. In the database 17 each overlay area has direction information associated with it, providing instructions as to which fork to take at the associated decision point. For example, the direction information associated with zone Si instructs users for destinations served by road N to go straight on at point P1, and users for destinations served by roads E, S, and W to turn left. It will be seen that traffic using the intersection will pass through one approach overlay area, one departure overlay area, and may also pass through one or more intermediate overlay areas. There may also be information associated with the departure overlay areas Nd, Sd, Ed, Wd, for example warning of hazards ahead. The departure overlay areas may be continuous with approach overlay areas for the next junction in each direction.

As a user approaches the junction on road S, a location update identifies the user equipment as being within overlay area Sa. If the co-ordinates of the user's destination are within the zone served by road W, the user is sent an instruction to turn left at point P2. If the user obeys this instruction, he will enter overlay area Wd and on the next location update he will be sent information relevant to that overlay area (if any).

If the co-ordinates of the user's destination are within the zone served by road N, the user in overlay area Sa is instead sent an instruction to continue straight on at point P2. If the user obeys this instruction, he will enter overlay area Si.

For a user in overlay area Si, if the co-ordinates of the user's destination are within the zone served by road N the user is sent an instruction to go straight on at point P1. On obeying this instruction, he will enter the overlay area Nd and on the next location update he will be sent information relevant to that overlay area (if any).

If the co-ordinates of the destination of a user in overlay area Si are in the zone served by roads E, S, or W, the user will be sent an instruction to turn left at point P1. On obeying this instruction, he will enter overlay area Wi.

Similar information is associated with the other overlay areas. By being given appropriate instructions as the user negotiates a succession of junctions (decision points), the user can be directed to any destination. It should be noted that all users who are to be directed to the same exit from the junction are given the same instruction, whatever their ultimate destination.

Figures 5a and 5b illustrate the reconfiguration of the overlay areas to meet changing circumstances. Initially (Figure 5a) an overlay area 31 is defined for the approach to a junction between a major road 33 and a side road 30, and a second overlay area 32 is defined for that part of the major road 33 beyond the junction. Information associated with the overlay area 31 includes turn information to instruct traffic for the zone served by the side road 30 to turn off. Information may also be associated with the overlay area 32.

In figure 5b the major road 33 has been blocked at a point X. In order to accommodate this, the overlay area 32 has been subdivided into two overlay areas 32a, 32b. The information (if any) associated with overlay area 32b is the same as that previously associated with overlay area 32. Traffic in overlay area 32a is given new information warning it of the hazard ahead. The information associated with the overlay area 31 is modified, so that all traffic is now instructed to turn off onto the side road 30. (Effectively this means that the destination zones associated with the overlay area 31 are merged into one)

Figure 6 shows how the overlay areas may be defined for a road network. In this example there is an overlay area 40, 41, 42, 43, 44, 45, 46, 47, 48, 49 corresponding to each side of each section of road. Information appropriate to each direction of travel on each section is therefore available to users throughout the relevant section. Superimposed on this overlay there is a cellular radio network, five cells of which (50, 51, 52, 53, 54) are shown. The position of the user, as determined for example by a satellite positioning system, determines which overlay area is appropriate to the user. The information is transmitted to the service control centre by means of the cellular radio network. Handovers between cellular base stations occur in conventional manner at cell boundaries. These handovers are, however, unrelated to the boundaries between the overlay areas 40 - 49

Although the described embodiment relates to the provision of route guidance information, other locality-dependant information may be provided as well, or instead, such as information about local facilities, tourist attractions, weather forecasts, public transport information, etc. The term "guidance information", as used in this specification, embraces any such information.

CLAIMS

1. A navigation information system for providing information to a mobile user dependant on the location of the mobile user, the system comprising a mobile communications system having a fixed part and one or more mobile part for communicating with the fixed part, the one or more mobile part including means for transmitting to the fixed part a request for guidance information and for receiving guidance information from the fixed part, and the fixed part including:

means for determining the location of a mobile part requesting guidance information,

means for generating guidance information according to the location of the mobile part, and

means for transmitting the guidance information so generated to the mobile part,

whereby information dependant on the location of the mobile unit can be transmitted to the mobile unit.

2. A system as claimed in Claim 1, the fixed part including means for determining the location of the mobile part in relation to a geographical overlay comprising a plurality of overlay areas, and means for transmitting information associated with an overlay area which includes the location of the mobile part, whereby a mobile part within that overlay area receives information associated with that overlay area.

3. A system as claimed in Claim 2, including means for storing a digital representation of the geographical overlay, and means for modifying the stored representation such that the configurations of the overlay areas may be selected to meet changing requirements.

4. A system according to Claim 2 or 3, including means for determining when a mobile part enters a predetermined overlay area, and means for transmitting a message to the mobile part in response to the mobile part entering the predetermined overlay area.