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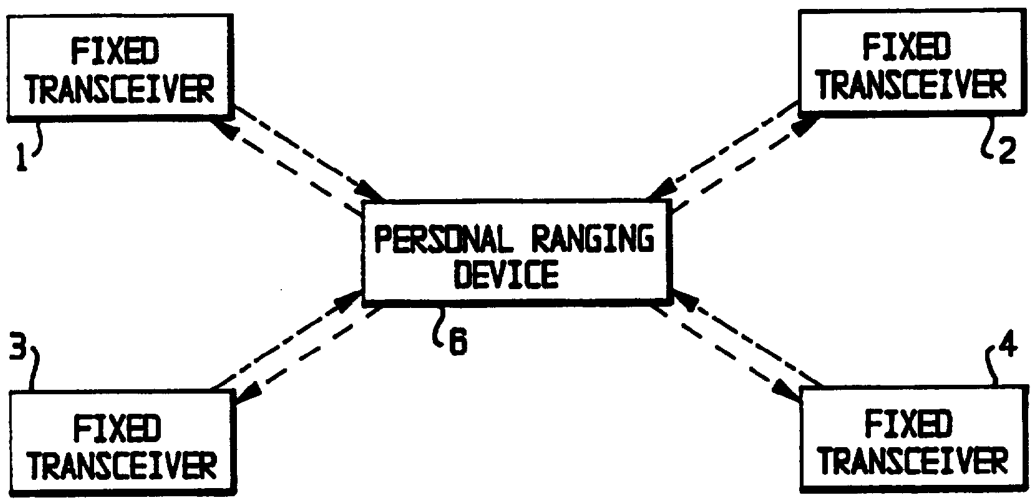

(57) Abstract

A ranging system which can be adapted for use at a golf course includes a number of fixed transceivers located around the golf course so that a hand-held personal ranging device can communicate with the fixed transceivers at any point. Each fixed transceiver uses a spread spectrum transceiver, which can transmit/receive at least two spread spectrum signals. One of the spread spectrum signal is a request from a hand-held personal ranging device for a determination of its position. The other signal is a separate synchronization signal. A hand-held personal ranging device communicates with the fixed transceivers by transmitting a spread spectrum signal, but only receives a narrowband signal in return. By eliminating spread spectrum receivers from the hand-held units, the system is significantly reduced in cost. When unusual conditions (e.g., lightning) occur, the system can be used to inform the golfer by sending a signal via narrowband transmission to activate annunciator (16) which may include a speaker for emitting sound, a LED, or a vibrating circuit. Similarly, the system may be operated in a mode whereby the spread spectrum signal transmitted by the personal ranging device is regarded as an emergency signal when, for example, a golfer becomes injured on the course.

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Golf Course Ranging System

Field of the Invention

The present invention relates to a distance and direction determining system, and more particularly, to a distance and direction determining system which employs spread-spectrum signaling.

The distance ranging system according to the present invention may be used in many applications. In order to facilitate a description of the invention, an example of the ranging system as adopted for golf course use will be set forth herein.

Background of the Invention

For correct shot and club selection, golfers need to have information on how far they are from certain key points on a golf course, particularly the pin. To this end, several ranging systems have been devised over the years, using various technologies for communicating distance information to the golfer.

For example, Woodward et al. (U.S. Patent No. 3,868,692) utilizes a simple system in which a transmitter is disposed on each of the 18 pins and broadcasts continuously. A receiver unit carried by the golfer measures the field strength of the transmitter output, and thereby indicates yardage. While this system is appealing because of its simplicity, it is technically crude and susceptible to RF interference. Moreover, the system requires its various transmitters to be pin-mounted, rendering them easily damaged.

Ranging systems which utilize portable transceivers that reckon distance by measuring the two-way signal between a portable unit and a fixed unit have also been previously proposed. Cockerell, Jr. (U.S. Patent No. 4,698,781) and Storms, Jr. et al. (U.S. Patent No. 4,703,444) illustrate such systems.

A more effective ranging system was proposed in Wang et al. (U.S. Patent No. 5,056,106, which is hereby incorporated by reference), which utilizes spread spectrum technology. This system uses a number of reference transmitters which can be placed in convenient locations around the golf course. Although all the reference transmitters transmit on the same RF frequency, each transmitter encodes its transmission with a unique pseudo-noise sequence. At least four transmitters are required to implement the system's hyperbolic location techniques for any given point.

One of the reference transmitters is a master synchronization transmitter. All of the other reference transmitters receive the signal from the master synchronization transmitter, and synchronize themselves to it. This method of synchronizing the elements of the system means that the spread spectrum signal of the master synchronization transmitters must perform two functions simultaneously, that of transmitter identifier and that of system synchronizer. Loss of signal from the master synchronization transmitter thus causes both a loss of the transmitter as a reference point as well as a loss of the synchronization (and thus the operability) of the entire system.

Moreover, the portable units of the Wang et al. system also receive the signal from the master synchronization transmitter, and synchronize themselves as well. Importantly, each of the portable units must possess a spread spectrum receiver in addition to a spread spectrum transmitter, which makes these units prohibitively large (requiring cart mounting) and expensive.

Summary of the Invention

It is an object of the present invention to provide a spread spectrum ranging system that has small, paper-sized inexpensive personal ranging devices which do not require spread spectrum receivers. It is another object of the present invention to provide a spread spectrum ranging system that possesses robust synchronization amongst its various elements. It is a third object to provide a spread spectrum ranging system that allows for easy transfer of information between users and the system.

The above and other objects are achieved by the present invention which is embodied in a ranging system comprising at least two fixed transceiver units disposed at different points in a predetermined area such as a golf course, each including a spread spectrum transceiver, a microcomputer for performing ranging calculations, a narrowband transmitter for transmitting ranging calculation results, and a plurality of personal ranging devices, each including a spread spectrum transmitter for transmitting a spread spectrum range request signal to the fixed transceivers to request a ranging calculation, and a narrowband receiver for receiving the ranging calculation results and other information from a narrowband transmitter of a fixed transceiver. The spread spectrum transceivers of the fixed transceiver units are capable of transmitting and receiving at least two spread spectrum signals, a first signal for determining the difference in epoch counter values and propagation between all of the fixed transceivers, and a second signal comprised of the spread spectrum range request signals from the personal ranging devices. The present invention further comprises an interface unit for enabling an interface between the system and users for transfer of data including transaction information.

Brief Description of Drawings

Fig. 1 is a schematic block diagram of the basic elements of the present invention illustrating communication amongst the elements.

Fig. 2 is a schematic block diagram of a typical personal ranging device according to the present invention.

Fig. 3 is a schematic block diagram of a typical fixed transceiver according to the present invention.

Fig. 4 is a schematic block diagram of an interface unit according to a first embodiment of the present invention.

Fig. 5 is a schematic block diagram of a battery charging unit according to the first embodiment of the present invention.

Fig. 6 is a schematic block diagram of an on-cart system according to a second embodiment of the present invention.

Fig. 7 is a schematic block diagram of an interface unit according to the second embodiment of the present invention.

Fig. 8 is a flow chart illustrating an operation of the system of the present invention.

Fig. 9 is a schematic block diagram of a central control device according to the present invention.

Detailed Description of the Preferred Embodiments

The basic elements of the ranging system described herein, as illustrated in Fig. 1, include personal ranging device 6, several fixed transceivers 1-4, and an interface unit (as shown in Fig. 4). The fixed transceivers are fixed position spread spectrum RF transceivers which calculate the position of a golfer or other person or system requesting distance information. The calculated position is transmitted via spread spectrum or narrowband RF depending upon the originator of the position request.

The personal ranging device is a hand-held battery powered device having a keypad for entering commands and a display for indicating, inter alia, distance information. The device allows the golfer to request and obtain the distance between his/her present position and a point of interest on the golf course, which may be the pin, a hazard, or some other feature of the course.

The personal ranging device is generally rented by the golfer at the golf course and there programmed with the X,Y coordinates of the points of interest for that course. However, personal ranging devices may also be sold to users where the capabilities of the device are in this case a superset of the capabilities of a rental device. The retail hand-held device would include additional RAM to store and maintain additional information such as to maintain the player's score during play, determine and display the user's shot distance versus club type over time, and other statistical information.

The hand-held device may also be used by golf course personnel for use as a system status receiver over which general golf course status can be monitored and directions to emergencies can be obtained in response to distress signals originating from players on the course.

The interface unit, according to a first embodiment of the present invention, is located at the point-of-sale at the golf course (e.g., the club house), and allows for the transmission and reception of business and other information (e.g., credit card transaction information) between a golfer and the system.

In a second embodiment, referred to herein as an "on-cart" system, each golf cart includes a personal ranging device information slot, a credit card reader, and a battery charger. The interface unit according to the second embodiment of the present invention is arranged in a location where the golf carts are stored and provides for the transfer of information between the personal ranging devices and the system, for example, by RF transmissions.

The elements of the system will now be described in greater detail.

The personal ranging device of the present invention is illustrated in Fig. 2. Each personal ranging device 10 includes a narrowband receiver 11 (e.g., similar to the types of receivers commonly employed in personal paging systems) and a spread spectrum transmitter 12. Spread spectrum transmitter 12 initiates and requests ranging operations by sending a spread spectrum signal to the fixed transceivers in response to the entry of one or more keystrokes by the user. Narrowband receiver 11 receives the results of the requested ranging operation from one or more narrowband transmitters 22 (of the fixed transceivers) in the form of X,Y cartesian coordinates. Microcomputer 17 calculates the distance between the present X,Y position as reported by the fixed transceivers and the stored location of one or more selected points of interest on the golf course. The programmed X-Y positions of all points of interest on the course are stored in a memory 19 within the personal ranging device. The user selects the pertinent point(s) of interest by entering keystrokes (such as, e.g., the hole number) on the personal ranging device. As some of the X-Y positions are subject to periodic change (e.g., pin placements), the interface unit, illustrated in Fig. 4, is periodically updated with such new X-Y information, which is subsequently passed on to the personal ranging devices at, e.g., the time of rental. The updating operation will be described in more detail below.

Requests for ranging operations are entered via one or more keystrokes on keyboard 13, as mentioned above, and the results thereof are displayed on LCD 14. The personal ranging device also includes battery 15, annunciator 16 (described in more detail below) and data port 18.

It should be noted that, while the cost of a spread spectrum transmitter is relatively inexpensive, the cost of a spread spectrum receiver is quite high. By implementing a design, as in the present invention, where the multiple personal ranging devices do not utilize spread spectrum receivers, the cost and size of the personal ranging devices can be dramatically reduced, i.e., to that comparable to commonly-employed pagers.

As indicated above, personal ranging device 6 contains a spread spectrum transmitter which can be activated by the user depressing one or more keys located on the keypad of the personal ranging device. When the user depresses this key or keys, the personal ranging device 6 begins transmission of a spread spectrum signal to the fixed transceivers as indicated by the dashed lines in Fig. 1. The transmission includes information to identify the personal ranging device requesting ranging information and a command to capture data from the fixed transceivers' ranging counters (discussed below).

The fixed transceivers are positioned on the golf course so that they may be contacted by a personal ranging device from any location on or near the course. A typical fixed transceiver 20 is illustrated in Fig. 3. Each fixed transceiver includes spread spectrum transceiver 21, power supply 23, microcomputer 24, data port 25, and antenna 26. One or more fixed transceivers 20 will also include narrowband transmitter 22 and antenna 27 for sending information to either a personal ranging device or the interface unit of the system.

Microcomputer 24 includes an epoch counter 28, a chip counter 29 and a sub-chip counter 30, which are discussed in more detail below. In addition, microcomputer 24 includes a data table stored in ROM 31 of each of the fixed transceivers which indicates which messages are to be used to perform an epoch tracking operation (described below) of a particular fixed transceiver. This is determined by programming each of the fixed transceivers with an identification number used to index the data table. The identification number as well as a message number are always broadcast when a fixed transceiver transmits.

Another data table located in RAM 32 contains the data necessary to store the information used to perform frequency tracking. This table is called the frequency deviation table.

Many different types of spread spectrum radios are in use today which produce a spreading function through the use of a spread sequence. Among the various types of spread spectrum radios, those which operate using frequency hopping and direct sequence are of particular interest. The system described herein utilizes a direct sequence spread spectrum radio since it is well suited for spread spectrum ranging applications.

All spread spectrum systems utilize a sequence or pattern of numbers with which the spreading of the original narrowband signal is accomplished. The type of sequence utilized in the system described herein is a modified linear maximal sequence. Each change in the sequence value is known as a chip. The rate at which the sequence progresses is thus known as the chip rate. The chip counter 29 counts the number of chips.

When a sequence reaches the end, and during repetition of the last value, a signal defined as the system epoch is generated. This signal indicates that the end of the sequence has occurred and that the sequence is about to repeat. The epoch counter counts the number of epochs. The epoch counter counts to a maximum value and then overflows to zero to begin the next counting operation. The epoch signal is heavily used in spread spectrum systems in general in order to synchronize the receiving system with the transmitting system.

In addition to the epoch counter and the chip counter, a phase angle error measurement is performed during each receive operation in order to obtain a sub-chip count value of the difference between timebases among the fixed transceivers. Therefore, the entire count value of a fixed transceiver timebase consists of an epoch counter value, a chip counter value and a sub-chip counter value (40 bits in the current system).

In the system illustrated in Fig. 1, all of the fixed transceivers include narrowband transmitters (the dotted lines represent narrowband signals from the fixed transceivers 1-4 to personal ranging device 6). However, it is also possible, as indicated previously, to dispose a narrowband transmitter in only one fixed transceiver, i.e., a master transceiver, which would then be responsible for all narrowband transmissions. The master transceiver may also be responsible for calculating and reporting to a personal ranging device the result of a range request operation. The master transceiver would also be responsible for setting and synchronizing the clocks of the system as needed to allow ranging and communication to take place.

In such a system, the remaining fixed transceivers may be referred to as slave transceivers. The slave transceiver serves as a measurement extension for the master transceiver. Its internal structure is virtually identical to that of the master transceiver. The microcomputer of a slave transceiver oversees the internal functions of the slave, and also can perform ranging calculations. Slave transceivers can also act as data relays between the master transceiver and any other element of the system with which, for some reason, the master transceiver cannot directly communicate.

Although the master/slave system as described above is considered to be within the ambit of the invention, in the specific embodiment described herein, each of the fixed transceivers includes a narrowband transmitter and none of the fixed transceivers is designated as a master transceiver.

The detailed operation of the fixed transceivers during a ranging operation will now be described.

Upon installation, the fixed position spread spectrum transceivers are surveyed, and their absolute position and distance relative to each other is identified and stored.

In order to perform ranging operations, each of the fixed transceivers must be aware of the differences in value of their timebase as compared to those of each of the other fixed transceivers. However, the fixed transceivers may not be powered up at exactly the same time, and therefore, the fixed transceivers may not be operating using the same timebase. The present invention employs a tracking method, called epoch tracking, to account for the asynchronous operation of the fixed transceivers calculates the absolute difference in value of its timebase to each of the other fixed transceivers. Additionally, the oscillator in each of the fixed transceivers which drives the spread spectrum sequence generator which, in turn, drives the epoch counter, will oscillate at slightly different rates for each of the fixed transceivers. The fixed transceivers according to the present invention therefore perform an additional tracking operation, called frequency tracking, in order to correct errors due to this frequency deviation.

Epoch tracking and frequency tracking operations will be discussed in more detail, beginning with a discussion of epoch tracking.

In order to perform a ranging operation, each fixed position transceiver must determine the difference in value of its timebase with the timebase of each of the other fixed transceivers prior to responding to any ranging request. In the present ranging system, each of the fixed position transceivers will consider the valid timebase to be its own timebase and will calculate the difference between its timebase and those of the other fixed position transceivers upon receipt of a user request, or periodically, in the absence of a user request.

Epoch tracking begins, for example, when two or more fixed transceivers each receive a message from another fixed transceiver. Each of the receiving transceivers informs the other transceivers of the time in its timebase at which the transaction occurred. In more detail, whenever a fixed transceiver broadcasts a message, a specified data preamble pattern is also broadcast. A series of many zeros are first transmitted in order to allow the receiving fixed transceiver to detect the signal, and then the receiving transceiver correlates to the transmitted preamble pattern by sliding correlation, thus determining how many chip slips are required to best synchronize a subsidiary sequence generator within the receiving transceiver (which is a copy of its main sequence generator) with the sequence generator within the transmitting fixed transceiver. (The subsidiary sequence generator is used only for communications synchronization by receiving transceivers, and thus a change in its timebase (via chip slipping) does not alter the timebase of the receiving transceiver itself). At this point, the subsidiary sequence generator within the receiving fixed transceiver is synchronized with the pseudo random sequence of the transmitting transceiver, that is, their pseudo-random sequence and epochs are aligned, but the data is not yet aligned on byte boundaries.

Next, a series of bytes (E5H bytes, for example) are transmitted in order to obtain byte alignment in the received data. The E5H byte value has been chosen as an example because the bits that make it up are not symmetrical and it is therefore possible to detect misalignment and synchronize data on byte boundaries.

Following the series of bytes, a special single byte (4AH byte, for example) is transmitted. This signals each receiver to record the exact time at which the last bit of this byte was received. This time includes the epoch count value, chip count value, and a portion of the sub-chip count value of the receiving transceiver's main timebase. Also, a signal is asserted to begin a fine resolution measurement of the phase angle timing error between the main sequence of the transmitter and that of the receiver.

Finally, data to be exchanged in the message is received by the receiving fixed transceiver(s) and the local epoch, chip and sub-chip values are captured and retained. Utilizing this information, it is possible to determine the deviations of the epoch counters with respect to each fixed transceiver relative to the other fixed transceivers at some known point in time.

An example of this epoch tracking method will now be described. The following example illustrates an epoch tracking operation which is performed periodically when no range request signal has been received for a predetermined period of time.

Fixed transceiver 1 broadcasts a message. The message is received by each of the other fixed transceivers 2, 3 and 4 and the time at which it was received by each of them is recorded (stored in RAM 32).

The time at which fixed transceiver 2 received the message from fixed transceiver 1 is broadcast and the other fixed transceivers 1, 3 and 4 then record the time that they received this signal from fixed transceiver 2 and the information indicating the time at which fixed transceiver 2 received the signal from fixed transceiver 1. At this time, fixed transceivers 3 and 4 know what time fixed transceiver 2 received the original message from fixed transceiver 1. (It should be noted that when fixed transceivers transmit, they do not epoch track, but only serve as a reference for the other fixed transceivers to measure against.) Fixed transceivers 3 and 4 have also recorded the time at which they received the original message from fixed transceiver 1. Therefore, a calculation can be performed to determine the difference between the epoch counter values in fixed transceivers 3 and 4 relative to fixed transceiver 2.

The time at which a message will be received by one fixed transceiver from another is the epoch count value at the receiving fixed transceiver at the time of transmission plus:

a. transmitter delay,

b. distance between fixed transceivers, and

c. receiver delay.

In this example, the transmitter delay will be the same for fixed transceivers 2, 3 and 4 since fixed transceiver 1 performed the broadcast. Therefore, it may be neglected in the calculation of the difference of epoch counter values.

The distance between the fixed transceivers is known from survey, and therefore, the difference in time at which a particular fixed transceiver should receive the broadcast relative to another fixed transceiver is known. In this example, fixed transceivers 3 and 4 have previously calculated the difference in time, due to distance factors, that they would receive a message from fixed transceiver 1 versus the time the message would be received at fixed transceiver 2.

The difference in receiver delay will become part of the epoch difference measurement in the calculation. Therefore, a receiver delay which is longer in one fixed transceiver relative to another will require both fixed transceivers to calculate an epoch counter difference value which compensates for the difference in receiver delays. This is important because any length cable may be utilized between a fixed transceiver and the antenna (26) attached to the fixed transceiver.

In this example, fixed transceivers 3 and 4 will calculate and retain the epoch value difference between themselves and fixed transceiver 2, and they will also retain their epoch count value reference for their timebase when the difference was measured (i.e., the time each of them received the original message from fixed transceiver 1).

A total of six messages are required for all four fixed transceivers in the example set forth herein to calculate the difference in epoch counter values between each other. In the current design, the fixed transceiver sequence is 1, 2, 3, 4, 1, 2.

In the above example, fixed transceivers 3 and 4 calculated the difference in the values of their epoch, chip and sub-chip counters with the value of these registers in fixed transceiver 2 based on a message transmitted from fixed transceiver 1. These calculations are performed by each of the fixed transceivers to determine the difference on a periodic basis between these particular registers of each of the fixed transceivers. In the case that a ranging request is made by a personal ranging device, additional data is transmitted by each of the fixed transceivers with regard to when each of them received the range request signal. The range request will be used to trigger a sequence of messages as described above. The processing of the range request signal will be discussed in greater detail below.

Since all fixed position transceivers know the physical distance between each of the fixed transceivers, it is possible to calculate the sum of the difference in epoch counter values and receiver delays among the units. In addition, each fixed transceiver will store the epoch counter value at which it last received a message used to epoch track each of the other fixed transceivers. This is used as a reference point in time as to when the other transceivers were last tracked.

The present system determines the position information based upon a hyperbolic solution. Therefore, when the fixed transceivers perform the required communication reporting the time at which they received the user request and all necessary tracking for the particular set of transactions has been accomplished, hyperbolic curves can be formed by subtracting the time of arrival of the user request signal at a particular fixed transceiver from that of the other fixed transceivers. Through the simultaneous solution of the intersection of the hyperbolae, a position of the user in a cartesian coordinate system can be determined. These coordinates are then transmitted back to the user via the narrowband RF data channel.

Receiver delays have long posed problems for ranging systems. The system according to the present invention will tolerate even wide differences in receiver delays or changing receiver delay since the differences in receiver delay are calculated periodically. The differences in transmitter delays between units is of no concern because the transmit delay in any given operation will be the same for all units making a measurement and this system utilizes differences in time of arrival of measurements. Epoch tracking is, therefore, a software solution for system timebase difference resolution.

Frequency tracking is utilized to determine the difference in epoch count rate rather than the difference in epoch counter value.

Fixed transceiver 1 broadcasts a message including the value of its epoch counter at the time of transmission of the special single byte. This epoch value (24-bits) is inserted, on the fly, into the data portion of the message after the last bit of the special single byte is transmitted. It has been described that the epoch counter value (at the time the special single byte is transmitted) of the transmitting fixed transceiver is embedded in the data of the message. It should also be noted that all spread spectrum transmissions in the fixed transceivers as well as the personal ranging device will begin on an epoch boundary. This requirement is made on purpose in hardware. Since two bits are sent during each epoch interval, the special single byte will always be transmitted on an epoch boundary with regard to the transmitter. Therefore, the chip and sub-chip counter values for the transmitter at the time the special single byte is transmitted is always zero.

As noted above, the data table located in ROM 31 of each of the fixed transceivers indicates which of the messages broadcast between the fixed transceivers they are to use to frequency track another particular fixed transceiver. In addition, the frequency deviation table contains the data necessary to store the information used to perform frequency tracking.

An example of the frequency tracking operation will now be described.

If the data table in ROM 31 indicates that frequency tracking is required for the particular reception, the frequency deviation table is examined.

If the frequency deviation table indicates that tracking has not occurred previously, the time of transmission and the time of reception are stored in the frequency deviation table. The frequency tracking algorithm terminates.

If the frequency deviation table indicates that tracking has previously occurred, a calculation of the oscillator differences between the fixed transceivers is performed.

The calculation is performed by dividing the difference of the current time of transmission and the last time of transmission by the difference of the current time of reception and the last time of reception. Note that the last time of transmission and reception were always previously stored in RAM 32 prior to any calculation. In other words, each of the fixed transceivers records the epoch value transmitted by each of the other fixed transceivers as well as their epoch counter value at the time of each reception. Upon subsequent receptions from other fixed transceivers, the differences in these values are calculated and a frequency ratio between oscillators in the receiving fixed transceiver and the transmitting fixed transceiver can be determined. This requires that at least two transactions between each of the transceivers must occur before frequency tracking can be accomplished.

The deviation in oscillator rates is stored in the frequency deviation table and the last time of transmission and reception are updated for subsequent tracking.

Another frequency tracking method may be used which does not require the transmission of the epoch value by monitoring changes in the epoch value differences over time.

The fixed transceivers will periodically broadcast to each other in the case that no range request is received. The period between these broadcasts is determined by the amount of time which may pass before the difference in the oscillator rates of any fixed transceiver could cause an ambiguous change in the sign of its epoch counter with that of another fixed transceiver. The most significant bit of the epoch counter is the sign bit. Currently, periods on the order of minutes could elapse before ambiguous operation would occur. However, this could be extended or reduced by changing the length of the epoch counter as desired.

Another effect of the epoch counter is to extend the area in which unambiguous ranging may occur without extending the sequence length. Extending the sequence length would cause delay in correlation and synchronization when acquiring the spread spectrum signal. The epoch counter may serve this purpose because it is driven by the sequence generator and its value is determined by the number of sequence repetitions that have occurred since reset. While the sequence is used to spread the RF signal, the epoch counter is not used for this purpose.

The processing of a range request is now described.

The time at which each fixed transceiver received the request is retained. This includes the epoch counter value, chip counter value and sub-chip counter value.

The retained time of each fixed transceiver is broadcast in a message sequence between fixed transceivers as described above.

During the sequence of messages, the following actions are taken in particular order:

a. Frequency tracking is performed as described above.

b. The last epoch differential calculation is used to calculate the difference in timebase from the received time of the range request at each of the other fixed transceivers. This is a method for converting the time the range request was received at each of the other fixed transceivers to the timebase of the fixed transceiver performing the calculation.

c. Then, a frequency differential adjustment as to the time the other fixed transceivers received the subscriber request is made utilizing the calculation performed during frequency tracking and the epoch tracking reference (the time at which the last epoch tracking event occurred).

d. A calculated time of arrival at each of the other fixed transceivers is retained.

e. Epoch tracking is then performed as described above in preparation for the next subscriber request.

Once the sequence of fixed transceiver transmissions has been completed, each of the fixed transceivers has calculated an estimate of what time the range request was received at each of the other fixed transceivers in that particular fixed transceiver's timebase.

Then, the differences in the time that the range request was received between each of the fixed transceivers is calculated and an estimate of the cartesian position of the user requesting the range information is estimated. The estimated location of the user is transmitted to the user via a narrowband RF signal.

The user's hand-held personal ranging device will calculate the distance to the selected location using the position estimate obtained and the pre-programmed points of interest locations nearby. The information is displayed to the user.

No epoch tracking or frequency tracking is utilized with the personal ranging device. The personal ranging device will operate asynchronously with the fixed transceivers. The personal ranging devices do not include an epoch counter and cannot receive spread spectrum messages. The fixed transceivers use the spread spectrum sequence generator in the personal ranging device as a reference with which to make the measurement of the time of arrival of the ranging request signal only.

As mentioned previously, the data transmitted to the personal ranging device may be in the form of X-Y coordinate data. Via a simple calculation carried out within the personal ranging device, the distance from the X-Y position of the personal ranging device to X-Y positions of objects on the golf course which are programmed into the personal ranging device may be obtained and displayed.

The interface unit according to a first embodiment of the present invention is illustrated in Fig. 4. The interface unit provides for the transfer of information to and from the personal ranging devices.

The interface unit 40 includes the standard user interface equipment such as bidirectional credit card reader 43, which identifies the golfer and debits the golfer's account in exchange for the use of a personal ranging device. Personal ranging device programming slot 44 receives personal ranging devices and programs them with the X-Y coordinates of various points of interest. Programming slot 44 can also obtain the identification of a particular personal ranging device. Information about the golfer can be input through keyboard 45 after appropriate prompting appears on display 48, and a receipt for the transaction can be printed by printer 49. In this way, personal ranging devices can be matched to specific golfers and vice versa. Modem 46 is provided so that the interface unit can communicate with a central receipt collection and storage system (not shown). Memory 50 can keep record of financial transactions between modem dumps.

Daily data of new pin locations and other changing points of interest are collected from the course via a hand-held device much like the personal ranging device. This is performed by a worker standing over each new location with the device and pushing a button which will transmit a signal to the fixed transceivers. This results in the calculation of the X-Y position of this point, which is then stored by the system. Once all new points are entered, the hand-held device is then inserted into personal ranging device programming slot 44 of the interface unit for downloading of the collected data. Alternatively, all new point information can be transmitted to the interface unit 40 via a fixed transceiver thereby eliminating the need for the device to be inserted into the programming slot 44. Either way, this information is stored in memory 50 and can then be purchased by the golfer by inserting a personal ranging device into programming slot 44. Once a credit card is swiped in credit card reader 43, the interface unit will download the data to the personal ranging device and generate a receipt. The golfer then has the ability to obtain almost immediately the range to any hole, a designated point of interest, or the distance of his/her last shot.

Fig. 5A and 5B illustrate a battery charging unit 90 which is provided for charging the battery packs arranged within the personal ranging devices. The personal ranging devices 6 are held in a charging slot 91 in the battery charging unit 90 until it is rented by a user. The ranging system may include an intelligent mass charge system in which personal ranging devices are fast-charged. Each charging unit includes a power supply operating off 120 VAC having a capacity to allow fast charging of many personal ranging devices, battery charge state detectors to determine the current state of charge of the batteries, and a front panel display indicator for each personal ranging device charging slot 91 which would provide status information.

For example, non-illumination of a LED display would indicate that the personal ranging device is not inserted or that a bad connection exists; red illumination would indicate a good connection, but that the battery is not yet charged to a sufficient level; yellow illumination would indicate that the battery is sufficiently charged for one round of golf but has not yet been fully charged; and green illumination to indicate that the battery is fully charged.

A non-intelligent mass charging unit may be provided where the personal ranging devices are slow-charged. This system would simply include a power supply operating off 120 VAC having a sufficient capacity to allow charging within a ten hour period, and a front panel LED display which indicates that the personal ranging device is not inserted or that there is a bad connection and that the personal ranging device should be reinserted when the LED is not illuminated, and which indicates that a good connection exists and that the charger is charging when the LED is illuminated.

The on-cart system according to a second embodiment of the present invention will now be described.

Referring to Fig. 6, a personal ranging device information slot 61 and a credit card reader 62 are provided on each golf cart (mobile unit) of the golf course. Moreover, each golf cart further includes a power supply 63 and a battery charging section 64 for charging the battery of the personal ranging device inserted into the personal ranging device information slot 61.

The interface unit 70 according to the second embodiment is illustrated in Fig. 7. The interface unit 70 is typically arranged in a location where the golf carts are stored. The interface unit 70 includes a spread spectrum transceiver 73 for transmitting and receiving information to and from the fixed transceivers, a narrowband transmitter/receiver unit 75 for transmitting and receiving information to and from the personal ranging devices, antennae 74, 76, a memory 77, a modem 78, a power supply 71, and a microcomputer 72.

Operation of the on-cart system will now be described with respect to one golf cart.

A personal ranging device is inserted into the personal ranging device information slot 61 on the golf cart. When a user wishes to utilize the ranging system, he/she swipes a credit card across the credit card reader 62 on the golf cart. Credit card information is then stored in the memory 19 of the personal ranging device. At a predetermined time, the interface unit 70 polls the personal ranging device, via RF transmission, for credit card information. In response, the credit card information stored in memory 19 of the microcomputer 17 is transmitted to the interface unit 70 via RF transmission. The narrowband transmitter/receiver unit 75 receives the credit card information from the personal ranging device. The credit card information is then stored in the memory 77 of the interface unit 70. At some predetermined time, the interface unit 70 transmits the credit card information stored in memory 77 to a central control system (described below) via modem 78.

According to the second embodiment, new pin locations and other changing points of interest are obtained by a hand-held device as set forth above with respect to the first embodiment of the present invention. Once the new data has been obtained, the hand-held device transmits the new data, via a narrowband channel, to the interface unit 70. The interface unit 70 then transmits this information to the personal ranging devices arranged on the golf carts via an RF signal.

Alternatively, the new pin locations can be stored by one of the fixed transceivers which transmits the new data to the interface unit 70 via RF transmission. The personal ranging devices cannot be used until the credit card reader has read the user's credit card information.

The operation of the system, in both the first and second embodiments, will be described with reference to the flow chart in Fig. 8.

When the golfer depresses the appropriate location request key (to perform a ranging request), a spread spectrum position request signal is sent to the fixed transceiver units on the spread spectrum channel used for ranging (Step S1). The transmission includes a preamble (to identify the personal ranging device requesting ranging information) and a command to capture data from the fixed transceivers' ranging counters.

The fixed transceivers then collect the captured ranging data from each other via an RF data link (Step S2). The data from the fixed transceivers is used to calculate the position of the device requesting such data using locating techniques (Step S3). The requested position information is transmitted (in the form of X-Y coordinates, for example) via narrowband RF back to personal ranging device (Step S4).

The personal ranging device determines the distance between its present location and the requested location via a simple calculation (Step S5). The distance from the X-Y position of the personal ranging device to the X-Y position of the requested point is then displayed (Step S6).

In the above description, the personal ranging device requests its position, which is supplied by the fixed transceiver units. The personal ranging device then calculates its distance from a pre-memorized point. In an alternative system, the fixed transceivers access the information stored in the system and perform the distance calculations before transmitting the information to the personal ranging device. The personal ranging device would merely act to make the distance request, but would not perform any calculations itself.

All ranging calculations can be directly transferred or related to the fixed transceivers which perform all ranging calculations and error detection, and subsequently report the results to the personal ranging device either directly or through another fixed transceiver that has a narrowband transmitter. As an alternative, the information flow can be better localized through the use of one of the fixed transceivers when all of the fixed transceivers include a narrowband transmitter.

Referring to Figure 9, the ranging system further includes a central control system 80 which initiates telephone calls to the individual golf course system interface units and downloads receipt and system status information in the form of credit card transactions and status. The telephone calls will be initiated by the central computer over modems 81 and will occur at night when telephone costs are at the lowest rate.

The central control system is also responsible for processing information received on the financial data from all golf courses and re-compiling the data into a report form acceptable to management, to print the reports, and prepare the information for credit card processing centers.

The central control system includes a central computer system 82, disk storage 83a, 83b, at least one modem 81, a telephone switching system, and control software.

The ranging system communicates with a known banking system to verify the validity of credit cards, to automatically debit the credit card account of those customers who have rented the hand-held device, and to automatically debit the credit card accounts of those customers who have failed to return the rented hand-held device within a prescribed interval.

Claims

1. A ranging system comprising:

a plurality of personal ranging devices each transmitting a spread spectrum position request signal upon activation by a user; and

at least two fixed transceivers, responsive to said spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said at least one of said personal ranging devices requesting ranging information.

2. The ranging system as claimed in claim 1, wherein each of said plurality of personal ranging devices comprises:

a spread spectrum transmitter for transmitting said spread spectrum position request signal;

a narrowband receiver for receiving said ranging signal from one of said fixed transceivers;

a power supply; and

a microcomputer coupled to said spread spectrum transmitter, said narrowband receiver and to said power supply.

3. The ranging system as claimed in any of claims 1-2, wherein said microcomputer comprises a memory for storing position information of predetermined locations within a specified area, wherein said microcomputer determines the distance to one of said predetermined locations based upon a difference between position information of said one of said predetermined locations and said result of said ranging operations represented by said ranging signal.

4. The ranging system as claimed in any of claims 1-3, wherein each of said personal ranging devices further comprises:

a keyboard coupled to said microcomputer; and

a display unit coupled to said microcomputer.

5. The ranging system as claimed in any of claims 1-4, wherein each of said personal ranging devices further comprises an annunciator, coupled to said microcomputer, which alerts a user by performing one of generating a sound, vibrating and activating a light emitting element.

6. The ranging system as claimed in any of claims 1-5, wherein each of said at least two fixed transceivers comprises:

a spread spectrum transceiver for receiving said spread spectrum position request signal and for transmitting and receiving information to and from at least one other fixed transceiver;

a narrowband transmitter for transmitting said ranging signal to said at least one of said personal ranging devices; and

a microcomputer, coupled to said spread spectrum transmitter and to said narrowband transmitter, for performing said ranging calculations.

7. The ranging system as claimed in any of claims 1-6, wherein said microcomputer in each of said fixed transceivers determines the distance from said at least one of said personal ranging devices to a predetermined location in a specified area based upon a difference between position information of said predetermined location and a result of said ranging operations.

8. The ranging system as claimed in any of claims 1-7, wherein each of said fixed transceivers generates an epoch signal when a sequence in said spread spectrum

position request signal is about to repeat, and wherein said microcomputer in each of said fixed transceivers comprises:

a ROM;

a RAM;

an epoch counter for counting occurrences of said epoch signal;

a chip counter for counting each change in said sequence of said spread spectrum position request signal; and

a sub-chip counter;

wherein each of said fixed transceivers performs an epoch tracking operation with respect to each of the other fixed transceivers upon receipt of said spread spectrum position request signal to compensate for a difference in timebase of operation between each of said fixed transceivers and a fixed transceiver performing sad epoch tracking operation; and

wherein each of said fixed transceivers selectively performs a frequency tracking operation with respect to each of the other fixed transceivers upon receipt of said spread spectrum position request signal to compensate for frequency deviation in signals transmitted from each of said fixed transceivers to said fixed transceiver during said epoch tracking operation.

9. The ranging system as claimed in any of claims 1-8, further comprising an interface unit for transferring information to and from said personal ranging devices, including a personal ranging device used for obtaining updated position information.

10. The ranging system as claimed in any of claims 1-9, wherein said interface unit comprises:

a microcomputer;

a credit card reader coupled to said microcomputer;

a personal ranging device programming slot, coupled to said microcomputer, for transferring information to and from a personal ranging device;

a memory, coupled to said microcomputer, which stores position information of predetermined locations within said specified area;

a keyboard;

a display;

a printer; and

at least one modem.

11. The ranging system as claimed in any of claims 1-10, further comprising a central control unit for transferring financial and status information to and from said interface unit, for processing financial information received from said interface unit, for generating reports of financial transactions at said interface unit, and for debiting credit card accounts of said users based upon said financial information received from said interface unit, said central control unit comprising:

a central processing unit coupled to at least one modem enabling transfer of financial information to and from said interface unit and credit and banking centers, a keyboard, a display unit, a memory, disk drives and a printer.

12. The ranging system as claimed in any of claims 1-11, wherein said interface unit provides for transfer of information between said interface unit and said central control unit via said modem.

13. The ranging system as claimed in any of claims 1-12, wherein said power supply is a battery power supply.

14. The ranging system as claimed in any of claims 1-13, further comprising a personal ranging device battery charging unit for simultaneously charging said battery power supply of a plurality of said personal ranging devices.

15. A ranging system comprising:

a plurality of personal ranging devices each transmitting a spread spectrum position request signal upon activation by a user;

at least two fixed transceivers, responsive to said spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said at least one of said personal ranging devices requesting ranging information; and

an interface unit comprising means for transferring information to and from said personal ranging devices.

16. A ranging system comprising:

a plurality of personal ranging devices each transmitting a spread spectrum position request signal upon activation by a user;

a plurality of mobile units, each carrying a personal ranging device;

at least two fixed transceivers, responsive to said spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said at least one of said personal ranging devices requesting ranging information; and

an interface unit for transferring information to and from said personal ranging devices.

17. The ranging system as claimed in any of claims 15-16, wherein each of said personal ranging devices comprises:

a spread spectrum transmitter for transmitting said spread spectrum position request signal;

a narrowband receiver for receiving said ranging signal from one of said fixed transceivers;

a power supply; and

a microcomputer, coupled to said spread spectrum transmitter, said narrowband receiver, and to said power supply.

18. The ranging system as claimed in any of claims 15-17, wherein said power supply in each of said personal ranging devices is a battery, and wherein each of said mobile units comprises:

a personal ranging device information slot for receiving said personal ranging device;

a credit card reader coupled to said personal ranging device information slot;

a power supply; and

a battery charging section, coupled to said personal ranging device information slot, for charging said battery in said personal ranging device.

19. The ranging system as claimed in any of claims 15-18, wherein each of said fixed transceivers generates an epoch signal when a sequence in said spread spectrum position request signal is about to repeat, and wherein said microcomputer in each of said fixed transceivers comprises:

a ROM;

a RAM;

an epoch counter for counting occurrences of said epoch signal;

a chip counter for counting each change in said sequence of said spread spectrum position request signal; and

a sub-chip counter;

wherein each of said fixed transceivers performs an epoch tracking operation with respect to each of the other fixed transceivers upon receipt of said spread spectrum position request signal to compensate for a difference in timebase of operation between each of said fixed transceivers and a fixed transceiver performing said epoch tracking operation; and

wherein each of said fixed transceivers electively performs a frequency tracking operation with respect to each of the other fixed transceivers upon receipt of said spread spectrum position request signal to compensate for frequency deviation in signals transmitted from each of said fixed transceivers to said fixed transceiver during said epoch tracking operation.

20. The ranging system as claimed in any of claims 15-19, wherein said interface unit comprises:

a spread spectrum transceiver;

a narrowband transmitting/receiving unit;

a memory;

a modem;

a power supply; and

a microcomputer, coupled to said spread spectrum transceiver, said narrowband transmitting/receiving unit, said memory, said modem, and to said power supply.

21. A method for performing a ranging operation in a ranging system comprising a plurality of personal ranging devices each transmitting a spread spectrum position request signal upon activation by a user, and at least two fixed

transceivers, responsive to said spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said at least one of said personal ranging devices requesting ranging information, each of said fixed transceivers comprising a microcomputer, including an epoch counter, a chip counter, a sub-chip counter, a ROM and a RAM, said method comprising the steps of:

transmitting, from at least one of said personal ranging devices, a spread spectrum position request signal to said fixed transceivers;

performing an epoch tracking operation, in each of said fixed transceivers, for converting a time at which said spread spectrum position request signal was received at each of said fixed transceivers with respect to a timebase of a fixed transceiver performing said epoch tracking operation, wherein said time is represented by values of said epoch counter, said chip counter and said sub-chip counter in each of said fixed transceivers;

selectively performing, in each of said fixed transceivers, a frequency tracking operation to correct errors in frequency deviation in signal transmissions and receptions between each of said fixed transceivers and said fixed transceiver performing said frequency tracking operation;

calculating, in each of said fixed transceivers, an estimated position of said personal ranging device transmitting said spread spectrum position request signal; and

transmitting said estimated position of said personal ranging device to said personal ranging device from one of said fixed transceivers.

22. The method as claimed in claim 21, wherein said epoch tracking step in each of said fixed transceivers comprises the steps of:

recording a time of arrival of said spread spectrum position request signal;

transmitting a message indicating said time of arrival of said spread spectrum position request signal to other fixed transceivers;

receiving a transmission from each of said other fixed transceivers which have received said spread spectrum position request signal, and recording a time of arrival of said spread spectrum position request signal, included in said transmission, at each of said other fixed transceivers; and

calculating differences in said time of arrival of said spread spectrum request position request signal at each of said other fixed transceivers with respect to a fixed transceiver performing said calculation, in said timebase of said fixed transceiver, wherein said estimated position is then calculated in said estimated position calculating step.

23. The method as claimed in any of claims 21-22, wherein said frequency tracking step in each of said fixed transceivers comprises the steps of:

determining whether frequency tracking is required when a transmission signal is received from one of said fixed transceivers;

storing, when said frequency tracking is required, a time of transmission and a time of reception of said transmission signal when said frequency tracking has not previously been performed.

24. The method as claimed in any of claims 21-23, wherein said frequency tracking step in each of said fixed transceivers further comprises the steps of:

calculating, when said frequency tracking is required and when said frequency tracking has previously been performed with respect to said one of said fixed transceivers transmitting said transmission signal, a frequency difference between a fixed transceiver receiving said transmission signal and said one of said fixed transceiver; and storing a value of said frequency difference in said RAM of said ranging system.

25. The method as claimed in any of claims 21-24, wherein said calculating step comprises the step of:

dividing a difference between a current time of transmission and a last time of transmission by said one of said fixed transceivers by a difference between a current time of reception and a last time of reception of said fixed transceiver.

26. The method as claimed in any of claims 21-25, wherein said method further comprises the steps of:

determining, in each of said fixed transceivers, whether a spread spectrum position request signal has been received within a predetermined period of time; and

initiating said epoch tracking operation and said frequency tracking operation when said spread spectrum position request signal has not been received for said predetermined period of time.

27. A method for updating position information in a ranging system comprising a plurality of personal ranging devices, at least two fixed transceivers, responsive to a spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said at least one of said personal ranging devices requesting ranging information, and an interface unit, comprising a memory, a personal ranging device programming slot, a narrowband transmitter/receiver unit, and a microcomputer, for transferring information to and from said personal ranging devices, said method comprising the steps of:

obtaining, via one of said personal ranging devices, position information for at least one point of interest;

storing said position information;

inserting said one of said personal ranging devices into said personal ranging device programming slot for downloading said position information into said memory of said interface unit;

inserting other personal ranging devices into personal ranging device programming slot; and

transferring said position information stored in said memory of said interface unit to said other personal ranging devices.

28. A method for updating position information in a ranging system comprising a plurality of personal ranging devices, at least two fixed transceivers, responsive to a spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said at least one of said personal ranging devices requesting ranging information, and an interface unit, said method comprising the steps of:

obtaining, via one of said personal ranging devices, position information for at least one point of interest;

storing said position information in said one of said personal ranging devices;

transmitting said position information from said one of said personal ranging devices to said interface unit; and

transmitting said position information from said interface unit to said personal ranging devices.

29. A method for updating position information in a ranging system comprising a plurality of personal ranging devices, at least two fixed transceivers, responsive to a spread spectrum position request signal transmitted by at least one of said personal ranging devices, for performing ranging calculations and for transmitting a ranging signal representing a result of said ranging calculations to said

at least one of said personal ranging devices requesting ranging information, and an interface unit, said method comprising the steps of;

obtaining, via one of said personal ranging devices, position information for at least one point of interest;

storing said position information in one of said fixed transceivers; and

transmitting said position information from said one of said fixed transceivers to said personal ranging devices.

30. A method of obtaining credit card information in a ranging device comprising a plurality of personal ranging devices, a plurality of mobile units, each carrying a personal ranging device, at least two fixed transceivers, an interface unit for transferring information to and from said personal ranging devices, and a central control unit comprising a central processing unit coupled to at least one modem enabling transfer of financial information to and from said interface unit and credit and banking centers, said method comprising the steps of:

determining, via a polling signal transmitted by said interface unit, whether each of said personal ranging devices contain credit card information;

transmitting, in response to said polling signal, said credit card information from those personal ranging devices storing credit card information to said interface unit; and

transmitting said credit card information, corresponding to said personal ranging devices, from said interface unit to said central control unit.

31. A method of obtaining credit card information in a ranging device comprising a plurality of personal ranging devices, at least two fixed transceivers, an interface unit, comprising a memory, a personal ranging device programming slot, a narrowband transmitter/receiver unit, and a microcomputer, for transferring information to and from said personal ranging devices, and a central control unit

comprising a central processing unit coupled to at least one modem enabling transfer of financial information to and from said interface unit and credit and banking centers, said method comprising the steps of:

determining, via a polling signal transmitted by said central control unit, whether said interface unit contains credit card information in said memory; and

transmitting, in response to said polling signal, said credit card information stored in memory, from said interface unit to said central control unit.

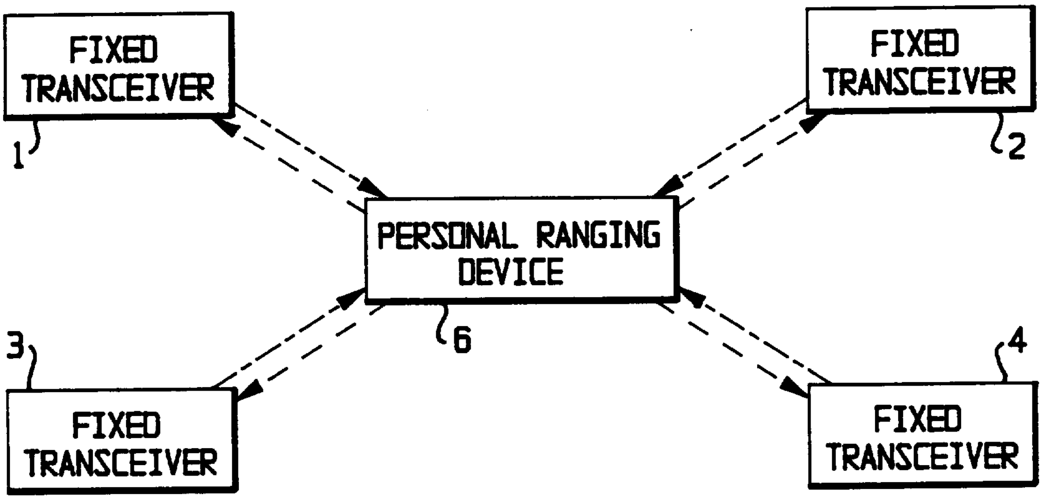

FIXED TRANSCEIVER
1
FIXED TRANSCEIVER
2
PERSONAL RANGING DEVICE
6
3
FIXED TRANSCEIVER
4
FIXED TRANSCEIVER

FIG.1

FIG.2

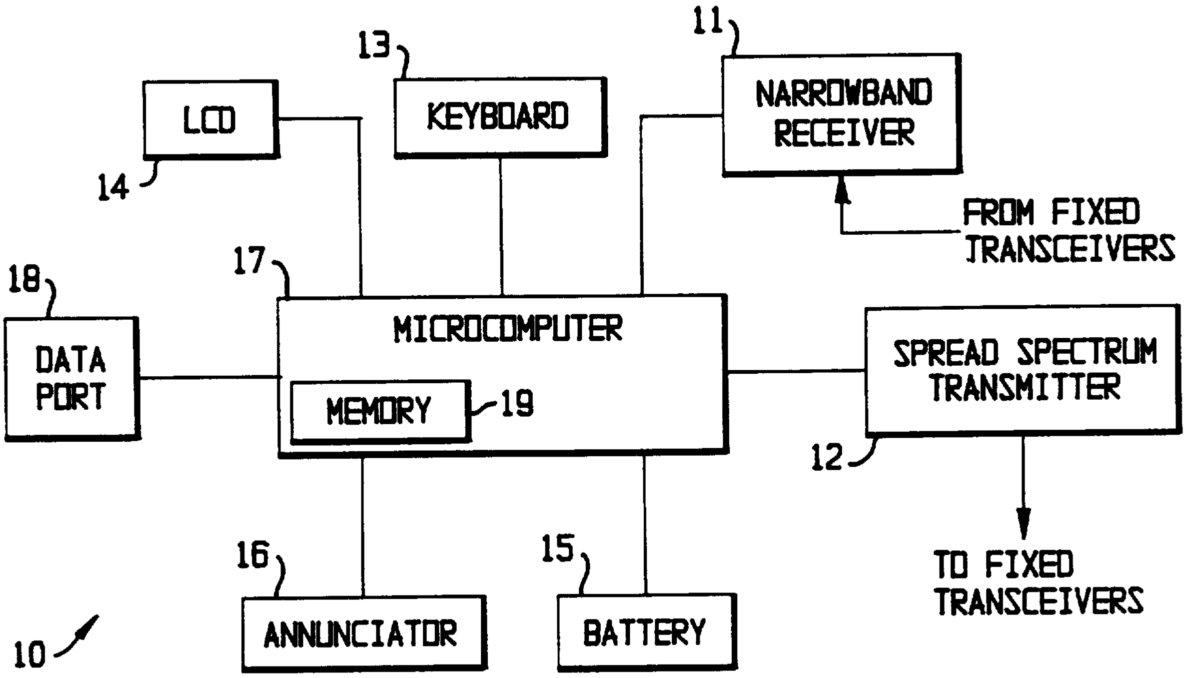
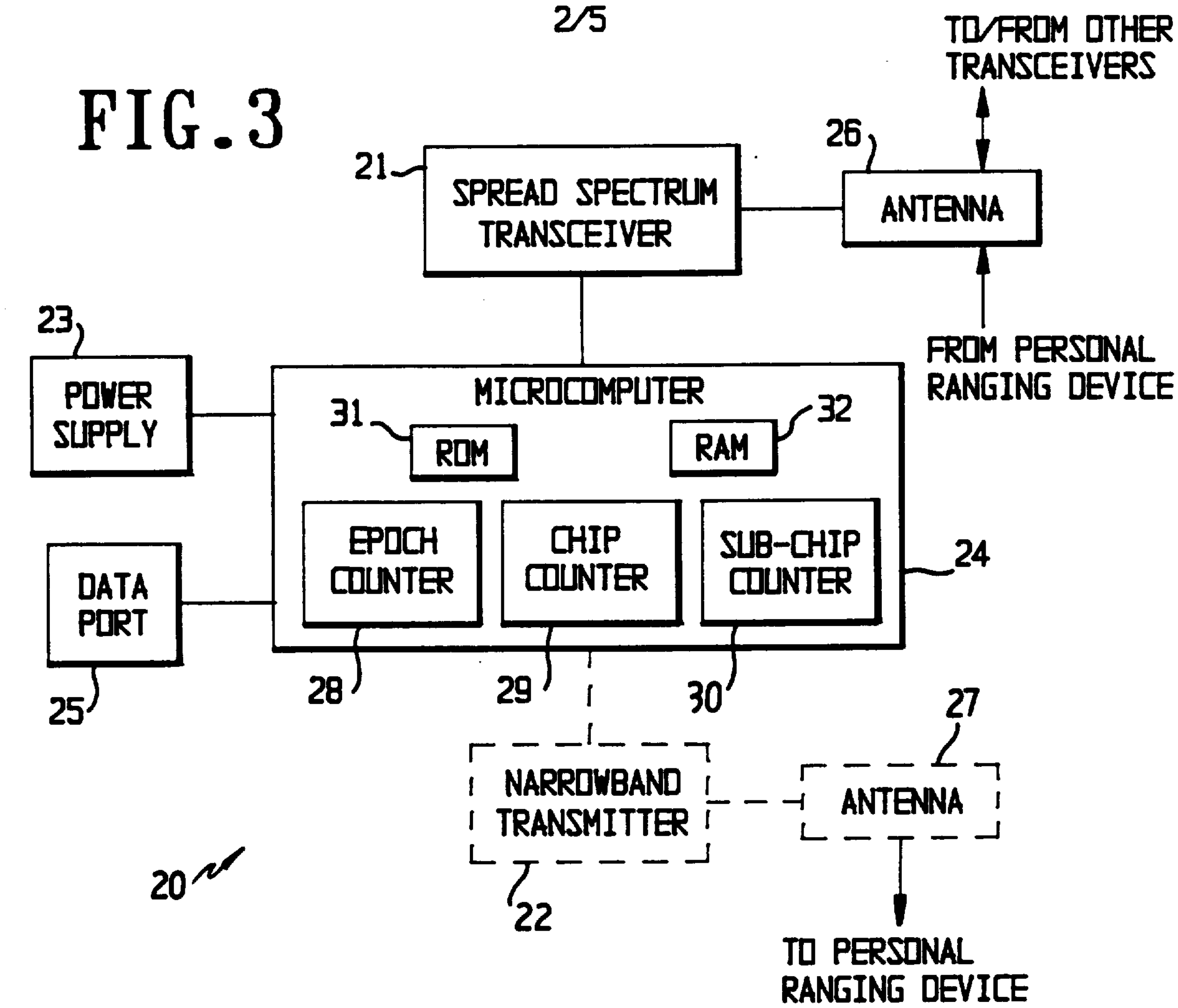

13
11
LCD
KEYBOARD
NARROWBAND RECEIVER
14
FROM FIXED TRANSCEIVERS
18
17
DATA PORT
MICROCOMPUTER
MEMORY
19
SPREAD SPECTRUM TRANSMITTER
12
16
15
TO FIXED TRANSCEIVERS
10
ANNUNCIATOR
BATTERY

FIG. 3


TO/FROM OTHER TRANSCEIVERS
26
21
SPREAD SPECTRUM TRANSCEIVER
ANTENNA
FROM PERSONAL RANGING DEVICE
23
POWER SUPPLY
MICROCOMPUTER
31
ROM
RAM
32
DATA PORT
EPOCH COUNTER
CHIP COUNTER
SUB-CHIP COUNTER
24
25
28
29
30
27
NARROWBAND TRANSMITTER
ANTENNA
20
22
TO PERSONAL RANGING DEVICE

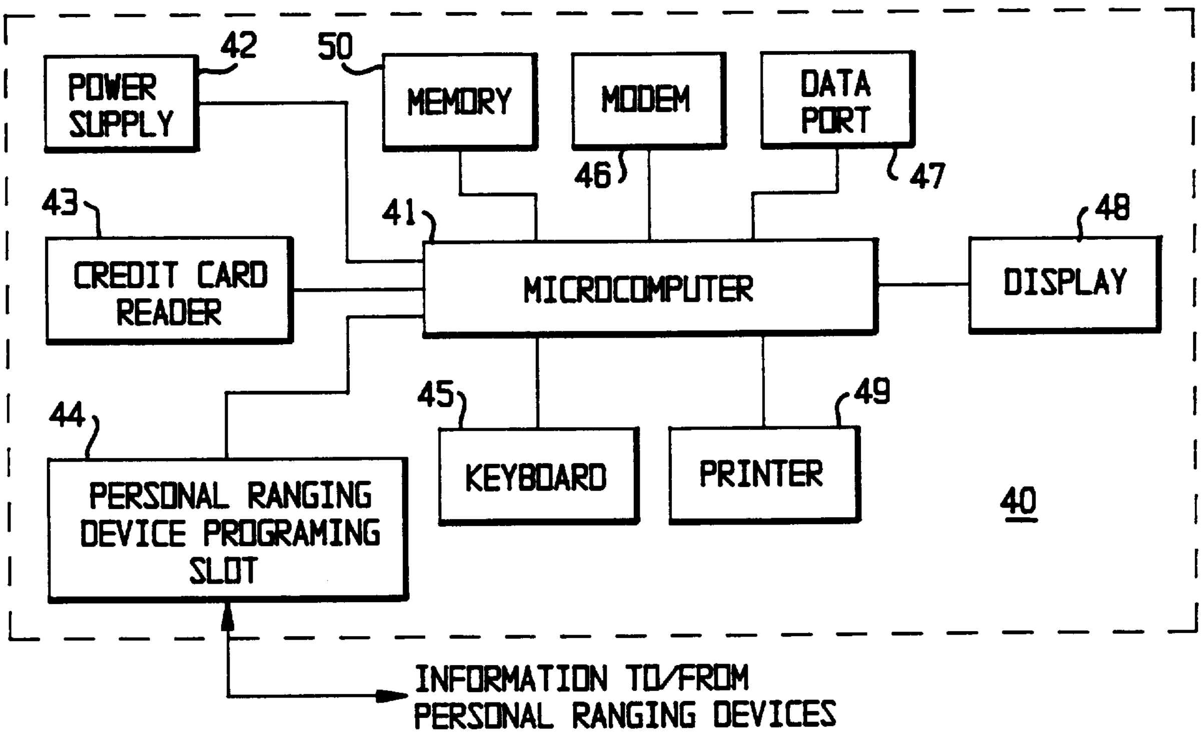

POWER SUPPLY
42
50
MEMORY
MODEM
DATA PORT
46
47
43
41
48
CREDIT CARD READER
MICROCOMPUTER
DISPLAY
45
49
44
PERSONAL RANGING DEVICE PROGRAMING SLOT
KEYBOARD
PRINTER
40
INFORMATION TO/FROM PERSONAL RANGING DEVICES

FIG. 4

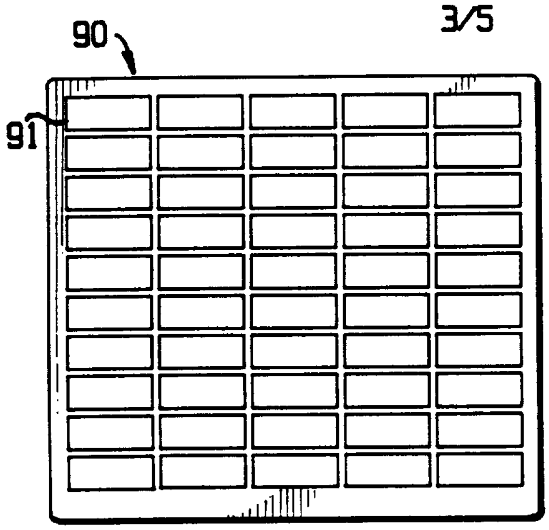


FIG.5A

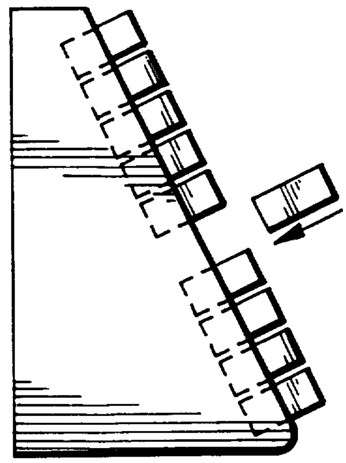


FIG.5B

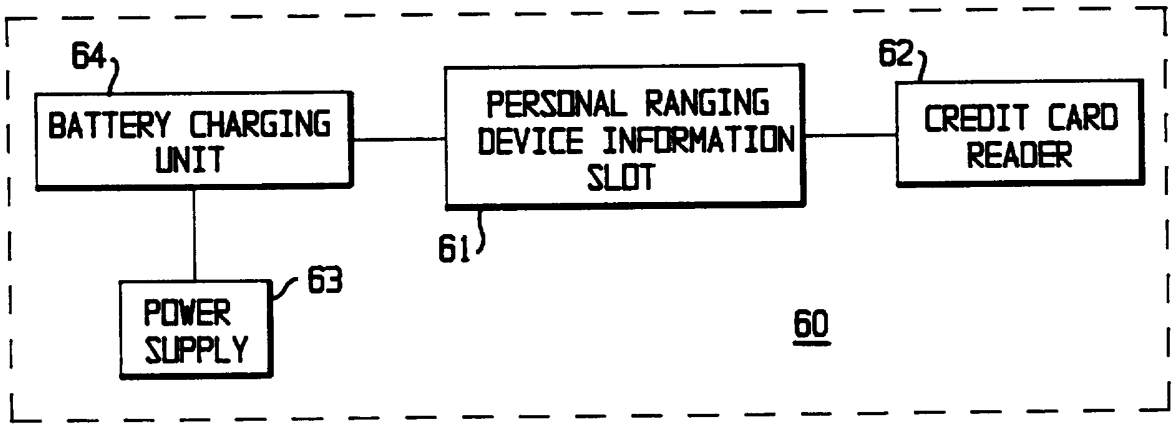


FIG.6

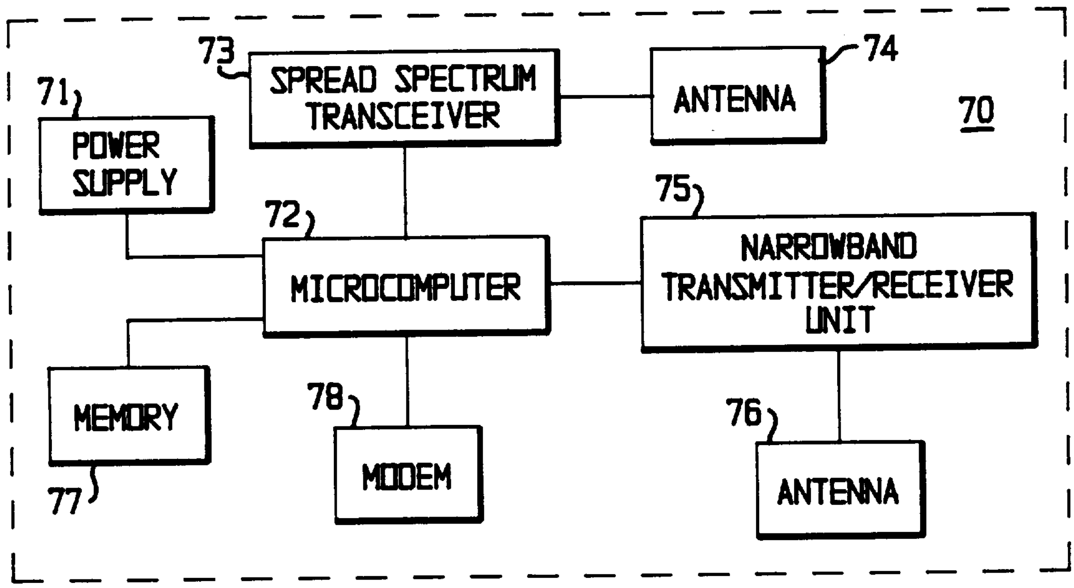

70
71
POWER SUPPLY
73
SPREAD SPECTRUM TRANSCEIVER
ANTENNA
74
72
MICROCOMPUTER
75
NARROWBAND TRANSMITTER/RECEIVER UNIT
MEMORY
77
78
MODEM
76
ANTENNA

FIG.7

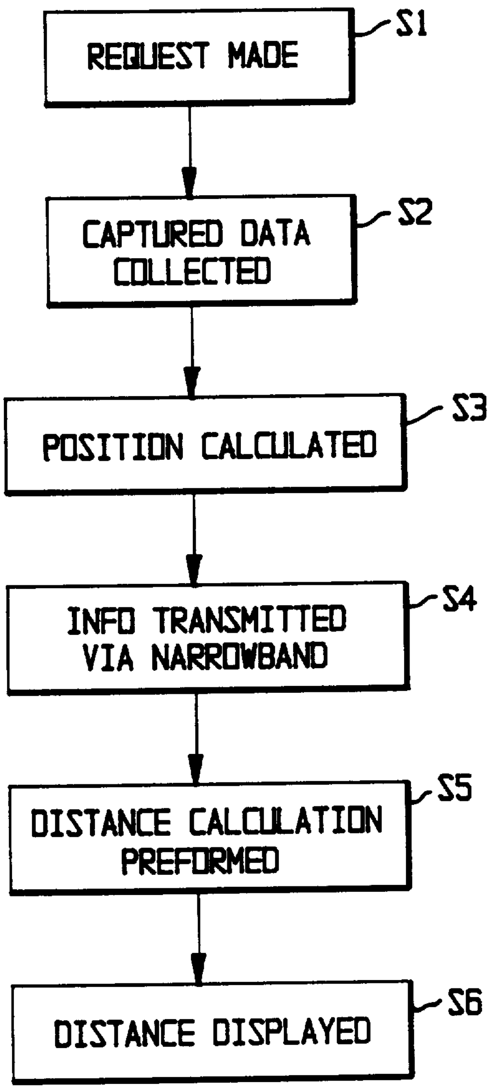

REQUEST MADE
S1
CAPTURED DATA COLLECTED
S2
POSITION CALCULATED
S3
INFO TRANSMITTED VIA NARROWBAND
S4
DISTANCE CALCULATION PREFORMED
S5
DISTANCE DISPLAYED
S6

FIG.8

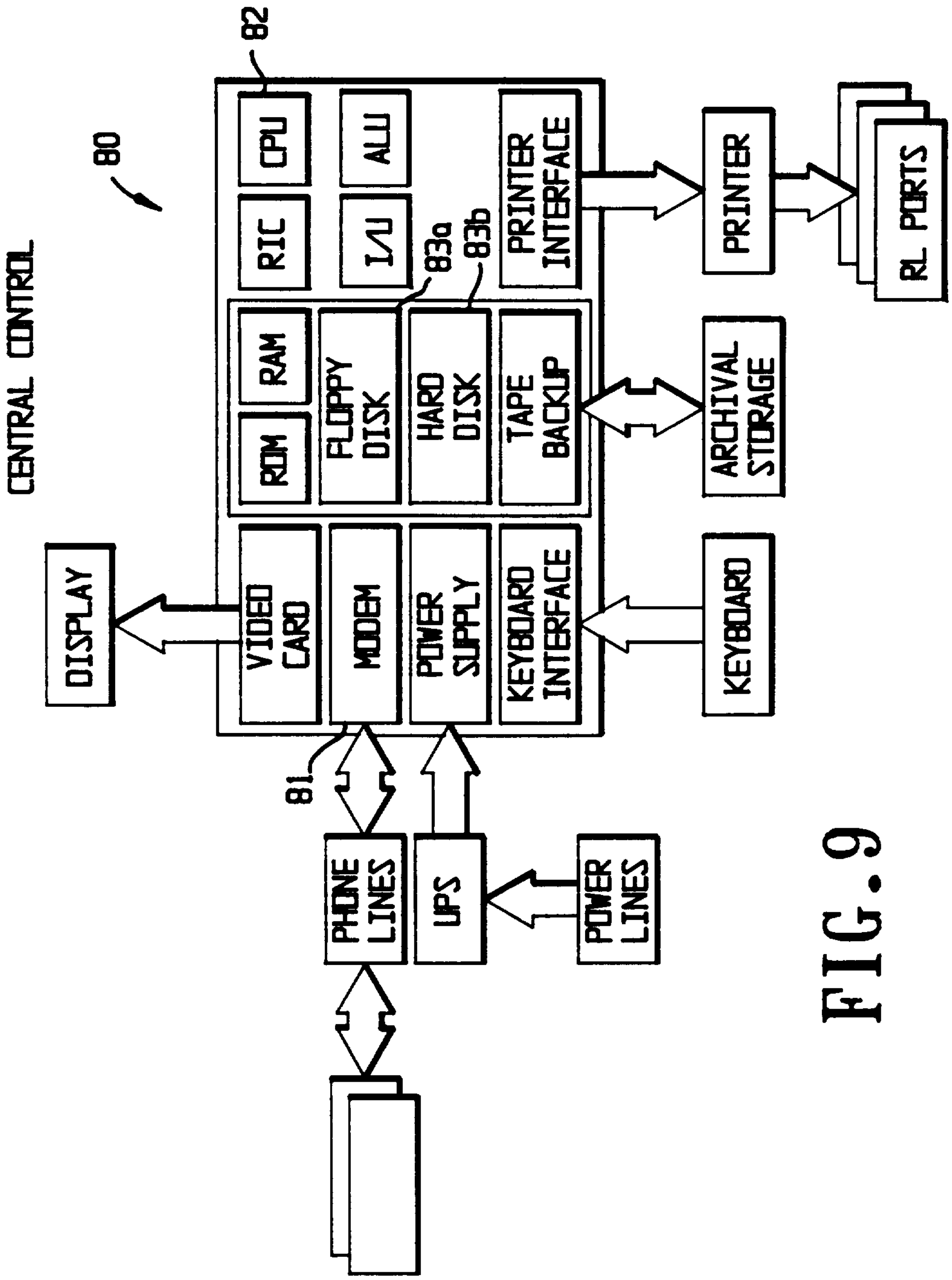

CENTRAL CONTROL
80
82
CPU
RIC
ALU
I/U
PRINTER INTERFACE
PRINTER
RL PORTS
RAM
ROM
FLOPPY DISK
83a
83b
HARD DISK
TAPE BACKUP
ARCHIVAL STORAGE
VIDEO CARD
DISPLAY
MODEM
POWER SUPPLY
KEYBOARD INTERFACE
KEYBOARD
81
PHONE LINES
UPS
POWER LINES

FIG.9