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(54) Title: POSITION MONITORING SYSTEM

(57) Abstract: Various embodiments include a system comprising a remote unit operable to determine a geographic location of the remote unit, and to transmit data indicating the location of the remote unit, the remote unit coupled to a subject to be tracked, the remote unit operable to provide a stimulation to the subject and a base unit operable receive the data indication the location of the remote unit, to determine if the remote unit is within a defined perimeter, and to signal the remote unit to provide the stimulation to the subject if the remote unit is not within the defined perimeter.

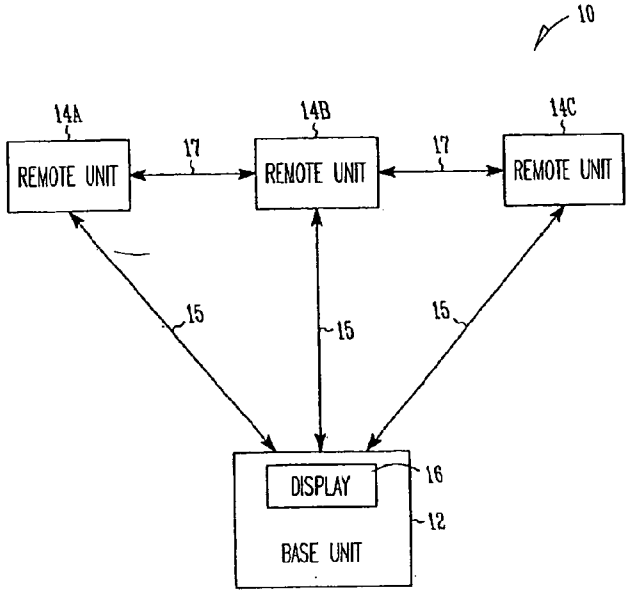

Fig. 1

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POSITION MONITORING SYSTEM

Cross-Reference to Related Applications

The present application claims the benefit of the filing date of U.S. provisional application Serial No. 61/030,832, filed on February 22, 2008, and the benefit of the filing date of U.S. provisional application Serial No. 61/055,918 filed May 23, 2008, and the benefit of the filing date of U.S. provisional application Serial No. 61/195,222, filed October 3, 2008, the disclosures of which are each incorporated by reference herein.

Background

Parents and others responsible for supervising the activities of children may sometimes find it difficult to ensure that such children do not wander away if playing outdoors. In addition, it is also sometimes difficult to keep a pet, such as a dog, within a desired area in the absence of a fence or wall enclosing the area. Accordingly, there is a need for systems, methods, and devices to reduce these difficulties.

Brief Description Of The Drawings

FIG. 1 is a block diagram of a portable position monitoring system;

FIG. 2A illustrates various embodiments of a base unit including a portable base unit having a visual display;

FIG. 2B illustrates various embodiments of a base unit including a portable base unit having a visual display;

FIG. 3A illustrates a visual display provided by a visual display of a base unit;

FIG. 3B illustrates another visual display provided by a visual display unit of a base unit;

FIG. 3C illustrates still another visual display provided by a visual display of a base unit;

FIG. 4 illustrates a base unit used in a fence definition mode;

FIG. 5 illustrates a particular implementation of the positional monitoring system including a pet collar;

FIG. 6 illustrates a pet location monitoring system according to various embodiments;

FIG. 7 illustrates an illustrative set of zone configurations according to various embodiments;

FIG. 8A illustrates a positional monitoring system according to various embodiments;

FIG. 8B illustrates another positional monitoring system according to various embodiments;

FIG. 9 illustrates one or more of Operational Modes 900 of a base unit;

FIG. 10 illustrates application modules of a base unit.

FIGs. 12A and 12B illustrate various embodiments of a collar.

Fig. 13 illustrates embodiments of an antenna.

FIGs. 14A-K illustrate schematic diagrams, board layouts, and part placement diagrams for various embodiments of a GPS/radio frequency unit that can be directly attached to a collar that can be used to track a subject.

Detailed Description of the Embodiments

In the following detailed description of exemplary embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific exemplary embodiments which may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the various embodiments, and it is to be understood that other embodiments may be utilized and that logical, mechanical, electrical and other changes may be made without departing from the scope of this disclosure. The following detailed description is, therefore, not to be taken in a limiting sense.

The following embodiments and others may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a machine-readable medium, which may be read and executed by at least one processor to perform the operations described herein. A machine-readable medium may include any mechanism for

storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.), and others.

In the Figures, the same reference number is used throughout to refer to an identical component which appears in multiple Figures. Signals and connections may be referred to by the same reference number or label, and the actual meaning may be clear from its use in the context of the description.

According to one example embodiment of the inventive subject matter, there is disclosed a method and apparatus to allow a user to locate and track a number objects. In one example embodiment of the inventive subject matter GPS and RF technology are used to capture and report the coordinates of the remote tracked units to a central base unit that may in one embodiment be portable. Optionally, the base unit may have a fixed or stationary location The user may be presented with the location information on a LCD screen.

FIG. 1 is a block diagram of a portable position monitoring system 10. In various embodiments, positional monitoring system 10 includes a portable base unit 12 and one or more portable remote units 14 that are each communicatively linked to the base unit 12 through a wireless communication link 15. In various embodiments, of the remote units 14 and the base unit 12 are GPS-enabled transceivers that transmit and receive signals from GPS satellites in a conventional manner so as to operably obtain and provide a geographical location for each of the remote units 14 and the base unit 12. According to some embodiments of the inventive subject matter, however, only the remote units 14 are GPS-enabled transceivers, with the base unit 12 optionally being preprogrammed to represent designated locations or boundaries. According to various embodiments, the base unit is fixed in position, such as in a home.

In various embodiments, one or more of remote units 14 is operable to obtain and provide a geographical location for the so operable remote unit 14 based on dead reckoning navigation capabilities.

According to various embodiments, the remote units 14 periodically or continuously transmit their respective GPS-identified location to the base unit 12 through wireless communication techniques including, for example, direct radio frequency transmissions. In various embodiments, one or more of remote units 14 periodically or continuously transmit their receptive locations to the base unit 12 through wireless communication techniques, the locations based on dead reckoning navigational techniques.

Such a wireless communication technique enables the system 10 to be fully independent of a separate and distinct network communication system. In various embodiments, positional information for one or more of remote units 14 is communicated to base unit 12 using communication link 15.

Through the self-contained network of the system 10, the base unit 12 is able to track the location, preferably the absolute position, of each of the remote units 14. In embodiments, wherein the base unit 12 is GPS-enabled to obtain its own geographical location, the base unit 12 can additionally track the positions of each of remote units 14 communicatively linked to the base unit 12 in the system 10 relative to one another and/or relative to the base unit 12. As such, the absolute and/or relative positions of each of the remote units in system 10 may be computed by the base unit 12, and displayed in a visual display 13 incorporated with the base unit 12. In various embodiments, the display provided at visual display 16 uniquely identifies each of the remote units 14 within the system 10, such that a user may readily discern the location and identity of each of the remote units 14 within the system 10. A variety of tracking and display options are contemplated as being useful in the visual display 16 portion of base unit 12. In various embodiments, system 10 includes more than one base unit 12.

System 10 as shown in FIG. 1 includes a plurality of remote units 14. However, the number of remote units is not limited to a particularly number of remote units. It would be understood that system 10 in some embodiments would include a single remote unit 14 and a base station 12. In various embodiments, system 10 includes up to some maximum number of remote units. In various embodiments, system 10 includes eight remote units. However, the

maximum number of remote units that are operable in conjunction with a base unit 12 is not limited to any particular number.

In various embodiments, one or more of remote units 14 are communicatively linked to another one of the remote units 14 through wireless communicative link 17. In various embodiments, wireless communication link 17 is a same type of communication link as communication link 15. In various embodiments, wireless communication link 17 is a different type of communication link as communication link 15. In various embodiments, communication link 15 and 17 are a same type of communication link, but operate at different carrier frequencies, the carrier frequency being a frequency or range of frequencies used as a carrier wave for the information being communicated between a given remote unit 14 and the base nit 12 or between different remote units 14.

In accordance with various embodiments of the inventive subject matter, the remote units 14 are capable of transmitting location information directly to the base unit 12 over a range of several kilometers. In fact, the system 10 may be capable of simultaneously tracking the positions of one or more units within system 10, wherein such units are, for example, up to 25 km apart from one another. It is contemplated, however, that such a range may be greater if the technology and power so permit. To obtain a range of up to about 25 km, the remote units 14 may transmit radio frequency wave forms at a power of at least about 2 watts. Such remote units 14, therefore, incorporate internal amplification mechanisms to generate the power necessary to carry a signal over many kilometers to the base unit 12. It is also contemplated that such range may be extended by relaying the GPS location information through intermediate transmittal receivers, or through a mobile telephone or data network.

The power required to generate the above-described signal can create significant drain upon the portable energy sources incorporated with the remote units 14. Accordingly, it is a further aspect of an embodiment to incorporate energy saving mechanisms in such remote units 14 to save as much power as possible in reserve for any necessary long-range communications to the base unit 12. For example, the remote units 14 may only intermittently transmit location information to the base unit 12. Such intermittent communication may be

designated by the user to occur only at selected times. As such, the communication between the remote units 14 and the base unit 12 may be automatically or manually generated, as is desired per application.

In some embodiments of the inventive subject matter, the remote units 14 are configured to receive direct communication from the base unit 12 and/or other remote units 14 within the system 10. As such, it is contemplated that each remote unit 14 within the system 10 may be configured to transmit their own respective GPS-identified location to at least selected ones of the remaining remote units 14 in the system 10, as well as to receive like information from such other remote units 14 in system 10, so that each remote unit 14 within the system 10 is able to track the positions of selected ones of every remote unit 14 within the system 10. To facilitate such tracking, the remote units 14 may further include a visual display similar to that described above with reference to the display 16 on the base unit 12. In some embodiments of the inventive subject matter, the base unit 12 itself may be configured for transmission of its GPS-identified location to the remaining remote units 14 within the system 10.

FIG. 2A illustrates various embodiments of a base unit 200 including a portable base unit 202 having a visual display 204. In various embodiments, portable base unit 202 is the base unit 12 as shown in FIG. 1. As shown in FIG. 2A, visual display 204 includes a viewable area 206. In various embodiments, viewable area 206 includes the area of a visual display screen that is operable to be controlled so as to provide a particular combination of visual images within the viewable area 206. In various embodiments, viewable area 206 includes a central screen area 208 surrounded by a plurality of individually controllable indicator segments 210. In various embodiments, individual ones, or various combinations of, the indicator segments 210 are controlled so as to provide a visual indication of the relative location of one or more remote units with respect to the base unit, as described further herein.

In various embodiments, a relative position between a base unit 212 and a remote unit 214 is visually depicted in the central screen area 208. In various embodiments, the base station 212 depicted on central screen area 208 represents a visual depiction of a position of the portable base unit 202 that includes the display on which base unit 212 is being depicted. In various embodiments,

remote unit 214 is any remote unit, such as but not limited to any of the remote units 14 as shown in FIG. 1, that is operable to provide positional information regarding the remote unit to the portable base unit.

As shown in FIG. 2A, line 216 represents a directional relationship between base unit 212 and remote unit 214, although it is not necessary for line 216 to appear on the central screen area 208. Line 216, when extended past the depiction of remote unit 214 on the viewable area 206, terminates at segment indicator 220. In various embodiments, when in a given mode where the relative position of remote unit 214 to base unit 212 is being tracked and displayed, indicator segment 220 will provide a visual indication of the directional alignment of base unit 212 and remote unit 214.

The visual indication provided by indicator segment 220 in not limited to any particular type of visual indication. In various embodiments, indicator segment 220 will simply be illuminated, wherein the remaining indicator segments 210 other than indicator segment 220 will not be illuminated. In various embodiments, indicator segment 220 will be displayed as a particular color that is different from the remaining indictor segments 210. By way of illustration, indicator segment 220 is displayed as white or a bright color, and the remaining indicator segments 210 are displayed as a dark color, such as a gray or black.

In various embodiments, indicator segment 220 will be animated in order to provide a visual perception of motion. By way of illustration, in some embodiments, indicator segment 220 will have strobing sets of lines 222 that are animated so as to produce a visual image of motion in the direction indicted by arrow 223. Arrow 223 is not necessarily visually displayed anywhere on the visual display area 206, but is merely indicative of the perceived direction of motion of the animation of indicator segment 220.

In various embodiments, other techniques to produce the visual perception of motion within a given indicator segment are used. By way of illustration, the visual perception of motion is created in an indicator segment such as but not limited to indicator segment 230 by alternatively illuminated a series of shapes 232 in a sequence so as to produce a visual perception of motion in the direction illustrated by arrow 234. Arrow 224 is not necessarily visually

displayed anywhere on the visual display area 206, but is merely indicative of the perceived direction of motion of the animation of indicator segment 230.

In various embodiments, each of indicator segments 210 are operable to be illuminated in order to provide a visual perception of motion indicative of a directional alignment between base unit 212 and a remote unit 214.

In various embodiments, as remote unit 214 moves relative to the position of base unit 212, the relative position of remote unit 214 to base unit 212 as depicted on visual display area 208 is updated. This is illustratively depicted in FIG. 2A by arrow 240 representing a change from position 244 to new position 246 by the remote unit 214.

As a result of the movement represented by arrow 240, the extended alignment of line 216 changes, and the new alignment is represented by line 242. The extension of the new alignment represented by line 242 no longer extends to indicative segment 220, and instead extends to indicative segment 248. Based on the new alignment of line 242, indicative segment 220 will no longer be activated to indicate the directional relationship between base unit 212 and remote unit 214. Instead, indicative segment 244 will be activated to indicate the now present directional alignment between base unit 212 and remote unit 214 when the remote unit 214 is at position 246.

In various embodiments, if the portable base unit 202 being depicted on the viewable area 206 as base unit 212 moves relative to the position of the remote unit 214 resulting in the extended alignment between the portable base unit 202 and the remote unit 214 extending to a particular one of the indicative segments 210 that is different from the currently activated indicated segment, the currently activated indicate segment 210 will no longer be activated, and a new indicative segment will be activated to illustrate the now present alignment between the portable base unit 202 and the remote unit 214.

In various embodiments, when the portable base unit 202 moves relative to the position of the remote unit 214, the relative position of the visual depiction of a base unit 212 as shown on the visual display area 206 will remain the same, but any visual indication of the alignment, and any other indications such as relative distance between the portable base unit 202 and the remote unit 214, will be updated to reflect the movement of the portable base unit.

It would be understood that both the portable base station 202 and the remote unit 214 could be moving simultaneously in a same or in different directions relative to each other. In such circumstances, the given one of the indicative segments 210 that is activated to indicate the current alignment between the portable base unit 202 and the remote unit 214 can be updated so that as the movement of either or both the portable base unit 212 and the remote unit 214 occurs, the given one of the indicative segments 210 that is activated indicates the most recent relative position.

In various embodiments, portable base unit 202 has a built in compass capability that allows the portable base unit 202 to know the directional orientation of the portable base unit 202. In various embodiments, a compass indication 250 is visually displayed on the central screen area 208, or in some other location on the viewable area 206.

In various embodiments, additional information 218 is displayed within the viewable area 206. Addition information is not limited to any particular information, and includes but is not limited to a quantity and units indication for a distance between the portable base unit 202 and the remote unit 214. By way of illustration, the additional information includes "57 yards," wherein the "57" represents a quantity for a distance between the portable base unit 202 and the remote unit 214, and the "yards" represents the units associated with the quantity. The additional information including "57 yards" is displayed on the viewable area 206 as an indication of the distance between the portable base unit 202 and the remote nit 214. In various embodiments, the units to be displayed are configurable, for example but not limited to configurable between English and Metric units. In various embodiments, the units to be displayed are configurable as to size of the unit, for example, inches, feet, yards, and miles. In various embodiments, the desired units and size of the units is selectable by a user.

In various embodiments, additional information 218 includes absolute position information based on longitude and latitude coordinates for either or both the portable base unit 202 and the remote unit 214. In various embodiments, other positional or geographical information is provided in the additional information 218, such as but not limited to time and date information,

altitude information, and movement information such as but not limited to velocity information, including instantaneous or average velocities associated with movements of either or both of the portable base unit 212 and the remote unit 214.

In various embodiments, portable base unit 202 includes one or more control/indicator devices 205. Control/indicator devices are not limited to any particular types of devices, or two any particular number of combination of devices.

Various embodiments include any types of devices such as pushbuttons, switches operable to provide and input signals, visual indicators such as lamps or light emitting diodes (LEDs) to provide visual indications, and audio input and audio output devices such s microphones and speakers respectively to provide audio input and output capabilities. In various embodiments, portable base unit 202 includes a power button 205A operable to be actuated to turn the portable base unit 202 on and off. In various embodiments, portable base unit 202 includes additional pushbuttons 205 B operable to provide some type of input to the portable base unit, such as but not limited to a mode select input. In various embodiments, any of pushbuttons 205A and 205B are illuminated type pushbuttons that can be illuminated to indicate a particular condition or state of portable base unit 212, associated with the pushbutton, such as an "on" condition.

In various embodiments, portable base unit 202 includes one or more visual indicators 205C and 205D. Visual indicators 205C and 205D are not limited to any particular type of visual indicators, and include any type or types of visual indicators that provide a visual indication, including but not limited to a indicator providing an illumination at a particular color or colors as an indication of some status or some state of the portable bas unit. In various embodiments, portable base unit 202 includes an audio output device 205E. Audio output device 205E is not limited to any particular type of audio output device, and includes any type of device, including but not limited to a speaker, operable to output audio sound. In various embodiments, audio output device 205E is operable to provide audio output of variable frequency, and for various time durations, and at various volume levels, including but not limited to sounds such

as beeps, or any combination of various sounds having various frequencies, various time durations, and various volumes, in order to indicate various types of information.

In various embodiments, base unit 200 includes an attached antenna 290. In various embodiments, base unit 200 includes an antenna jack 294 operable to allow an external antenna to be coupled to base unit 200. In various embodiments, base unit 200 includes one or more pushbuttons 292 located on a side surface of base unit 200.

FIG. 2B illustrates various embodiments of a base unit 250 including a portable base unit 202 having a visual display 204. In various embodiments, visual display 204 includes a viewable area 206 including a plurality of indicative segments and a central viewable area 208. As illustrated in FIG. 2B, central viewable area 208 includes a visual indication of a base station 212, a first remote unit 214, and a second remote unit 252. The graphical symbols used as the visual indications of the base station 212 (the square), the first remote unit 214 (the star) and the second remote unit (the triangle) are not limited to theses or any other particular graphic symbols, and may include any graphic symbols, text, or combination of graphic symbols and text, including numbers, to visually display and differentiate between the base station and any remote units that are depicted in a given visual representation being provided by base unit 250.

As illustratively shown in FIG. 2B, a relative position between base unit 212 and the first remote unit 214 is depicted by line 216, which extends to indicative segment 256, and a relative position between base unit 212 and the second remote unit 252 is depicted by line 254, which extends to indicative segment 260. In various embodiments, it is not necessary that either one of lines 216 or 254 are visually displayed the visual display 204. In various embodiments, lines 216 and 254 are merely illustrative of the relative position between the base unit 212 and remote units 214 and 252 respectively.

In various embodiments, indicative segment 256 is activated to visually indicate the relative position of base station 212 and the first remote unit 214, and indicative segment 260 is activated to visually indicate the relative position of base station 212 and the second remote unit 252. The visual indication utilized by indicative segments 256 and 260 are not limited to any particular type

of visual indication, and includes any of the types of visual indication for indicative segments described herein. In various embodiments, either one or both of indicative segments 256 and 260 utilize strobed lines 259 and 261 respectively to visually depict the relative position of the first remote unit 214 and the second remote unit 252 respectively . In various embodiments, the visual indication utilized by indicative segments 256 and 260 is the same type of visual indication. In various embodiments, the types of visual indication used by indicative segments 256 and 260 is different. By way of illustration, in some embodiments indicative segments 256 uses a first color to indicated that it is activated, and indicative segment 260 uses a second and different color to indicate that it is activated. In various embodiments, the different colors are incorporated with the strobed line segments, wherein the strobed line segments are displayed for both the indicative segments 256 and 260 but wherein the color of the indicative segments 256 and 260 are different.

In various embodiments, the color of the indicative segments used to indicate a relative potion of a particular remote unit matches the color used to display the symbol of the remote unit on the visual display 204. By way of illustration, if a green symbol is used to visually depict remote unit 214 on the visual display 204, indicative segment 256 will be activated to appear green when the relative position of base unit 212 and remote 214 align with indicative segment 256 on the visual display 204. A different color can be used to visually display the second remote unit and the indicative segment 260.

It would be understood that any number of different remote units could be displayed using any combination of symbols, numbers, text, and colors in order to visually discriminate the different relative positions of the base units and the any number of different remote units being tracked by a system within which the portable base unit is operating.

In various embodiments, base unit 250 includes a one or more displays of additional information 218 and 258. The information included in additional information 218 and 258 is not limited to any particular type of information, and includes but is not limited to any of the information described herein with regards to additional information 218 and FIG. 2A.

Referring again to FIG. 2B, in various embodiments additional information 218 includes information related to the first remote unit 214, including relative or absolute positional information associated with remote unit 214. In various embodiments, additional information 258 includes information related to the second remote unit 252, including relative or absolute position information associated with remote unit 252.

In various embodiments, only one tracked subject, such as 214 or 252, are shown on the viewable area 206 at any one time. Base unit 200 is operable to allow a user to select with subject being tracked is to be displayed at any given time. Selection of the subject being tracked that is to be displayed in various embodiments is made using a pushbutton.

FIG. 3A illustrates a visual display 300 provided by a visual display of a base unit. In various embodiments, visual display 300 is an illustrative display that is provided on a visually display 204 of a portable base unit 200 as shown in FIG. 2A, or is display 16 of base unit 12 as shown in FIG. 1.

In FIG. 3A, the visual display 300 includes a viewable area 302 including a graphical representation of a base unit 312 and a graphical representation of a remote unit 314. Although the base unit 312 is shown as paw-print including a number "1" within the paw-print, the graphical representation of the base unit 312 is not limited to such symbols. Further, although the remote unit 314 is depicted as a silhouette of a dog, the graphical depiction of the remote unit 314 is not limited to such a symbol.

FIG. 3A includes additional information 318, which includes a quantity of "429." In various embodiments, the quantity 429 indicates a distance, in some pre-determined units of distance, between base unit 312 and remote unit 314.

In various embodiments, viewable display 302 includes a plurality of indicative segments 310 that surround the central viewing area 308. A particular indicative segment 320 of the plurality of indicated segments 310 is activated to indicate the relative positional relationship between base unit 312 and remote unit 314.

In various embodiments, visual display 300 includes a visual indication 330 of a status indication for a battery powering the remote unit 314. The visual indication 330 is not limited to any particular type of indicative symbol, and in

various embodiments includes a numerical indication of the level of charge present on a battery located in remote unit 314. In various embodiments, battery identification symbol 331 is displayed near some portion of visual indication 330 to associate the visual indication of the battery state with the particular remote unit where the battery is located. In various embodiments, battery identification symbol 331 includes a number, for illustrative purposes a "1," that associates the visual indication 330 with the remote unit 314.

In various embodiments, graphical depiction of the remote unit 314 is only displayed when the subject being tracked is stationary, such as when a dog being tracked lays down, or in various embodiments including pointing dogs, is stationary and pointing, commonly referred to as being "on point."

In various embodiments, visual display 300 includes one or more additonal indicative display areas 340. In various embodiments, the additional indicative display areas 340 are a portion of the viewable area 302, and the control of the addition indicative display areas 340 is preformed by the same device and means as used to provide the other portions of viewable area 302. The additional inductive display areas 340 are not limited to any particular types of symbols, graphics, text, or colors, or to any particular combinations of symbols, graphics, text, or colors, and include any symbols, graphics, text and colors that can be generated and displayed on viewable area 302 and used to display information.

In various embodiments, addition indicative display 340 include a battery status indicator 342 operable to display a status associated with the battery included in a base unit that includes the visual display 300.

In various embodiments, additional indicative display areas 340 includes a signal strength indication 344 operable to display information related to whether a connection is established between the base unit 312 and remote unit 314. In various embodiments, signal strength indication 344 includes a number or some other indication of the strength of any signal being received from remote unit 314 by base unit 312.

In various embodiments, additional indicative display areas 340 includes a satellite signal indication 346. In various embodiments, satellite signal indiction 346 is operable to display information related to whether a satellite

signal connection is established by a remote unit being tracked, by the base unit 312, or both.

In various embodiments, additional indicative display areas 340 includes a home base position indication 348. In various embodiments, a home base position indication 348 is operable to display information related to one or more designated home base positions. In various embodiments, the visual display is operable to display information, including directional and distance information related to a relative or absolute position of the one or more designated home base positions. By way of illustration, when a user leaves their vehicle to walk their dog, the location of the vehicle can be designated as a home base position. The display is then operable to indicate through visual display the loction of the base unit with respect to the designated home base position.

FIG. 3B illustrates another visual display 350 provided by a visual display unit of a base unit. The visual display unit providing display 350 can be any base unit described herein. In various embodiments, visual display 350 is referred to as a "splash" display, and in various embodiments, is displayed during times when the base unit is preparing to provide a different visual display, such a when the base unit is first turned on, or when the base unit is changing from one mode to another mode. In various embodiments, visual display 350 includes an animated plurality of graphic symbols 352, such as but not limited to an series of squares, that are sequentially displayed in order to provide a visual perception of motion in a direction indicated by arrow 354. arrow 354 is not necessarily visible as part of visual display 350, and i merely included in FIG. 3B to represent the direction of the perceived motion provided by the animation of graphic symbol 352.

The type of animation used to animate graphic symbol 352 is not limited to any particular type or types of animation, and is chosen to be a type of animation that would indicate to a user that the base unit is operating, but is in some type of preparation or other in-between state.

FIG. 3C illustrates still another visual display 370 provided by a visual display of a base unit. In various embodiments, visual display 370 is an "all segments" display, wherein all the available segments programmed for display are provided at once, or in some pre-determined sequence. In various

embodiments, all of the plurality of indicative segments 310 are activated at a same time. In various embodiments, the plurality of indicative segments 310 are activated in some pre-determined sequence, such as but not limited to one at a time in a consecutive order around the viewable areas 308. In various embodiments, visual display 370 includes a first remote unit indication 312A and a second remote unit indiction 312B. In various embodiments, the number of remote units indications included in visual display 370 include the number of remote units that the base unit providing the visual display 370 is configured to track, as described herein.

FIG. 4 illustrates a base unit 412 used in a fence definition mode. According to various embodiments, a perimeter 420 may be defined by moving the base unit 412 along a desired path. In various embodiments, the base unit 412 is put into a mode to retrieve its GPS location data along a path and to store that data as the boundary for a perimeter 420. In this manner, the perimeter 420 is stored as a series of points or coordinates defining a path. By defining the perimeter 420 as a series of coordinates, the perimeter can take any shape, geometric or otherwise. Alternatively, according to another embodiment, the base unit 412 may be moved along a perimeter 420 and specific corner points or "fence posts" 422 may be input, and the perimeter 420 data may be stored with respect to the fence posts 422. In this manner, the perimeter may be stored as a number of points and vectors between the points. The perimeter may also be described as a circular area by defining a center point and a particular radial length. Other methods of defining a perimeter are also contemplated as embodiments of the inventive subject matter. These methods include using two or more base units to create boundary points or lines based on the location of the base units.

The perimeter itself may be created in a number of ways. According to one embodiment of the inventive subject matter, a boundary creation tool may be used to create a customized perimeter. The boundary creation tool may reside on the base unit or alternatively on a personal computer or an internet website or other convenient places for a user to access. The tool may allow a user to create a perimeter as described above by recording GPS coordinates. Alternatively, perimeter information may be created by simple drawing of lines and points. In

yet another embodiment of the inventive subject matter, perimeter information may be downloaded from the a computer network, or created using mapping software. A number of embodiments are contemplated for the creation of the perimeter information. Additionally, the perimeter need not be fixed. Once defined, the perimeter may be moveable at a predetermined rate, or with reference to a base unit or a remote device, or some other mobile reference point.

FIG. 5 illustrates a particular implementation of the positional monitoring system including a pet collar 500. In various embodiments, pet collar 500 involves a remote unit 514 being incorporated into pet collar 500, wherein remote unit 514 can be, but is not limited to, any of the remote units 14 as shown in FIG. 1. In various embodiments, pet collar 500 includes the collar strap 502, and a remote unit 514 coupled to the collar strap 501. In various embodiments, the remote unit 514 is adapted to automatically periodically or continuously transmit its GPS-identified location to a base unit, such as but not limited to base unit 412 as illustrated in FIG. 4, so that the pet owner may monitor the location of the pet wearing collar 500.

A variety of operational options may be further included in such a system to enhance the overall effectiveness of the location monitoring apparatus.

In various embodiments, collar 500 includes a stimulation module 510. In various embodiments, stimulation module 510 is operable to receive signals from a base unit (not shown in FIG. 5), the signals requesting that that stimulation be provided at the collar 500. In various embodiments, stimulation module 510 includes one or more devices operable to produce and provide one or more forms of stimulation. In various embodiments, stimulation device 512 includes a device operable to provide an audio sound as a stimulation. In various embodiments, stimulation device 512 includes a device operable to provide vibration as a stimulation.

In various embodiments, stimulation module 510 includes an audio device, such as a buzzer or a speaker, operable to provide audio sound as a form of stimulation. In various embodiments, stimulation module 510 is coupled to probes 526, wherein stimulation module 510 is operable to provide electric power to the probes 526 as a form of electrical stimulation. In various

embodiments, stimulation module 510 includes a scent generator 514 operable to generate and release an odor in the area of collar 500 as a form of stimulation.

In various embodiments, stimulation module 510 is operable to provide different forms of stimulation at a same time. In various embodiments, stimulation module 510 is operable to provide a first form of stimulation during a first time, and then a second and different form of stimulation at a second and subsequent time. In various embodiments, stimulation module 510 provides one or more types of stimulation in response to one or more signal received at the stimulation module 510 that have as a source of the signals a device remotely located from the collar 500, such any embodiments of a base unit or a base station as described herein.

In alternative embodiments, the strap represented by pet collar 500 is a belt or a wrist band that can be worn by a child that is a subject to be tracked. Such belt or wrist band would not include the probes 526 and would not be capable of providing electrical stimulation. However, the belt or wrist band in various embodiments' includes device 512 operable to provide audio or vibratory stimulation.

FIG. 6 illustrates a pet location monitoring system 600 according to various embodiments. By way of illustration, a perimeter 620 as described above with respect to FIG. 4 is programmed into a base unit 612 to define a "safe-zone" within which the pet 626 may be allowed to freely roam. A collar 624, such as the pet collar 500 illustrated in FIG. 5 including a remote unit 614, is attached to the pet 626. In various embodiments, remote unit 614 any combination of the features described for remote unit 514, as described in conjunction with FIG. 5.

Referring again to FIG. 6, while pet 626 remains within the perimeter 620, pet 626 is determined to be within the "safe-zone." In various embodiments, a relative position of base unit 612 and pet 626 is displayed on visual display 616 of base unit 612, and may be viewed by a user 628. In various embodiments, all or some portion of perimeter 620 is displayed on visual display 616, including showing the relative position of pet 626 to perimeter 620. Various positions 630, 631, 632, and 633 for pet 626 are shown in FIG. 6 as illustrative positions for pet 626 that are within perimeter 620. Since each of

these positions is within the defined "safe-zone," no alarm conditions would be activated by the base unit 612.

Once the remote unit 614 on the pet collar 624 attached to the pet 626 goes beyond the predefined boundary of perimeter 620, as illustrated by pet 626A at position 635, the pet 626 is determined to be outside the perimeter 620, and is therefore outside the "safe-zone." In various embodiments, an alarm is activated at the base unit 612 to alert the user 628 to the undesired location of the pet 626. In various embodiments, the alarm is an audio alarm, a visual alarm, or both an audio alarm and a visual alarm.

In other embodiments of the inventive subject matter, base unit 612 is configured to emit an instructional signal to remote unit 614 to activate an stimulation provided at collar 624 when pet 626 is outside the perimeter 620. In various embodiments, collar 624 and remote unit 614 include a stimulation module, such as stimulation module 510 as shown in FIG. 5.

Stimulation is not limited to any particular type of stimulation, and includes but is not limited to any type of stimulation that is perceivable by one or more senses of the subject being tracked. Stimulation includes electrical stimulation provided by probes, such as probes 526 as shown in FIG. 5, operable to provide an electrical stimulation to a pet 626 wearing the collar 624. In various embodiments, stimulations includes releasing a substance at or near the collar 624 that can be sensed as a smell by the pet 626 wearing the collar 626. In various embodiments, the released scent is a odor determined to be unpleasant to the pet 626, and thus when released as a stimulation, discourages the pet 626 from crossing the perimeter 620 to any position outside the "safe-zone."

In various embodiments, the stimulation provided is an audible tone that is detectable by the sense of hearing of pet 626. In various embodiments, the audible tone indicates that the pet 620 is outside perimeter 620.

In some embodiments, pet 626 does not return to within the perimeter 620 within the pre-determined time, additional stimulation, such as electrical shock stimulation, will be provided at the collar 624. In some such embodiments, pet 626 first receives an audio stimulation when first leaving the safe-zone as encouragement to return to the safe-zone within a given time in order to avoid the electrical stimulation. If pet 626 does not return to the safe-

zone within the given time, electrical stimulation is applied to pet 626. In various embodiments, the signals the prompt stimulation module of collar 624 to provide the stimulation are provided by base unit 612 as a transmitted signal received at remote unit 614, or directly by stimulation module included in remote unit 614.

In various embodiments, when it is determined that pet 626 has left the safe-zone and is outside the perimeter 620, base unit 612 provides an audio alarm signal. In various embodiments, display 616 of base unit 612 provides positional information regarding the location of pet 626, even when pet 626 is outside the perimeter 620. using the base unit 612, a user 628 is able to determine, by using visual display 616, the location of pet 626 even after the pet 26 has left the safe-zone.

In various embodiments, electrical pulse to an exterior surface or probe 526 extending from remote unit 614 and in contact with the pet 626, so as to "shock" the pet 626 when, for example, the pet has traveled beyond the predefined boundary. Other options and capabilities are contemplated as being useful according to various embodiments of the inventive subject matter, which options and capabilities may be directed through wireless radio frequency communication between the respective units of the system 600.

In various embodiment of positional monitoring system 600, perimeter 620 is set up around a number of dogs. By way of illustration, instead of pet 626 as shown at positional locations 630, 631, 632, and 633 being a single dog, each of these positions represents a different dog 626B-E at each of positional locations 630, 631, 632, and 633 respectively. Each dog 626B-E is wearing a pet collar 624 equipped with a remote device 614. From another location, the user 28 can monitor the dogs 626B-E as individual remote units using the base unit 612. In various embodiments, each of the dogs 626B-E are tracked by displaying on display 616 the positional relationship of each dog relative to base unit 612.

According to some embodiments of the inventive subject matter, displaying the location of each dog 626B-E on the display 616 may be confusing, or may be too much information to show if the display 616 is relatively small. The base unit 612 may optionally display the location of a

remote unit 614 coupled to a given one or more of dogs 626B-E only if the remote unit 614 is outside of the perimeter (see dog 626A). In this case, because remote unit 614A is outside of the perimeter 620, the base unit 612 alerts the user 628 and the display 616 shows the location of dog 626A wearing remote unit 614A with respect to the base unit 612. According to this embodiment, tracking and location information only needs to be displayed to the user 628 when a remote unit 614 has crossed the perimeter 620. This embodiment may also be applicable to teachers or parents trying to keep track of children, or a number of other similar situations.

FIG. 7A illustrates an illustrative set of zone configurations 700 according to various embodiments. Zone configurations 700 include a safe-zone 702 defined and bounded by a perimeter 710. Perimeter 710 can be established by any method or technique, such as but not limited to using the fence definition mode as described herein. As shown in FIG. 7, safe zone 702 includes one or more exclusion zones 720, 722, 724, and 726. Exclusion zones are zones that may be partially or completely within a "safe-zone" but are also determined to be off limits to subjects that might be moving within the safe-zone and are being tracked by a remote device within the positional monitoring system.

by way of illustration, perimeter 710 defines a "'safe-zone" within which it is desirable to have a child or a pet remain within. In addition, exclusion zone 724, by way of illustration, represents a swimming pool that, in the case of a child, may represent a hazard, and thus is excluded from the "safe-zone" space within perimeter 710.

In various embodiments, whenever a subject being tracked, (i.e. a child or a pet illustratively represented by remote unit 730), remains within the safe-zone defined by perimeter 710 and remains outside any defined exclusion zones, such as exclusion zones 720, 277, 724, and 726, no alarm conditions are activated on a base unit (illustratively shown as base unit 740 in illustrative house 742). being used to monitor and tack the remote units associated with the subject being tracked.

If the subject being tracked enters any one of the exclusions zones, as illustratively depicted by arrow 731 and remote unit 730, wherein remote unite 730 is tracked as being within exclusion zone 724 an alarm condition will be

activated at base unit 740. In various embodiments, the location of remote unit 730A is displayed on a display included in base unit 740. In this way, a user of the positional monitoring system can be alerted to the fact that the subject being traced has entered into an exclusion zone.

In various embodiments, an alarm is also activated if the subject being tracked exits the safe-zone defined by perimeter710, and indicated by arrow 732 and the position of remote unit 730B.

In various embodiments, the type of indication activated when a subject being tracked enters an exclusion zone is the same as when the subject being tracked exits the safe-zone as defined by the perimeter 710. In various embodiments, the type of indication includes an audio alarm. In various embodiments, the type of indication includes a alarm display provided on the display included in base unit 740. In various embodiments, the type of indication provided includes both an audio and a visual alarm.

In various embodiments, the type of indiction provided when a subject being tracked enters an exclusion zone is different from the type of indication provided when the same subject big tracked exits the safe-zone as defined by perimeter 710.

In various embodiments, different subjects being tracked have different safe zones and different exclusion zones associated with each individual subject being tracked. By way of illustration, a child (subject 1) and a dog (subject 2) may both be coupled to separate remote units, wherein each of the separate remote units are being tracked from a common base unit, such as base unit 740 in FIG. 7. In various embodiments, the perimeter 710 is the same for both the child and the dog, as this represents a boundary of a property where the child and the dog live. Exclusion zone 724 is a swimming pool, with is determined to be an excluded zone for both the child and the dog (assuming the child is allowed not use the pool unless and only when there is adult supervision present). Exclusion zone 720 surrounds a garden area, the child being allowed to go into the garden area, but the dog is not supposed to enter this same garden area. In various embodiments, different exclusion zones, including the pool of exclusion zone 724 but not including the garden of exclusion zone 720 are configured for the remote unit used to track the child, and exclusion zones including the pool

and the garden exclusion zones 724 and 7200 are configured for the remote unit used to track the dog. The activation of the alarms at base unit 740 would be capable of providing alarms specific to each remote units and based on the configuration designated for each of the particular remote units.

Continuing with the above illustration, an alarm would be activated with either the dog or the child, or both the dog and the child, are within the pool exclusion zone 724, and an alarm would only be activated if the dog entered the exclusion zone 720, regardless of whether the child was within the garden exclusion zone 720. No alarm condition would be activated if the child entered the garden exclusion zone 720.

In various embodiments, exclusion zones can be selectively activated and deactivated without losing the locational information associated with the exclusion zone. By way of example, the exclusion zone 724 associated with the swimming pool can be selectively activated when conditions are appropriate for the child to be in and around the swimming pool , such as when an adult is present to watch over the swimming pool area. When deactivated, the child can enter the exclusion zone 724 to swim and use the pool area without activating an alarm at the base unit. Once the child has finished using the swimming pool, the exclusion zone 724 can be activated again with respect to the remote unit being used to track the child, and the child would be allowed to play in the yard, but if the child would enter the exclusion zone 724, an alarm condition would be activated at base unit 740.

In addition, different types of stimulation can be provided to different subjects being tracked based on the same set of configured zones. By way of illustration, electrical stimulation can be provided to a dog if the dog leaves the "safe-zone" as defined by perimeter 710, and electrical stimulation can be provided to the dog if the dog enters any of the exclusion zones 720, 722, 724, 726. Such electrical stimulation would never be appropriate for use in connection with a remote device coupled to and used to track a child. A remote device coupled to a child is never to have the physical means, such as the electrical probes 526 as shown in FIG. 5 operable to deliver electrical stimulation.

However, a remote unit coupled to a child and used to track the child could have an audio alarm included as part of the remote device. In various embodiments, the audio alarm could be activated to provide the child with a audio indication that they are proceeding to move either outside of the safe-zone or into an excluded area.

Configurations of exclusion zones are not limited to any particular size or shape. Illustrative same zone 720 is rectangular, illustrative exclusion zone 722 is triangular in shape, and exclusion zone 724 is circular in shape. In various embodiments, any size or shape zones are that the positional monitor system is capable of defining can be used.

The extent of an exclusion zone is not necessarily limited to being totally or partially within any given perimeter. By way of illustration, exclusion zone 726 is has a portion 726A that is within the safe-zone defied by perimeter 710, and a portion that is outside the safe-zone defined by perimeter 710. In such instances, in various embodiments, the activation or non-activation of alarms associated with a particular remote unit, such as remote unit 730, is configured individually and separately for the safe-zone 710 and the exclusion zone 726, and is not necessarily impacted by a change to the location, or the activation or deactivation of one zone configuration versus another. By way of illustration, the location of perimeter 710 can be modified without affecting the loction and the configuration associated with any of exclusion zones 720, 722, 724, 726.

In various embodiments, any one of the perimeter 710 or the exclusion zones 720, 722, 224, 726 can be configured to be dynamical movable. By way of illustration, an exclusion zone 752 can be configured to be an area around a remote unit 750. As remote unit 750 moves, the area include in exclusion zone 752 moves so as to maintain a certain relationship, such as an area defied by a given radius, around remote unit 750. In various embodiments, exclusion zone 750 is configured to be an exclusion zone of another remote unit, such as the remote unit coupled to the dog, wherein if the dog comes within the exclusion zone defined by exclusion unit 752, an alarm is activated at base unit 740.

In various embodiments, one or more of the configurable zones is associated by a buffer zone and a second perimeter. By way of illustration, perimeter 710 can be associated with a buffer zone 762 and a second perimeter

762. In various embodiments, the location of second perimeter 763 is determined by a given distance 763 perpendicular to perimeter 710 at every point along perimeter 710. Other techniques can be used to determine the location of the second perimeter 760, including any techniques or methods described for establishing a first perimeter using a fence determination mode as described herein.

In various embodiments, the area in the space between the perimeter 710 and the second perimeter 760 is a safe-zone buffer area 762. In various embodiments, different types of alarms are activated depending on if the subject being tracked is outside perimeter 710 but within the safe-zone buffer areas 762, as represented by the location of remote unit 730B, and when the subject being tracked is outside the second perimeter 760, as represented by the location of remote unit 730C.

In various embodiments, a first stimulation is provided to a subject being tracked when the subject enters the safe-area buffer zone 762, and a second stimulation is provided to the subject when the enter an area outsize the second perimeter 760. By way of illustration, a dog being tracked by a remote unit is provided an audio stimulation when the dog enters the safe-zone buffer area 762. When the dog is provided the audio stimulation, the dog has been conditioned to understand that they are outside the safe-zone, and should not proceed farther. If the dog continues to move until they are outside the second perimeter 760, a second stimulation, such as electrical shock, will be provided at the remote unit collar to the dog. In this way, a dog will be provided a warning, such as the audible alarm, before being provided with an electrical stimulation, and this may discourage the dog from exiting the area of the second perimeter 760, and encourage the dog by the auto alarm to return to the safe-zone defined by perimeter 710.

In various embodiments, one or more of the exclusion zones includes a buffer area and a second perimeter. By way of illustration, exclusion zone 724 is surrounded by a second perimeter 764, wherein the area between the outside perimeter of exclusion zone 724 and 764 includes a buffer area 766. In various embodiments, when a subject being tracked, as represented by remote unit 730E, is within buffer area 766, a first alarm is activated at base unit 740. If the subject

being tracked proceeds into the exclusion zone 724, a second alarm is activated base unit 740. By way of illustration, second perimeter 764 represents a boundary line around a swimming pool area, the buffer zone 766 represents the area of the pool deck, and the area within exclusion zone 724 is the actual area of water within the swimming pool area. A first type of alarm, such as an audio beeping, can be activated if a subject being tracked, such as a child, enters the buffer areas 766. The alarm is intended to alert some that the child may be too near to the pool. If the subject being tracked enters the exclusion area 724, a second alarm, using a constant audio tone that is much louder than the first of beeping alarm, is activated to alert someone that the child may have fallen into the swimming pool.

In various embodiments, elevational information is provided as part of tracking, or as part of an alarm. By way of illustration, an indication of the elevation of the subject being tacked is provided as part of normal tracking, or as part of information provided when an alarm is activated, or both. In various embodiments, the elevational information can indicate that the subject being tracked, for example a child, has fallen into a pool or a pond, and is below the water level, or has fallen into a hole or a well. Elevational information can be useful in quickly location the subject being tracked, and as an indication of some unusually dangerous situation the subject being tracked has encountered.

FIG. 7B illustrates an illustrative exclusion zone 792 and base unit 790 according to various embodiments. As shown in FIG. 7B, no perimeters that are intended to contain a subject to be tracked are necessary. In various embodiments, only an exclusion zone, wherein the subject being tracked is not allowed to enter into, is included in the areas defined for the subject being tracked.

FIG. 8A illustrates a positional monitoring system 800. Positional monitoring system 800 includes a base station 820 that is operable to be wireless communicatively coupled to remote units, such as remote units 814A-C. Remote units 814A-C are not limited to any particular type or types of remotes units, and can include any type of or combination of typos of remote units described herein,. In various embodiments, base station 820 is operable to communicatively like with one or a plurality of remote units 814A-C using one

or more types of wireless connections 815-A-C respectively. Wireless connections 815A-C are not limed to any particular type or types of wireless connection, and include any types or types of wireless connections operable to provide wireless commutations between the remote units 815A-C and base station 820.

In various embodiments, base station is operable to perform error correction, re-amplification of received signals, and to function as a computer router.

In various embodiments, base station 820 is operable to be communicatively couple to one or more base units 812A-C. In various embodiments, a base unit such as base unit 812A is coupled to base station 820 using a connection 840A. connection 840 is not limited to any particular type of connection, and in some embodiment, is a wireless connection. In various embodiments, connection 840 includes physical conductors, such as but not limited to wires, busses, and transmission lines, operable to allow communications between base station 820 and base unit 812A. In various embodiments connection 840A is a same type connection as wireless connections 815A-C.

In various embodiments, base station 820 is operable to provide data processing of data received from remote units 814A-C, including but not limited to processing of positional data provided by any of remote units 814A-C. In various embodiments, base station 820 is operable to provide processed data, including but not limited to positional data associated with remote units 814A-C, to one or more of base units 812A-C. In various embodiments, base station 820 provides information about selected ones of remote units 814A-C to a given one, or some combination of, the base units 812A. By way of illustration, base station 820 is configurable to provide locational information provided by remote unit 814A to base unit 812A, to provide locational information provide by remote unit 814B to base unit 814B,and to provide locational informational information provided by remote unit 814C to base unit 812C. In various embodiments, base station 820 is operable to provide any one of base units 812A-C with locational information provided by any one, or any plurality of, the

remote units 814A-C. Thus, in various embodiments, base station 820 functions as router.

In various embodiments, base station 820 is operable to provide signal processing of signals sent from the any of the base units 813A-C to a given one, or some given combination of, remote units 814A-C. By way of illustration, when base unit 812A provides a signal intended to cause remote unit 814A to provide a stimulation, the signal from the base unit 812A is received and processed by base station 820. Base station 820 then produces a singal in a format and of a type that should be received and properly interpreted as a signal to provide the estimation by remote unit 814A.

In various embodiments, base station 820 is operable to process signals provided by a base unit that would not be received or properly interpreted by a remote unit, and to process these received signals into a format or into a type of signal that can be properly received and properly interpreted by the remote unit for which the signal was intended. In various embodiments, signals provided by remote units 814A-C and that would not be received or properly interpreted by a base unit are processed by base station 820 and transmitted these processed signals to the base units in a format and using a signal type that should be properly received and interpreted at the base units. In various embodiments, one or more of the remote units 814 are operable to provide signals that are in different format from one another, and the base station 820 is operable to transform these various signal formats into a same formant. This common format can then be transmitted to one or more of base units 813. In a similar fashion, signals provided by one or more of the base units 816A-C are provide signal in a format that is different from other ones of the base units. In various embodiments, and base station 820 is operable to transform these various and different formats into a single format that should be properly received and interpreted by one or more of the remote units 814A-C. Thus, in various embodiments, base station 820 is operable a to allow base units operating under different formats, or remote units operating under different formats, to operate as a system.

In various embodiments, a remote unit such as remote unit 814C is operable to communicate directly with a base unit when is connection is

operational, as represented by arrow 825, and to communicate with a base unit through base station 820 when communications directly with the base unit is not operational.

FIG. 8B illustrates a positional monitoring system 850 according to various embodiments. Positional monitoring system 850 includes a base station 820 located at a high position over a geographical barrier 822. A geographical barrier is not limited by any particular type of geographical barrier, and includes any type of geographical barrier that would inhibit certain types of communication links, such as but not limited to certain types of communication carrier waves that would not be functional to travel across the geographical beerier 822. By way of illustration, certain frequencies of carrier waves have reduced or no ability to travel and to traverse geographical barriers such as hills, or to pass through water. In some instance, certain types of transmission such as infra-red and transmissions associated with commercial televisions broadcasts or commercial Frequency Modulation (FM) transmissions are limited to substantially a line-of-sight type transmission. By providing a base station 820 at a location 822 above geographical barrier 822, a remote unit 814A located on one side of eh geographical barrier 822 is able to be communicatively link to a base station 812B on the opposite side of the geographical barrier 8722 through communications link 815A, base station 820, and communications link 840A.

By using a base station 820 to communicatively couple remote units and base station over geographic barriers, frequencies of signal that are useful with respect to the amount of bandwidth and information which the frequencies are capable of carrying but that have poor or inferior transmission characteristics with respect to terrain and range of transmission, can be implemented in communicative links 815 and 840 and still be operable to work over geographical barriers, such as geographic barrier 822.

The use of a compute hub 820 as illustrated in FIG. 8B allows for an extension of range over which the remote units 813A and the base station 812A can be communicatively coupled which using carrier frequencies or types of transmissions signals that would not operate over such a geographical barrier without the base station 820.

In various embodiments, base station 820 includes a solar panel or a solar cell, represented as device 890, and can derive some or all of its power requirements from device 890.

System Detail

According to one example embodiment, the system is made up of a single base unit and one or more remote units. The user manipulates the base unit to determine the location of the remote units, the direction from the user, the speed and heading of the remote unit and the distance to the remote unit from the base unit.

The following features may be available according to one or more embodiments of the inventive subject matter:

A base unit may be a portable battery operated device.

A remote unit may be a portable battery operated device.

The base unit may provide 24 hours of service under nominal usage conditions.

The remote unit may provide 72 hours of service under nominal usage conditions.

The base unit may provide a LCD screen for the user interface.

Remote Units

The remote units may be attached to the objects to be tracked. The remote units need to be small and relative light so that it can be attached to smaller pets. The remote unit may consist of a battery, a GPS module, and a RF module. The battery may include a charger or a charging circuit. The battery on the remote unit may be charged with an external power supply using a universal or custom connector according to some embodiments of the inventive subject matter. The system intelligence for the remote unit may be placed in the RF module.

The following features may be available according to one or more embodiments of the inventive subject matter:

The remote unit may be enrolled with only a single base unit at a time.

The remote unit may support reenrollment.

The remote unit may support 1 or more frequency for reporting GPS coordinates to the base unit.

The remote unit may send the GPS X, Y, Z to the base unit at regular intervals while it is active.

The remote unit may send the battery status to the base unit at regular intervals while it is active.

The remote unit may support a battery saver mode to preserve the battery life once the battery has less than a certain life left.

Base Unit

According to one example embodiment, the base unit is similar to a PDA (Portable Digital Assistant) in size, weight and portability. The base unit may contain a LCD screen, a number of buttons, and internally, GPS and RF modules. The base unit has the capability of determining its GPS location, communicate to the remote units through a RF link, determine and display a compass heading, generate a tone, display location information of the active remote units on a LCD screen, and take user input through pushbutton keys.

Through the course of operation, the user may be presented with several modes of operation. When the unit is powered on, the user may be presented with the startup mode. During the startup mode, the base unit is acquiring a GPS lock, and determining which remote units are powered on and within range.

The tracking mode is the mode where the remote units are tracked. In this mode, information is gathered from each active remote unit through the RF module, and displayed on the base unit LCD screen. The position of the remotes is displayed relative to the position of the base unit.

Fence definition mode is used to define a perimeter that is based on a collection of GPS waypoints. The user can monitor the fence building process by viewing the LCD screen. The base unit uses the GPS coordinates that it collects to build a geographical fence.

Enrollment mode is a mode that allows the user to pair a remote unit with the base unit. Once this pairing is performed, the base unit can track the remote unit. Otherwise, the base unit ignores the presence of the remote unit.

The base unit firmware may provide modes of operation that keeps the user informed of progress during the base units GPS first fix operation, normal tracking and locating operation, while building an electronic fence, and while the user enrolls remotes to the base unit.

FIG. 9 illustrates one or more of Operational Modes 900 of a base unit. In various embodiment, the base unit is any base unit described herein, including but not limited to base unit 12 of system 10 as shown in FIG. 1.

In various embodiments, Operational Modes 900 include any combination of the following:

Startup Mode 930;

Tracking Mode 932;

Fence Definition Mode 934;

Search Mode 936; and

Enrollment Mode 938.

In various embodiments, fence definition mode 934 includes either or both a Perimeter Definition Mode 934A and an Exclusion Zone Mode 934B. Modes of operation 900 are further described herein.

Startup Mode

With reference to the operational modes laid out in FIG 9, when the user powers on the base unit, it may enter startup mode 930. In startup mode 930, the base unit may attempt to acquire a GPS fix, and determine which remotes it can communicate with. Initially, the startup mode may display a splash screen. This splash screen may help "brand" the base unit and welcome the user.

Upon power on, the base unit may display a splash screen (or sequence of screens) for a desired number of seconds.

Once the splash screen has been displayed, the user may be given a visual indication, through the use of an icon, the status of the initial GPS fix.

After the splash screen has been displayed, the status of the initial GPS fix may be displayed. Until a valid initial GPS fix has been obtained, an acquiring GPS fix icon may be displayed.

The startup screen may also display a status bar on the LCD screen. While the GPS module in the base station is attempting to acquire an initial GPS

fix, the base station may determine which units are powered on and within range. The remote units found to be turned on and in range may be displayed as active in the status bar. The initial GPS fix status of the remote units found may also be displayed. To aid the user in the determination of the remaining battery life of the remote unit, a battery icon may accompany the remote unit icon.

The following features may be available according to one or more embodiments of the inventive subject matter:

In startup mode 930, the base unit may determine which bonded remote units are powered on and within range. Those bonded remote units found and within range may be displayed.

The remote units displayed in the wayside rest are may contain an acquiring GPS fix icon while the corresponding remote unit is acquiring the initial GPS fix.

Each remote unit displayed may contain a battery icon that provides an indication of remaining battery life. The battery icon may contain 0, 1, 2, or 3 bars corresponding to <15%, from15% to <50%, from 50% to < 85%, > 85% respectfully. According to an alternative embodiment, the battery icon may contain 0, 1, 2, or 3 bars corresponding to <25%, from25% to <50%, from 50% to < 75%, > 75% respectfully, or other combinations of battery life percentages.

Each icon displayed for the remote units may be unique as to allow the user to differentiate between them. The same icon for a remote unit must be used from one use session to the next.

Once the base station has acquired an initial GPS fix, the startup mode 930 has been completed and the base station operation may proceed to the tracking mode screen without further user intervention.

Once the initial GPS fix for the base station has been established, operation of the base station may continue in the tracking mode 932.

Tracking Mode

With reference to the operational modes laid out in FIG. 9, tracking mode 932 provides the user with direction, distance, velocity, and other status of the remote units being monitored.

The tracking screen contains a relative overall view of the base station and the remote units. The base station may be centered, with the remote stations displayed relative to their position. The built in compass may be used to rotate the remote units on the screen such the physical direction corresponds to the screen position. This provides a more natural interface such that the user doesn't have to translate the direction on the screen to a real world direction.

The following features may be available according to one or more embodiments of the inventive subject matter:

When fully zoomed in, the portion of the screen devoted to the tracking of the remote units may cover 150 feet along the X or Y axis, whichever is the smaller dimension.

When fully zoomed out, the portion of the screen devoted to the tracking of the remote units may cover 7500 feet along the X or Y axis, whichever is the smaller dimension.

A pair of physical switches may control the level of zoom in or zoom out.

The level of zoom in or zoom out may be communicated to the user on the LCD screen.

The tracking screen may rotate to maintain the compass bearing.

The compass bearing may be checked a number of times a minute.

According to one embodiment, the compass bearing may be checked once every second.

The remote units may be displayed in the tracking area scaled from the base unit, and position by compass bearing taking the current compass bearing into account.

In general, it is easier for the user to relate to positions of objects with respect to themselves. To aid in use of the base station, the base station may be placed in the center of the tracking screen with the remotes units in their corresponding positions around it.

The user may be provided with the ability of creating and using an electronic fence. This fence may be defined in GPS coordinates. The user will have the ability of turning on and off the electronic fence. When appropriate, the electronic fence may be displayed in the tracking screen, scaled and rotated as

appropriate. When the electronic fence is turned on, the user may be given an alarm when one or more remotes approach or pass through the electronic fence.

The following features may be available according to one or more embodiments of the inventive subject matter:

The electronic fence may have, and be displayed with a width that may compensate for the GPS inaccuracies.

The state of the electronic fence may be saved between sessions. If the electronic fence is turned off when the base unit is powered off, when turned back on, the electronic fence may remain off. Likewise, when the electronic fence is turned on when the base unit is powered off, it may be turned on when the base unit is powered on.

The electronic fence may display an indication in the tracking area of the LCD screen showing where the fence is, providing that the zoom factor allows it.

When the electronic fence has been turned on, an electronic fence icon may be displayed. When the electronic fence has been turned off, an electronic fence icon shall not be displayed.

If the user attempts to be turn on the electronic fence when one has not been defined; an alert may be presented to the user.

When one or more of the remotes approach and pass through the electronic fence when it is turned on, the user may be presented with an alert.

When the scale of the tracking screen is such that one or more remotes can no longer be drawn within the confines of the screen, the PIP mode for those remotes off the screen may be invoked. The remote icon may change to an arrow. This arrow may be pinned to an edge of the screen and may point from the base unit to where the remote unit would be displayed of the physical screen were large enough to contain it.

According to an alternative embodiment. the PIP may be shown in one of eight positions around the perimeter of the tracking screen. These PIP screens may be used to track the remotes that have left the screen (at the current scaling). The remote that is off the screen may be displayed in the one of eight PIP locations that most closely maintains it relative position. While the PIP is on the screen, it may be semitransparent to allow any other remote being track, and

under the PIP, to still be seen by the user. In the PIP, the base station may be either centered along the line, or the corner, whichever is closest to the center of the tracking screen. The scale from the PIP base station icon to the closest edge of the tracking screen may be such that it allows for the full range of the remote. To aid the user in the determining which remote is in the PIP and which may be under it, the icons contained in the PIP may be smaller than those used on the tracking screen.

Fence Definition Mode

With reference to the operational modes laid out in FIG. 9, according to another example embodiment, the method and apparatus of the inventive subject matter may allow the user to define an electronic fence utilizing a fence definition mode 934. In various embodiments, Fence Definition Mode 934 includes a Perimeter Definition Mode 934A, wherein the electronic fence is used to provide a perimeter that when a remote unit approaches and breaches the electronic fence, a warning is issued to the user. The electronic fence is defined by a set of GPS coordinates. Before the electronic fence can be used, the user must first define the fence.

In various embodiments, fence definition mode includes an Exclusion Zone Definition Mode 934B, wherein one or more exclusion zones are defined by defining an exclusion zone boundaries. In various embodiments, the defined exclusion zones are either completely or partially within an perimeter defined in the Fence Definition Mode 934. While the description includes various descriptions related to the definition of a perimeter fence, any techniques and method used to define a perimeter fence can be used to define an the boundaries of an exclusion zone.

The following features may be available according to one or more embodiments of the inventive subject matter:

When shipped, the base unit may not contain any electric fence definitions.

The base unit may support a number of electronic fence definition at a time.

To use the fence definition mode 934, the user may define or redefine the electronic fence by pressing the option and create fence buttons simultaneously,

slowly walk the fence perimeter, using the fence button to create a fencepost, and pressing the option and create fence buttons again. Since the fence is defined using GPS coordinates, the user may define the fence once the initial GPS fix has been accomplished. The user should be kept informed of the progress of the operation by displaying the portion of the fence currently defined and the number of fence posts that are stored in memory.

The following features may be available according to one or more embodiments of the inventive subject matter:

The fence may only be defined when the base unit is in the tracking mode 932.

When in tracking mode 932, the fence definition mode 934 may be entered when the option and fence button are pressed simultaneously. Alternatively, fence definition mode 34 may be entered by pressing a define fence button.

Once in fence definition mode 934, exit back to tracking mode 932 may be made when the option and fence button are pressed simultaneously.

When in fence definition mode 934, GPS coordinates are collected when fence posts are defined by pressing the fence button and are used to create the electronic fence.

The current progress of the fence definition may be displayed on the LCD screen along with the indication of the GPS lock and the number of fence posts defined.

When exiting from fence definition mode 34 into tracking mode, the electronic fence shall be turned on.

Search Mode

With reference to the operational modes laid out in FIG. 9, search mode 936 may optionally be used to aid the user of the base unit find one or more of the remote units. To preserve power, the remote units may only occasionally transmit their location. When in search mode 936, the remote units may transmit their position more frequently.

The following features may be available according to one or more embodiments of the inventive subject matter:

The base unit may support a search mode 936.

This search mode 936 may request all the remote units to return their GPS coordinates at a more frequent than normal rate.

An additional feature of search mode 936 is to allow additional base stations join the search. When additional base units join the search, those units may suspend tracking of their remote units and may start tracking the remote units of the target base station.

Enrollment Mode

With reference to the operational modes laid out in FIG. 9, before the base unit may communicate with to the remote units, an enrollment mode 938 may be entered in order for an enrollment process to take place. Once enrolled, the remote units and the base units are allowed to communicate with one another. The user may enroll a remote unit into one of a number of separate slots. The user may select which of the slots to use by pressing the corresponding enrollment button. The user may be allowed to reenroll the unit into a different slot, removing it from the previous slot.

The following features may be available according to one or more embodiments of the inventive subject matter:

The base unit may allow a remote unit to be enrolled into one of one or more slots.

The enrollment mode 938 may be entered/exited by simultaneously pressing the option and enrollment buttons. Alternatively, the enrollment operation may be available during the startup mode.

The base unit may allow a previously enrolled remote to be reenrolled into the same or a different slot. If it is reenrolled into a different slot, the remote is removed from its previous slot.

The base unit may indicate a successful enrollment operation by illuminating a LED once the enrollment operation has been successful concluded and may extinguish it once the enrollment button is released. If the enrollment operation is unsuccessful, the LED may not be illuminated.

Example Implementation

The following represents detailed descriptions of features and functions according to one or more example embodiments of the inventive subject matter. The following is not meant to limit the previous sections or the claims, it is provided as a detailed disclosure of a practical implementation according to one or more embodiments of the inventive subject matter. Various alternatives are available according to other embodiments of the inventive subject matter.

According to one example embodiment, there is provided a RF Module designed to provide RF communication for the "Base" and "Remote" products. The RF module hardware for the base and remote is very similar. The firmware has significant differences, as the module on the remote must communicate to the GPS module and the module on the Base must communicate to the Base processor.

Remote

The RF module on the remote performs the following functions:

- Receive commands from the base over the RF link. These commands put the remote in different "modes". These modes include various update rates and sleep modes.
- Configure the GPS module to the correct TricklePower settings for best battery life, based on the mode requested by the base.
- Poll the GPS module for GPS position data.
- Communicate GPS position data to the base over the RF link according to the current update rate.
- Monitor the battery level and communicate it to the base as part of the normal updates.
- Monitor a momentary switch for enrollment packet transmission.

Base

The RF module on the base performs the following functions:

- Transmit commands to the remote over the RF link. These commands put the remote in different "modes". These modes include various update rates and sleep modes.

- Communicate with the host processor over the UART connection. This communication allows the host to put the RF module in various states, enroll or delete remotes from the RF module, put enrolled remotes in various modes, and request data from the RF module relating to enrolled remotes.
- Keep track of latest position data from all enrolled remotes.
- Optionally keep a list of "emergency" remotes and provide a means of communicating the IDs of these remotes to other bases.

RF System Operation

Physical Layer

The link between RF modules operates on one of the five MURS channels. The frequency and bandwidth are as follows:

Band	Frequency	Bandwidth
MURS Chan 4	154.600 MHz	20kHz

In various embodiments, other frequencies are used as designated, for example, by the laws and regulations of the country where the systems are being operated.

The MURS bands allow 2 watts maximum transmit power. This, along with the favorable propagation characteristics of these frequency bands, allows for significant range.

Manchester encoding is used to encode the RF packet data. The narrow bandwidth requirements of the MURS bands forces a slow RF data rate of 2.777kbps. The RF data is modulated on the carrier in an FSK manner with a deviation of approximately 5kHz.

RF packet length from remote to base is approximately 78ms. RF packet length from base to remote is approximately 41ms.

Channel Usage

Channel usage may be on a random basis. Remotes that are updating on a certain schedule (every 2 seconds, for example) may dither their random

transmissions around the 2-second tick. The average time between packets may be 2 seconds, but the actual time between any 2 packets may vary randomly. Any device that wishes to transmit, remote or base, may first check to see if the channel is being used by another device in range. If so, the transmission is postponed for a random wait period, at which time the device may try again. The base and remote may each keep their receivers on anytime they are not transmitting.

Remote Operation

Modes

The remotes send GPS position updates to the base at regular intervals. The interval is configured by the base by transmitting to the remote. The minimum update interval is 2 seconds. Each separate update rate is defined as a different remote "mode". The remote also has an inactive mode, in which it does not transmit at all. During all modes, the remote has its receiver on to listen for new commands from the base.

The remote may decide to automatically drop down to a lower update rate if there has been no movement of the remote since the last update. The method for determining whether the remote has moved is TBD.

Immediate Update

The user may request an immediate update in GPS position for one of the remotes. In this case, the host tells the base RF module to command that remote to go to the fastest update rate, which is every 2 seconds. Upon reception of this command, the remote enters 2 second update mode, asks the GPS module for a new fix, and transmits the new fix back to the base on the next opportunity. The best case response time for the immediate update is 2 seconds, and the worst case is 4 seconds.

Enrollment

The base radio module is capable of enrolling up to three remotes. Each remote is enrolled by its 24 bit random ID, and is given a unit number by the base, ranging from 0 – 2. Enrollment is accomplished by putting the base

module in a special enrollment mode via the user interface, then causing the remote to transmit a special enrollment packet by holding a momentary switch down for three seconds. Alternatively, the option and enrollment buttons may be held down to accomplish enrollment.

Enrollment is a three packet process. The first packet from the remote is asynchronous, occurring when the momentary switch has been down for three seconds. If the base hears the enrollment packet from the remote and is in enrollment mode, it may transmit a response. This response is on the correct time slot for the unit number the base may enroll the unit into. Upon reception of the response, the remote stores its new unit number and operation mode, and transmits its acknowledgement. Only upon reception of the acknowledgement does the base enroll the remote. This ensures that the remote is only enrolled into the base if it has the correct unit number and avoids issues with multiple remotes having the same unit number.

The base module may allow a particular remote to be enrolled in only one slot. If enrollment is attempted again for the same remote, the base module may perform the requested enrollment but may delete any other enrollment of the same unit. The base module allows remotes to be enrolled over the top of other remotes, and also allows for the host to delete all enrolled remotes.

In addition to the three normal units, each base module allows for the enrollment of three emergency units. These units are enrolled via a special process of transferring the normal units from one base module into the emergency units of another base module over the RF link. The user interface on the receptor base is used to put the RF module in "emergency unit enroll mode". The user interface on the transmitting base is used to instruct the RF module to transmit its units over the RF link.

The host may instruct the base radio module to exit enrollment mode unconditionally. There is also a command that allows the host to query the base radio during enrollment mode. If an enrollment has occurred, the base radio informs the host and exits enrollment mode. If an enrollment has not occurred, the base radio informs the host and stays in enrollment mode.

RF Module Electrical Specifications

General

PARAMETER and CONDITIONS	UNITS	MIN	TYP	MAX
Supply Voltage	V	3.1		4.2
Current Consumption (receive mode)	mA	-	30	
Current Consumption (transmit mode)	mA	-	1000	
Current Consumption (shutdown mode)	mA	-	.1	
UART Data Rate	kBAUD		9.6	

RF Receiver

PARAMETER and CONDITIONS	UNITS	MIN	TYP	MAX
RF Reception Frequency	MHz	-	154.6	-
IF Frequency	MHz		10.7	
IF Bandwidth	kHz		30	-
Sensitivity (direct injection from a 50 Ohm source, antenna not installed)	dBm	-	-114	-107
Dynamic Range (direct injection from a 50 Ohm source, antenna not installed)	dBm	20	25	
Open Air Range	Feet	5,000	7,000	-

5

RF Transmitter

PARAMETER and CONDITIONS	UNITS	MIN	TYP	MAX
Frequency Range	MHz	-	154.6	-
Frequency Deviation	kHz	3	5	-
Output power (into 50 Ohms, antenna not installed)	dBm	27	-	33
Transmit duty cycle, Remote	%			3.9
Transmit duty cycle, Base	%		.01	4.1

Mechanical Specifications

Board

CHARACTERISTIC	DESCRIPTION

Size	1.775 in x 1.25 in
Material	.0625" FR4

External Connections

TERMINAL	DESCRIPTION	EXTERNAL CONNECTION
1	LED	Connection to anode of LED on external board, through resistor on external board.
2	+3V	Used for in-circuit programming, no connection to external board
3	+Vbatt	Direct connection to battery
4	MCLR/MOM_SW	Used for in-circuit programming, connection to momentary switch to ground on external board
5	UART_RX	Direct connection to UART_TX on external board
6	UART_TX	Direct connection to UART_RX on external board
7	GND	Direct connection to GND on external board
8	1pps	Direct connection to 1pps signal on external module

Production Configuration and Testing

Microcontroller Programming

The Microchip PIC18LF1220-I/SS Microcontroller is used on the RF module. This part may be programmed either before assembly or in circuit. There may be two different firmware versions, one for the base module and one for the remote module.

Functional Testing

The test fixture may communicate with the DUT by connecting to its UART lines. It may also have control of a test radio. The following procedure may be used to test the boards. The procedure is identical for base or remote radio boards.

Enter Test Mode

The DUT may enter test mode when reset with its momentary switch input held low. This is pin 4 of the connector, and TP6 of the board.

Dump Unique ID

EEPROM locations in the DUT microcontoller hold the unique 24-bit ID for the module. These locations must be programmed to random values by the test fixture. This occurs over the serial interface. The interface may use a standard UART communication format of 9600 baud, 8, N, 1. The command used to transfer the 24-bit ID to the DUT is a 4-byte command as follows, where ID1 is the most significant byte of the ID and ID3 is the least significant byte:

0x70

ID1

ID2

ID3

When the DUT receives this command, it may store the received ID in RAM. There may be no response back to the test fixture, and the ID may not be written to EEPROM at this time.

Send RF Packet to DUT

The test fixture may send an RF packet to the DUT. This packet is a special packet that may be recognized by the DUT when it is in test mode. Upon reception of this packet, the DUT may write the current ID residing in RAM to EEPROM.

Release Test Mode

The test fixture may release the test pin (TP6). The DUT may detect this release. If the DUT received the special RF packet from the test fixture while it was in test mode, it may read its ID from EEPROM and transmit a special packet of its own. This special packet will include its newly read ID. The test fixture will receive this packet and verify the ID against the one it sent to this unit over the serial interface.

Software/Firmware

Described below is an example embodiment of a design and working of the firmware embedded into a base unit with the exception of the workings of the embOS Real Time Operating system. The internal workings of the embOS Real Time operating system is described in the embOS Ref and embOS ARM Ref specifications. The architecture and design of a base unit application (firmware) as discussed below is one example embodiment of the inventive subject matter. The architecture provides the overall breakdown of modules and their higher-level interdependence with one another. The design may provide specifications of the public interfaces and public data for the modules along with their responsibilities. A module, when used in this document, is a group of public interfaces that perform a logical service for the application. It may be coded into a single or multiple source files.

The following coding examples are for illustrative use only and should not be taken as a requirement of their use. The necessity is that the code efficiently fulfills the requirements of the public interfaces.

Acronyms and Abbreviations

The following acronyms and abbreviations are used within the text of this document.

ADC	Analog to Digital Converter
API	Application Programming Interface
ECEF	Earth Centered, Earth Fixed.
Flash	A form of non-volatile memory
GPS	Global Positioning System
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LLA	Latitude, Longitude, and Altitude
SRAM	Static Random Access Memory

Definitions

- *embOS* – A real time operating system available from SEGGER Microcontroller Systeme GmbH. It is a multithreaded single application priority controlled operating system.
- *ECEF* – Earth Centered, Earth Fixed uses three-dimensional XYZ coordinates (in meters) to describe the location of a GPS user or satellite. The origin is at the center of the earth, with the Z-axis piercing the North Pole, and the XY-axis defines the equatorial plane.
- *IAR Embedded Workbench* – An integrated cross development environment for developing software for the ARM processor on Windows based hardware.
- *RF Module* – Radio transceiver module. The base station and each of the collars may contain one of these. The Transceiver may be used to exchange GPS position and control information between the base station and the collars.
- *JTAG Port* – A hardware debugging port supported by the IAR Embedded Workbench. It can also be used to burn the firmware into the flash memory before the debug cycle.
- NavMan GPS Receiver – A hardware implementation of a GPS receiver with an onboard processor and software. Communicates through a serial port to the base unit hardware.

Notation and Conventions

Accuracy and tolerance for API parameters and firmware measurements may be within 10% unless otherwise specified.

References

Reference	Title or Description
embOS Ref	embOS Real Time Operating System Software Version 3.28 CPU independent User's & Reference manual

Reference	Title or Description
embOS ARM ref	embOS Real Time Operating System CPU & Compiler specifics for ARM core using IAR Embedded Workshop
GPS Binary Protocol	SiRF Binary Protocol Reference Manual
NMEA Protocol	NMEA Reference Manual
3D Compass Ref	Applications of Magnetic Sensors for Low Cost Compass Systems
Sharp CPU Ref	LH75400/01/10/11 System-on-Chip User's Guide
RF Module Functional Spec	RF Module Functional Specification
RF Module Interface Spec	RF Module Interface Specification

Application Module Descriptions

FIG. 10 illustrates application modules 1040-1052 of a base unit 1012, along with any algorithms used may be described in the sections below. Base unit 1012 can be, but is not limited to, any of the base units described herein. Some modules are active objects that run in their own thread of execution. As active objects are running asynchronous with one another, collaboration and mailbox mechanisms are used to pass data between these modules.

Those modules that are not active objects, calls to the API are processed synchronously. Note that some of the modules that are active objects may present one or more API calls that are synchronous.

AD Converter

The AD Converter module 1040 is an API used to access the Analog to Digital converter. All access to the ADC may be controlled through the AD

Converter module 1040. The AD Converter module 1040 may be implemented using a singleton-coding pattern. The API may serialize the calls to the hardware so that calls from multiple threads of execution will work properly.

The API may implement an over sampling call. The over sampling call may up the ADC control bank to read the same analog line at all 16 of the samplings times. The raw ADC count values may be summed, 2 is added (as rounding), and the sum is then divided by 4. This increases the ADC precision from 10 bits to 12 bits (give or take some noise). While this API call is synchronous, the conversion is interrupt driven. This lessens the load on the CPU by causing the calling thread to be suspended while the conversion is taking place.

It is up to the consumer of this module to make sense of the return data. That is, the data being returned is raw. The caller of the AD Converter API must make the conversion from the raw data to a form more understandable to that module.

The following features may be available according to one or more embodiments of the inventive subject matter:

The AD Converter module 1040 may be implemented using a singleton-coding pattern.

The AD Converter module 1040 API may serialize access to the ADC hardware.

The AD Converter module 1040 API may implement an over sampling call to increase the precision of the ADC from 10 bits to 12 bits. Equation to use $\left[\left(\sum_{i}^{16} samples[i]\right)+2\right]/4$

The over sampling call may suspend until the conversion is complete using an interrupt coding pattern.

Battery Module

The Battery Module 1042 is an active object that monitors the voltage and the charging state of the LiIon battery in the base unit. It may also monitor the AC present state. It may periodically use the AD Converter module 1040 to

read the battery voltage and report the results to any registered collaborator. It may be coded using a singleton coding pattern.

The Battery Module 1042 may contain and make available through API calls the state from the last sampling. Each sampling period is made up of 20 programmable interval times. At each of the 20 sampling periods, the state of the battery charge and AC present is checked against those of the saved state. If the state of either of these two have changed, a sampling sequence is started. Otherwise, if 20 sampling periods have expired, again, a sampling sequence is started.

The Battery Module 1042 may make available through an API call, a method to synchronously cause a sampling sequence. The caller is blocked, a sampling sequence is performed, and the caller is resumed. The caller may then use the API to read the results of the sampling sequence.

The battery voltage is sampled across a resistor divider circuit. The AD Converter is set up to use Vcc as the upper reference voltage, and Gnd as the lower reference voltage. This produces 1024 counts across the 3.3V, or4096 counts across the 3.3V when over sampled.

The following features may be available according to one or more embodiments of the inventive subject matter:

The Battery Module 1042 may be coded using a singleton coding pattern.

Each Battery Module 1042 sampling interval may be made up of 20 sampling periods. The default sampling period may be 1 second.

During each Battery Module 42 sampling period, the AC present status may be sampled. If the AC present status has changed, then a full sampling sequence may be performed.

During each Battery Module 1042 sampling period, the Battery Charging status may be sampled. If the Battery Charging status has changed, then a full sampling sequence may be performed.

The Battery Module 1042 API may provide a method to perform a full sampling sequence synchronously.

The Battery Module 1042 API may provide API methods to retrieve the last sample battery voltage, the AC present status, and the Battery Charging status.

The conversion from the over sampled battery voltage ADC count to actual voltage may use the equation

$double(ADCcount) \times 260 \div 100 \times 3.3 \div 4096$

The Battery Module 1042 may provide an analyzer to convert the battery voltage into a number from 0 to 15 roughly indicating remaining battery life.

Compass Module

A base unit contains a 3-axis magnetic compass sensor with an accelerometer sensor used to determine the pitch and tilt of the platform. The Compass Module 1044, an active object, may periodically, using the AD Converter Module 1040, measure the raw X/Y/Z magnetic vectors magnitudes, along with the accelerometer pitch and roll magnitudes. The Compass Module 1044 performs the necessary calculations to generate a magnetic vector. The Compass Module 1044 also controls the degauss circuit; the set/reset straps of the magnetic compass sensors.

The Compass Module 1044 is an active object coded using a singleton-coding pattern. It maintains the last sampled state of the magnetic compass and exposes it through its API calls. Also included in the API calls is a method to perform a synchronous compass measurement; methods to perform calibrations; and methods to persist and restore the calibration data.

When the accelerator sensor is in a plane tangential to the earth, the gravitational vector is perpendicular to the pitch and roll axis and should read "center scale". This center scale reading needs to be calibrated to be zero. This is the only calibration that needs to be applied to the tilt/acceleration sensor.

The following features may be available according to one or more embodiments of the inventive subject matter:

The Compass Module 1044 may provide a calibration method that determines the ADC count offsets of the accelerometer pitch and roll axis when the platform has no tilt or pitch.

The pitch may be calculated by the following equation

$\phi = a\sin((countX - offsetX)/mCount)$ where $countX$ is the value read

from the AD Converter, *offsetX* is the corresponding calibration offset and *mCount* represents the AD Converter count at 1 G which is calculated.

The roll may be calculated by the following equation $\theta = a\sin((countY - offsetY)/mCount)$ where *countY* is the value read from the AD Converter, *offsetY* is the corresponding calibration offset and *mCount* represents the AD Converter count at 1 G which is calculated.

The magnetic sensor can measure the magnitude of the magnetic vector in all 3 axis. To properly convert the AD Converter counts, both the Op Amp reference voltage (Vref) must be measured as must the bridge offset. The bridge offset is measured during the degauss cycle, in between the set and reset pulses. To compensate for soft and hard iron influences, a further offset and scaling of the value measured along each axis is necessary.

The following features may be available according to one or more embodiments of the inventive subject matter:

The Compass Module 1044 may perform a degauss of the magnetic compass bridges once every 10 minutes.

During the degauss cycle, the Compass Module 1044 may read and determine the bridge offsets.

The Compass Module 1044 may provide calibration routines to determine the offsets due to soft and hard iron influence.

During the X/Y/Z calibration, Compass Module 1044 may keep track of the minimum and maximum values of $Xcompass - Vref - XbridgeOffset$, $Ycompass - Vref - YbridgeOffset$, and $Zcompass - Vref - ZbridgeOffset$..

The Compass Module 44 may calculate the magnetic compass offsets with the equations $(X\max - X\min)/2 - X\max$, $(Y\max - Y\min)/2 - Y\max$, and $(Z\max - Z\min)/2 - Z\max$

Given the pitch, roll and the magnitude of the magnetic vector in all three axes it is possible to determine the magnetic heading. Due to the inverted placement of the components (placed on the bottom side of the board), the equation differs slightly from the classic form.

The following features may be available according to one or more embodiments of the inventive subject matter:

The Compass Module 1044 may correct the magnetic vector magnitude values, read with the AD Converter, using the following equations,

$xRaw = (Xvalue - Vref - XbridgeOffset + Xoffset) * Xscale$,

$yRaw = (Yvalue - Vref - YbridgeOffset + Yoffset) * Yscale$, and

$zRaw = (Zvalue - Vref - ZbridgeOffset + Zoffset) * Zscale$.

The Compass Module 1044 may use the following equations to determine the magnetic heading of the unit.

$x = xRaw * \cos(\phi) + yRaw * \sin(\theta) * \sin(\phi) + zRaw * \cos(\theta) * \sin(\phi)$,

$y = yRaw * \cos(\theta) - zRaw * \sin(\theta)$, and $heading = a\tan 2(y, x) * 180 / \pi$

The Compass Module 1044 may perform sampling of the magnetic and accelerometer sensors at a rate of 1 complete sample each 1 second and convert those reading to a magnetic heading.

The Compass Module 1044 API may make available the last measured magnetic heading.

GPS Module

The purpose of the GPS Module 1046 code is to initialize the NavMan GPS receiver, receive and process sentences from it. The NavMan GPS receiver can send sentences in either a binary protocol or the more standard NMEA ASCII protocol. The GPS Module 1046 may setup the NavMan GPS Receiver to use the NMEA ASCII protocol.

The GPS Module 1046 may provide methods for the decoding of the NMEA sentences for GPS position ($GPGGA) and GPS velocity ($GPVTG). Additionally, the GPS Module 1046 may keep the last received and last valid decoded GPS position and the last received and last valid decoded GPS velocity data.

The GPS Module 1046 may provide API methods to work with distance and headings; and with easting/northing conversions. The equations used to convert the latitude and longitude to a given easting/northing starting at an arbitrary longitude are given in the figures below.

The following features may be available according to one or more embodiments of the inventive subject matter:

The GPS Module 1046 may be coded as a singleton active object with a collaborative mechanism.

The GPS Module 1046 may initialize the NavMan GPS module to return NMEA $GPGGA and $GPVTG sentences at a desired rate.

The GPS Module 1046 API may provide methods to decode the NMEA $GPGGA and $GPVTG sentences.

The GPS Module 1046 may contain API methods to convert latitude and longitude into easting/northing values using the equations in Equations Sets 1, 2, 3.

The GPS Module 1046 API may provide the last measured GPS position and the last measured valid GPS position.

The GPS Module 1046 API may provide the last measured velocity and heading reading in addition to the last measured valid velocity and heading reading.

$$a = 6378137$$
$$b = 6356752.3142$$
$$f = \frac{a-b}{b}$$
$$k_0 = 0.9996$$
$$e = \sqrt{1-\frac{b^2}{a^2}}$$
$$e'^2 = \left(\frac{ea}{b}\right)^2 = \frac{e^2}{1-e^2}$$
$$n = \frac{a-b}{a+b}$$
$$\phi = \frac{a\left(1-e^2\right)}{\left(1-e^2\sin^2(lat)\right)^{\frac{3}{2}}}$$
$$\nu = \frac{a}{\left(1-e^2\sin^2(lat)\right)^{\frac{1}{2}}}$$
$$p = (long - long_0)$$
$$\sin 1'' \cong \frac{\pi}{180*60*60}$$

Equation Set 1: Equations for Easting/Northing Part 1

$$A' \cong a\left[1 - n + \frac{5}{4}\left(n^2 - n^3\right) = \frac{81}{64}\left(n^4 - n^5\right)\right]$$

$$B' \cong \frac{3an}{2}\left[1 - n + \frac{7}{8}\left(n^2 - n^3\right) + \frac{55}{64}\left(n^4 - n^5\right)\right]$$

$$C' \cong \frac{15an^2}{16}\left[1 - n + \frac{3}{4}\left(n^2 - n^3\right)\right]$$

$$D' \cong \frac{35an^3}{48}\left[1 - n + \frac{11}{16}\left(n^2 - n^3\right)\right]$$

$$E' \cong \frac{315an^4}{51}\left[1 - n\right]$$

$$S = A'lat - B'\sin(2lat) + C'\sin(4lat) - D'\sin(6lat) + E'\sin(8lat)$$

Equation Set 2: Equations for Easting/Northing Part 2

$$K' = Sk_0$$

$$K'' = \frac{k_0(\sin 1'')^2 \nu \sin(lat)\cos(lat)}{2}$$

$$K''' = \left[\frac{k_0(\sin 1'')^4 \nu \sin(lat)\cos^3(lat)}{24}\right]\left[5 - \tan^2(lat) + 9e'^2\cos^2(lat) + 4e'^4\cos^4(lat)\right]$$

$$K'''' = k_0 \sin 1'' \nu \cos(lat)$$

$$K''''' = \left(\frac{k_0(\sin 1'')^3 \nu \cos^3(lat)}{6}\right)\left[1 - \tan^2(lat) + e'^2\cos^2(lat)\right]$$

$$y = northing = K' + K''p^2 + K'''p^4$$

$$x = easting = K''''4p + K'''''p^3$$

Equation Set 3: Equations for Easting/Northing Part 3

The GPS Module 1046 API may provide methods of converting ECEF coordinates into longitude and latitude coordinates

LCD Module

The LCD module 1048 is responsible for the placement of data onto the LCD screen hardware. It is also used to drive the backlighting of the LCD hardware. The hardware implements the LCD hardware as a simple frame buffer

device. The hardware supports either a 12 bit direct color, or an 8 bit palletized color model.

The following features may be available according to one or more embodiments of the inventive subject matter:

The LCD Module 1048 may be coding using a singleton pattern.

The LCD Module 1048 may provide API methods to control the LCD backlighting hardware.

The Base Unit may use the 8 bit palletized color model with a single fixed pallet loaded into the CPU onboard pallet RAM. The CPU also has a single DMA channel that can handle memory-to-memory data transfer. This makes it possible to use a off screen frame buffer to draw on, then use the DMA to transfer the contents into the LCD frame buffer. This may make the drawing look smoother. Additionally, the DMA channel can be used to quickly clear the frame buffer to a single pallet value.

The following features may be available according to one or more embodiments of the inventive subject matter:

The LCD Module 1048 may run the LCD hardware in 8 bit palletized color mode.

The LCD Module 1048 may provide a single global color pallet.

The LCD Module 1048 API may provide methods to move data from an off screen frame buffer to the on screen frame buffer using hardware DMA.

The LCD Module 1048 API may provide methods to fill a frame buffer with a single pallet color using hardware DMA.

All drawing, whether it is graphics or text, requires a graphics context. This graphics context contains information about background colors, foreground colors, currently selected font, clipping region, raster operation, etc

The graphics operations may include the ability to draw lines, rectangles, ellipses, and bitmaps. The text operations allow the drawing of a single character or a string of characters.

The following features may be available according to one or more embodiments of the inventive subject matter:

The LCD Module 1048 API may provide methods that perform drawing of lines, rectangles, ellipses, and bitmaps.

The LCD Module 1048 API may provide methods that perform drawing of single characters along with strings of characters.

The LCD Module 1048 API may provide multiple font sizes.

RF Module

The RF Module 1050 is used to communicate with the RF Radio hardware. All communications from the Base Unit to the RF Radio is through a serial UART port. Communications with the RF Radio hardware is with any desired protocol.

The RF Radio keeps in contact with a number of remote (collar) units that have been enrolled. The enrolling process is used to pair a remote collar unit with a single Base Unit. Once enrolled, the remote collar unit may communicate its GPS position to the Base Unit.

The RF Module 1050 API may provide methods of converting the ECEF coordinates returned by the remote collar unit into easting and northing numbers.

Sound Module

The Sound Module 1052 is used to drive the speaker in the base unit. The speaker is hooked up to one of the counter outputs through an amplifier circuit. The amount of amplification is controlled through a digital potentiometer. The Sound Module 1052 provides API methods to set the volume, play a single tone, or play multiple tones.

The following features may be available according to one or more embodiments of the inventive subject matter:

The Sound Module 1052 may be coded using an active object and singleton coding patterns.

The Sound Module 1052 may provide API methods to asynchronously play a single or multiple tones.

The Sound Module 1052 may provide an API method to control the volume of the sound.

In various embodiments, a dead reckoning module 1054 is included in a base unit. In various embodiments, the dead reckoning module 1054 includes various sensors operable to allow tracking of animals walking on four feet, such as but not limited to a dog. In various embodiments, the various sensors include gyros, accelerometers, and magnetic sensors, the magnetic sensors operable to determine variation in the earth's magnetic fields.

FIGs. 12A and 12B illustrate various embodiments of a collar 1200. In various embodiments, collar 1200 includes a Antenna for a GPS unit and a radio frequency transmitter all in a single unit 1202. In various embodiments, collar 1200 includes a battery pack 1204. In various embodiments, collar 1200 includes a sensor 1212, such as a Hall effect switch, to indicate to the unit 1202 that the collar may have fallen off the subject being tracked.

In various embodiments, the collar 1200 can form a collar having a circumference of between 12 and 28 inches, and is waterproof, vibration and shock proof. In various embodiments, positional tracking accuracy of the system including collar 1200 is 2 meters.

Fig. 13 illustrates embodiments of an antenna that can be used on unit 1202. In various embodiments, antenna 1300 includes a length of an antenna element, such as a wire looped back an forth to from a flexible antenna 1302. In various embodiments, antenna 1300 includes a additional length 1304. In various embodiment, the length of the element forming antenna 1302 is no more than 37 inches. In various embodiments, the length of additional section 1304 is no more than 8 inches.

FIGs. 14A-B illustrate a schematic diagram for various embodiments of a GPS/radio frequency unit that can be directly attached to a collar that can be used to track a subject.

FIG. 14C-E include a bill of material for the schematic diagram of FIGs. 14A-B.

FIG. 14F illustrates a board layout for a first side, the GPS side, of the GPS/radio frequency unit.

FIG. 14G illustrates a board layout for a second side, the radio frequency side, of the GPS/radio frequency unit.

FIGs. 14I-J illustrate a part placement diagram for various embodiments of a GPS/radio frequency unit that can be directly attached to a collar that can be used to track a subject, such as the unit of FIGs. 14A-B.

FIG. 14K illustrates a hole drill board layout the GPS/radio frequency unit.

Embodiments of the inventive subject matter may be referred to herein, individually and/or collectively, by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept if more than one is in fact disclosed. Thus, although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, may be apparent to those of skill in the art upon reviewing the above description.

The accompanying drawings that form a part hereof show by way of illustration, and not of limitation, specific embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

We claim:

1. A system comprising:

a remote unit operable to determine a geographic location of the remote unit, and to transmit data indicating the location of the remote unit, the remote unit coupled to a subject to be tracked, the remote unit operable to provide a stimulation to the subject; and

a base unit operable receive the data indication the location of the remote unit, to determine if the remote unit is within a defined perimeter, and to signal the remote unit to provide the stimulation to the subject if the remote unit is not within the defined perimeter.

2. A system comprising:

a portable remote unit including a dead reckoning unit, the dead reckoning unit operable to provide a locational fix for the portable remote unit based on data inputs associated with movements of the portable remote unit, the portable remote unit operable to transmit data indicative of the locational fix;

a base unit operable to receive the data indication of the locational fix and to display a visual indication of the locational fix based on the received data,

wherein a transmission of data between the portable remote unit and the base unit includes a radio frequency transmission on one of the five MURS channels.

3. An apparatus comprising:

a collar including a global positioning antenna coupled to a global positioning system, and

a radio frequency antenna coupled to a radio frequency transmitter, wherein the radio frequency antenna is formed as a flexible antenna coupled to and at least partially included within the collar, and the global positioning system and the radio frequency transmitter physically located on a same circuit board within the collar.

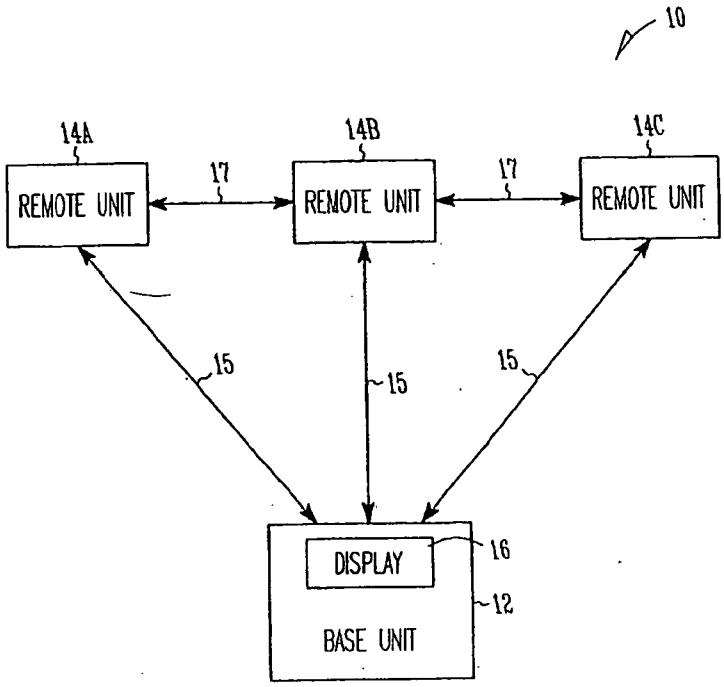
10
14A
14B
14C
REMOTE UNIT
REMOTE UNIT
REMOTE UNIT
17
17
15
15
15
DISPLAY
16
12
BASE UNIT

Fig. 1

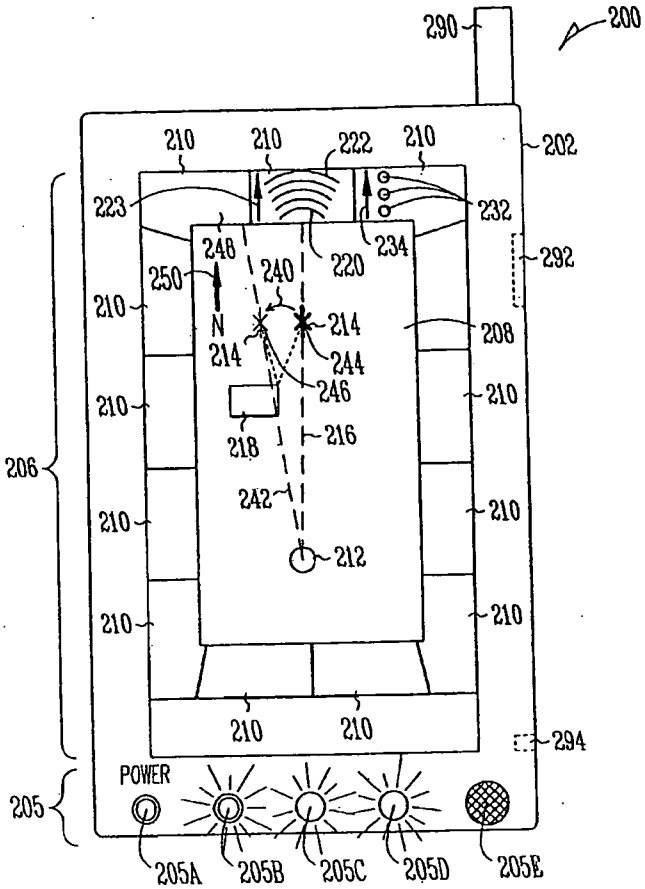
290
200
210
210
222
210
202
223
232
248
234
220
292
250
240
210
N
214
214
208
244
246
210
210
218
216
206
242
210
210
212
210
210
210
294
POWER
205
205A
205B
205C
205D
205E

Fig. 2A

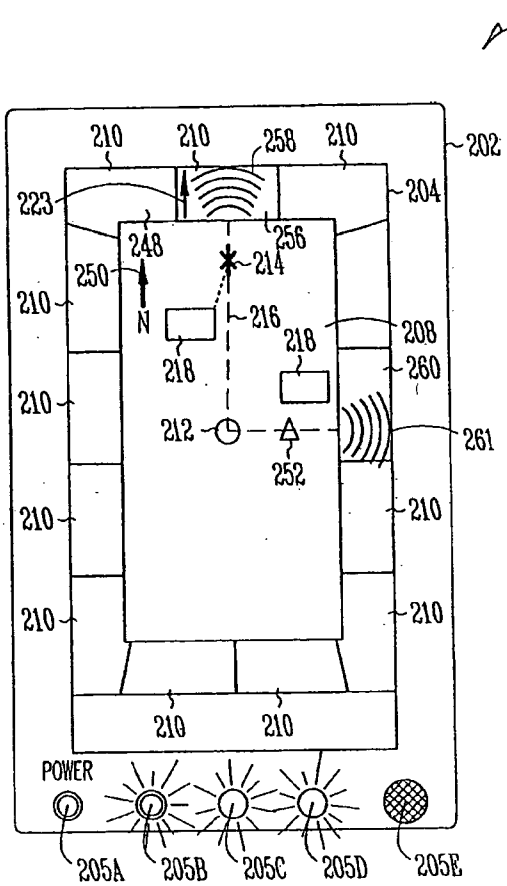
200
202
204
210
223
248
250
N
256
214
216
218
208
260
212
252
261
POWER
205A
205B
205C
205D
205E

Fig. 2B

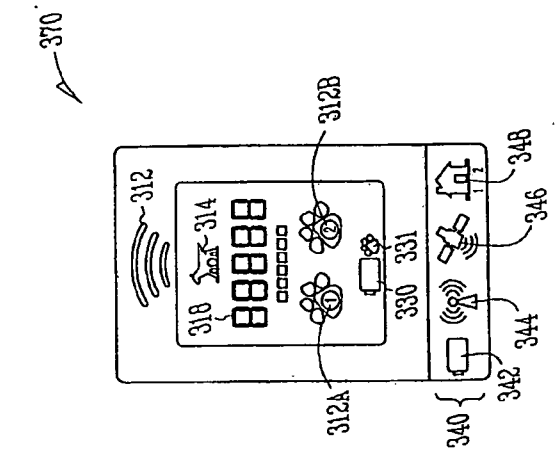

Fig. 3C

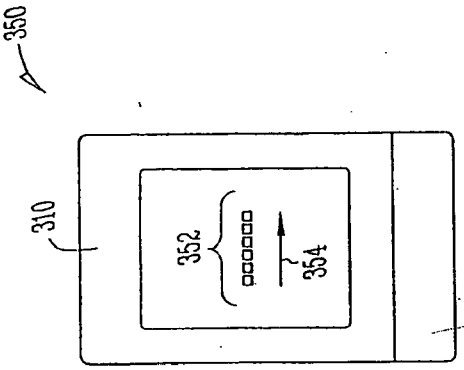

Fig. 3B

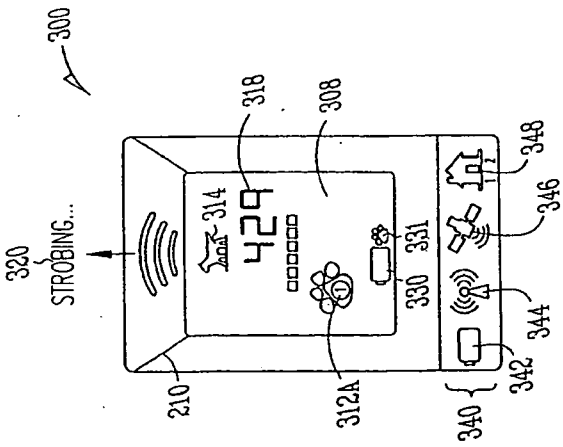

Fig. 3A

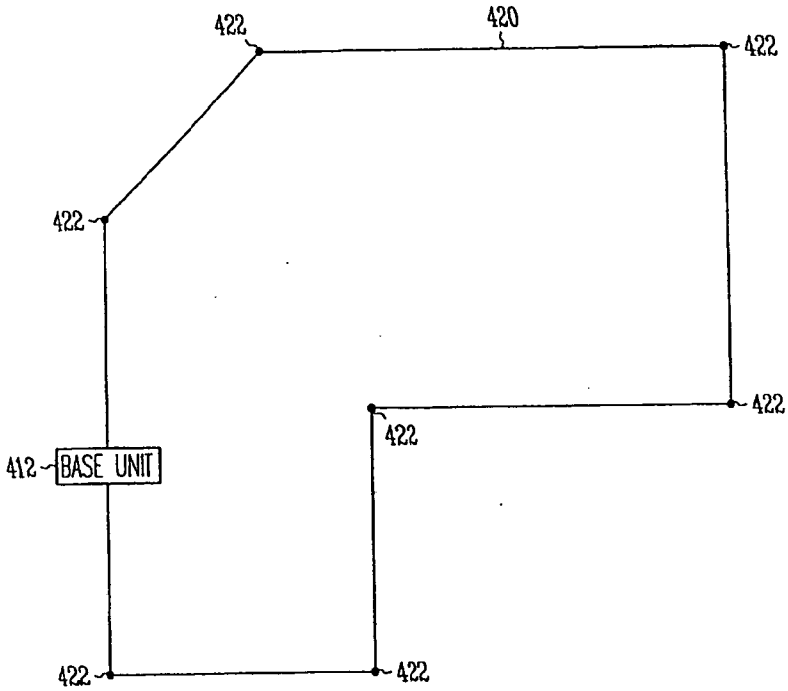
422
420
422
422
422
422
412
BASE UNIT
422
422

Fig. 4

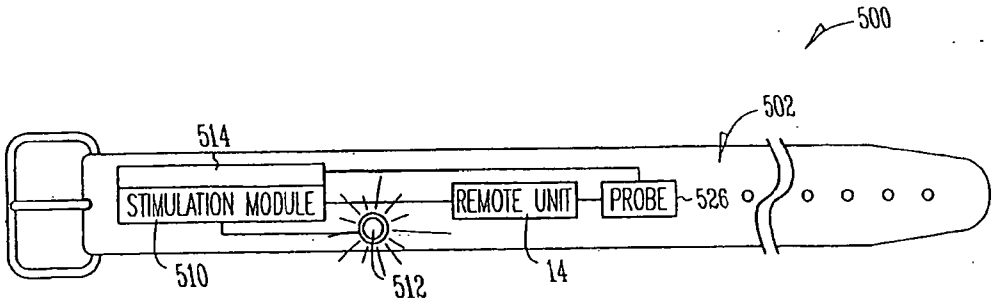
500
502
514
STIMULATION MODULE
REMOTE UNIT
PROBE
526
510
512
14

Fig. 5

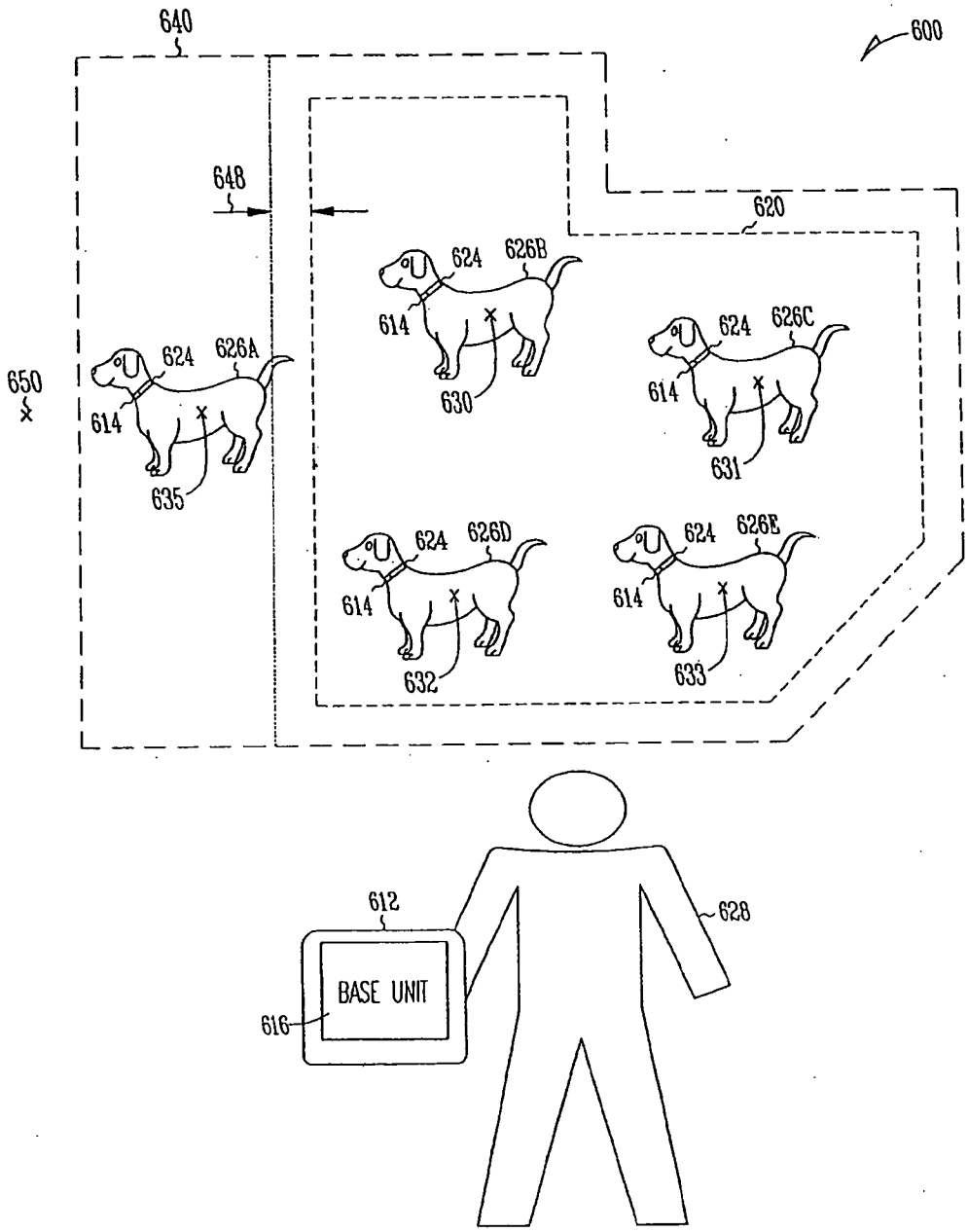
640
600
648
620
650
624
626B
614
630
624
626C
614
631
624
626A
614
635
624
626D
614
632
624
626E
614
633
612
628
BASE UNIT
616

Fig. 6

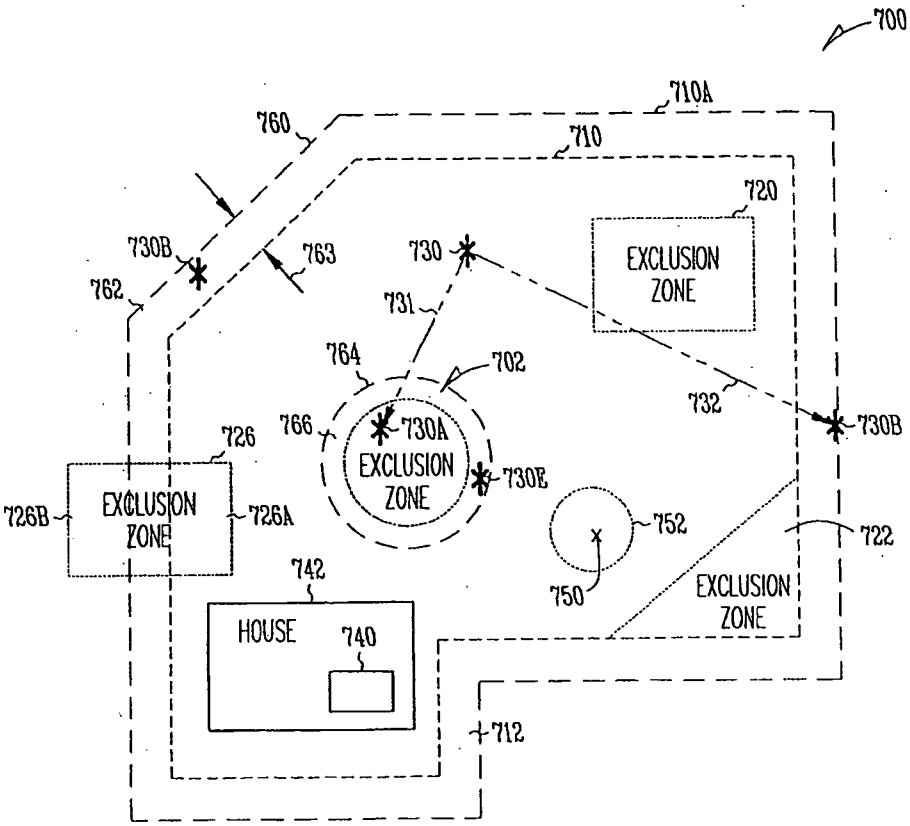
700
710A
760
710
720
730B
763
730
EXCLUSION ZONE
762
731
764
702
732
730B
766
730A
EXCLUSION ZONE
730E
726
726B
EXCLUSION ZONE
726A
752
722
742
750
EXCLUSION ZONE
HOUSE
740
712

Fig. 7A

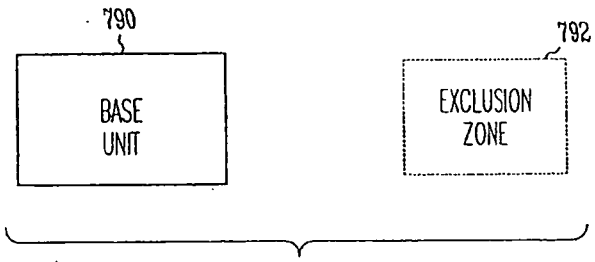
790
BASE UNIT
792
EXCLUSION ZONE

Fig. 7B

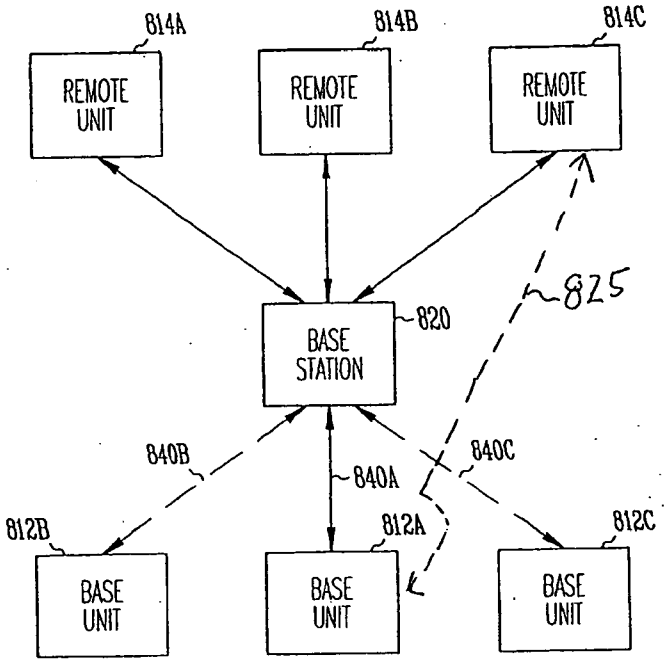
814A
814B
814C
REMOTE UNIT
REMOTE UNIT
REMOTE UNIT
825
820
BASE STATION
840B
840A
840C
812B
812A
812C
BASE UNIT
BASE UNIT
BASE UNIT

Fig. 8A

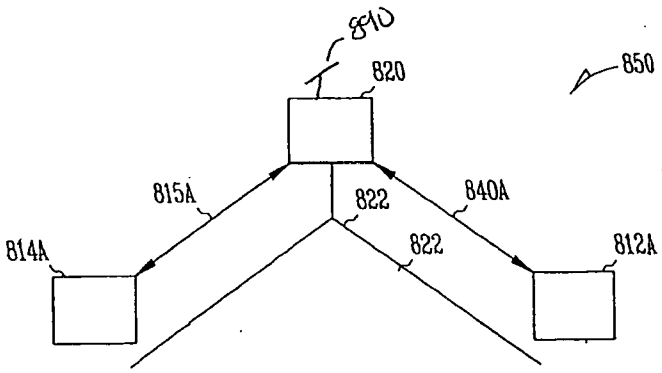
810
820
850
815A
822
840A
814A
822
812A

Fig. 8B

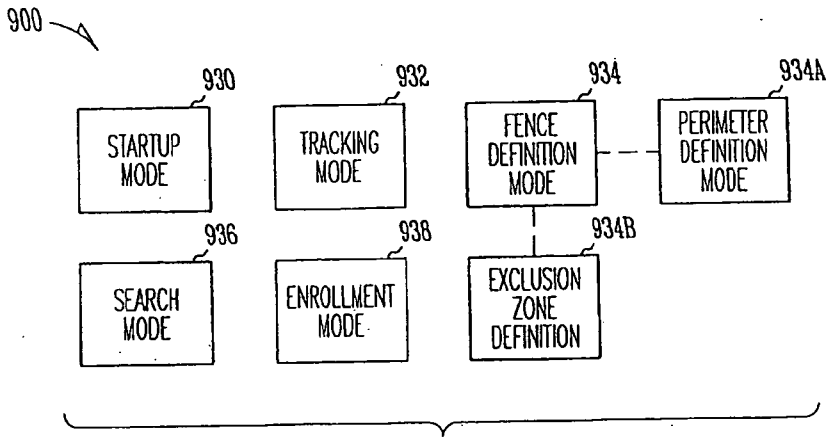
900
930
STARTUP MODE
932
TRACKING MODE
934
FENCE DEFINITION MODE
934A
PERIMETER DEFINITION MODE
936
SEARCH MODE
938
ENROLLMENT MODE
934B
EXCLUSION ZONE DEFINITION

Fig. 9

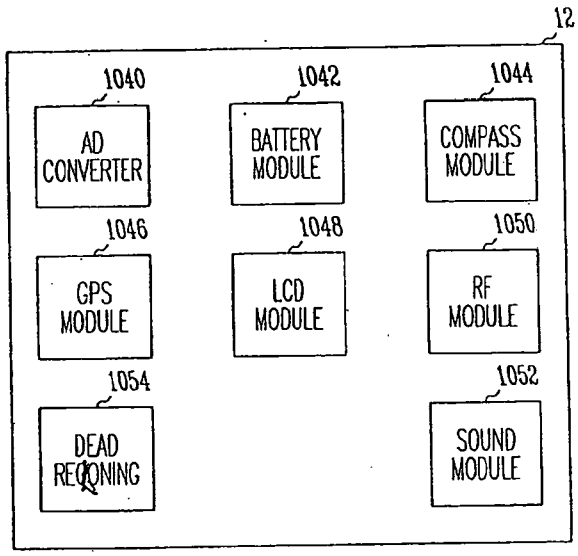
12
1040
AD CONVERTER
1042
BATTERY MODULE
1044
COMPASS MODULE
1046
GPS MODULE
1048
LCD MODULE
1050
RF MODULE
1054
DEAD RECKONING
1052
SOUND MODULE

Fig. 10

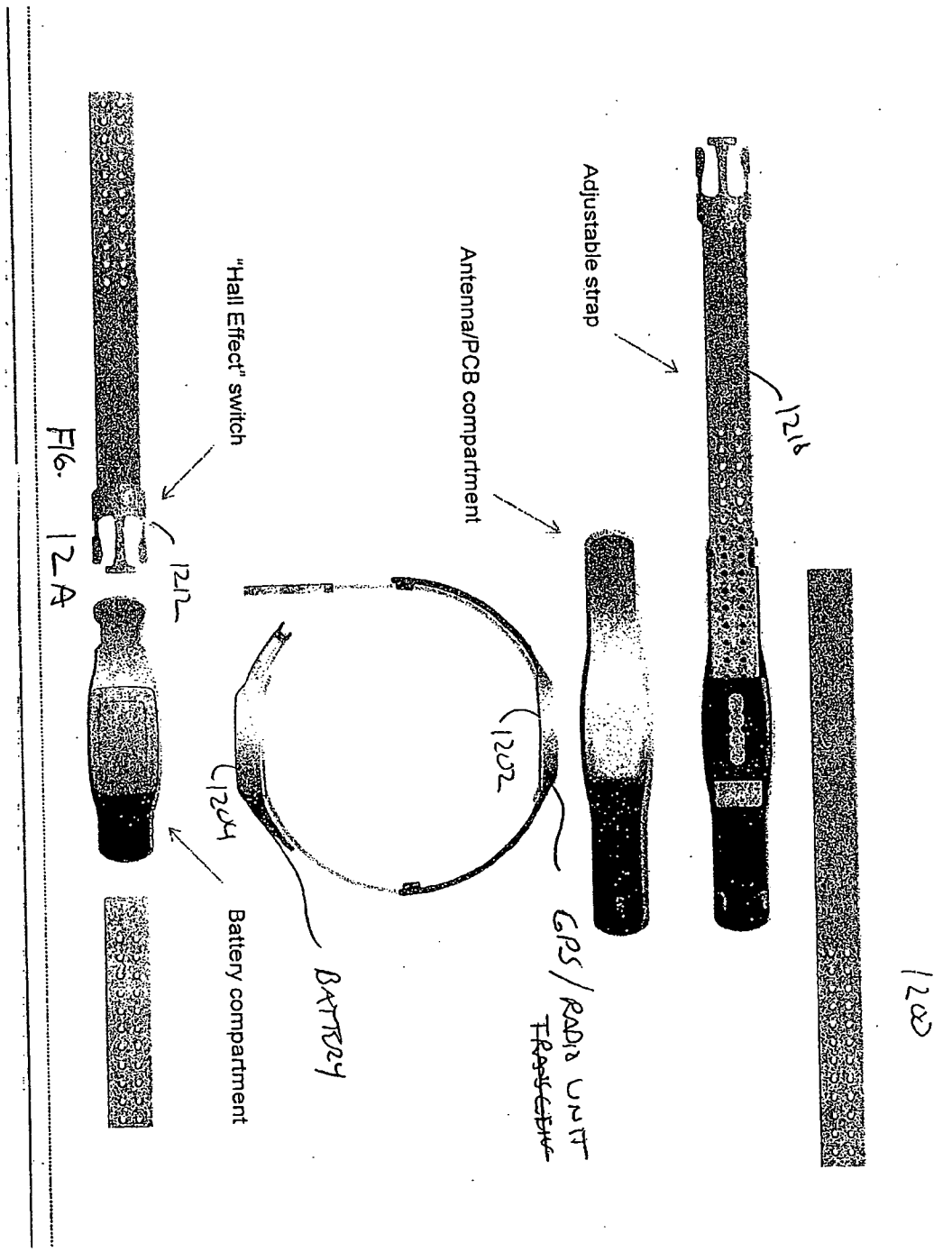
"Hall Effect" switch
Antenna/PCB compartment
Adjustable strap
Battery compartment
GPS / RADIO UNIT
BATTERY
1202
1204
1206
1208
1210

FIG. 12A

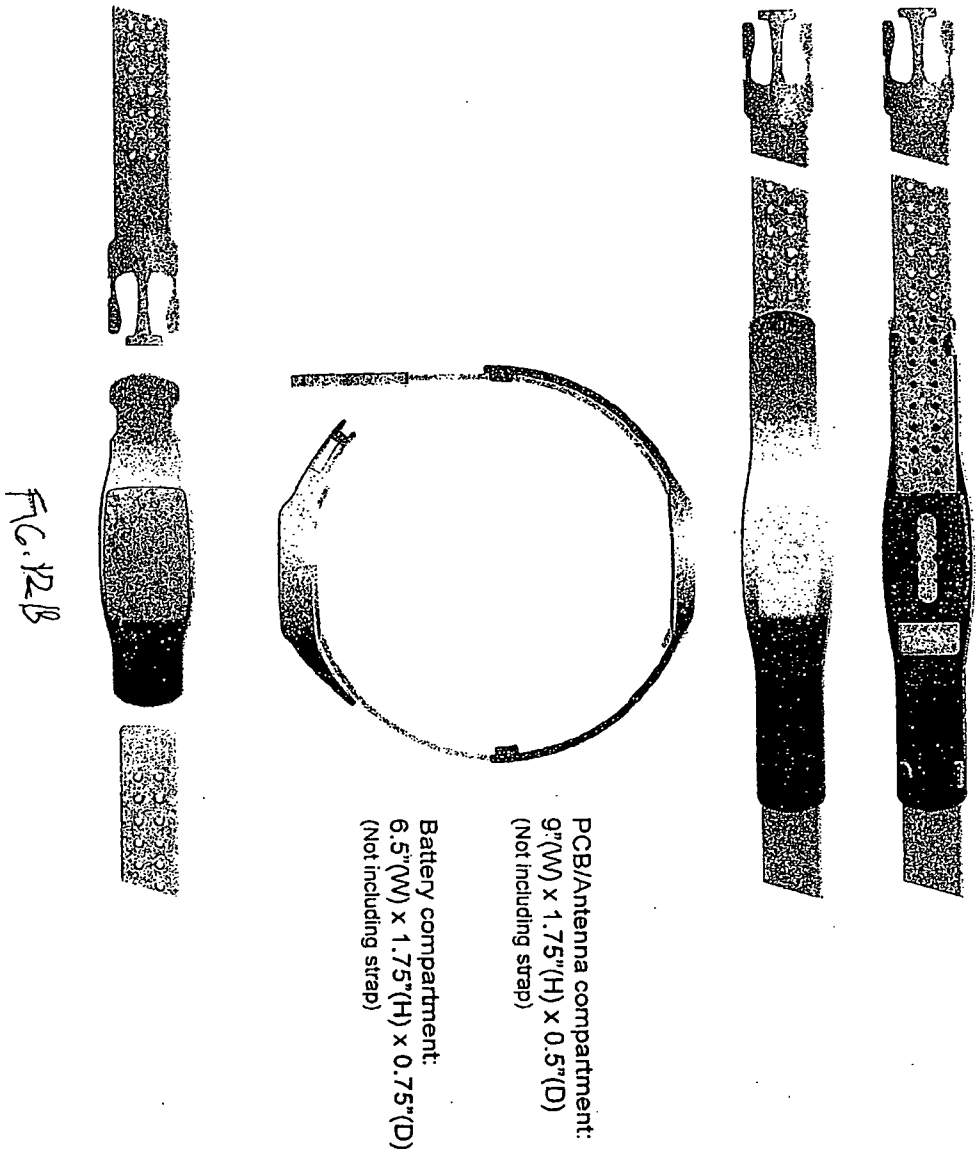
PCB/Antenna compartment:
9"(W) x 1.75"(H) x 0.5"(D)
(Not including strap)
Battery compartment:
6.5"(W) x 1.75"(H) x 0.75"(D)
(Not including strap)

FIG. 12B

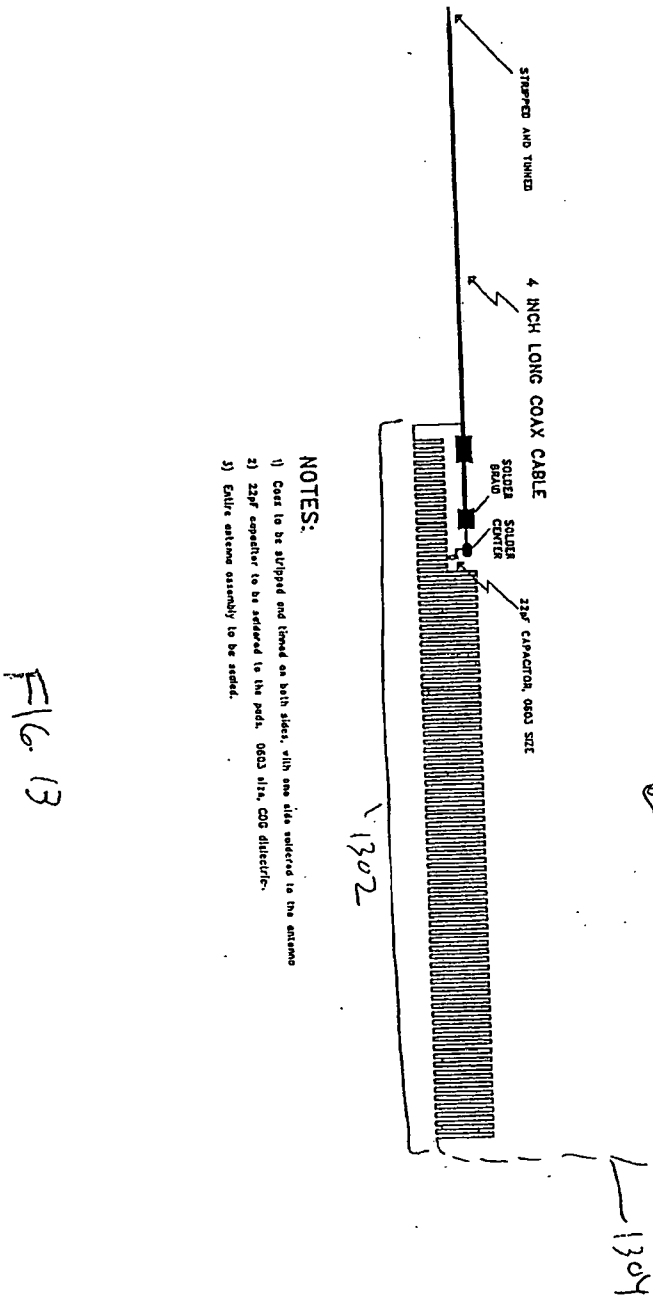
STRIPPED AND TINNED
4 INCH LONG COAX CABLE
SOLDER BRAID
SOLDER CENTER
22pF CAPACITOR, 0603 SIZE
1302
1304
NOTES:
1) Coax to be stripped and tinned on both sides, with one side soldered to the antenna
2) 22pF capacitor to be soldered to the pads, 0603 size, COG dielectric.
3) Entire antenna assembly to be sealed.

FIG. 13

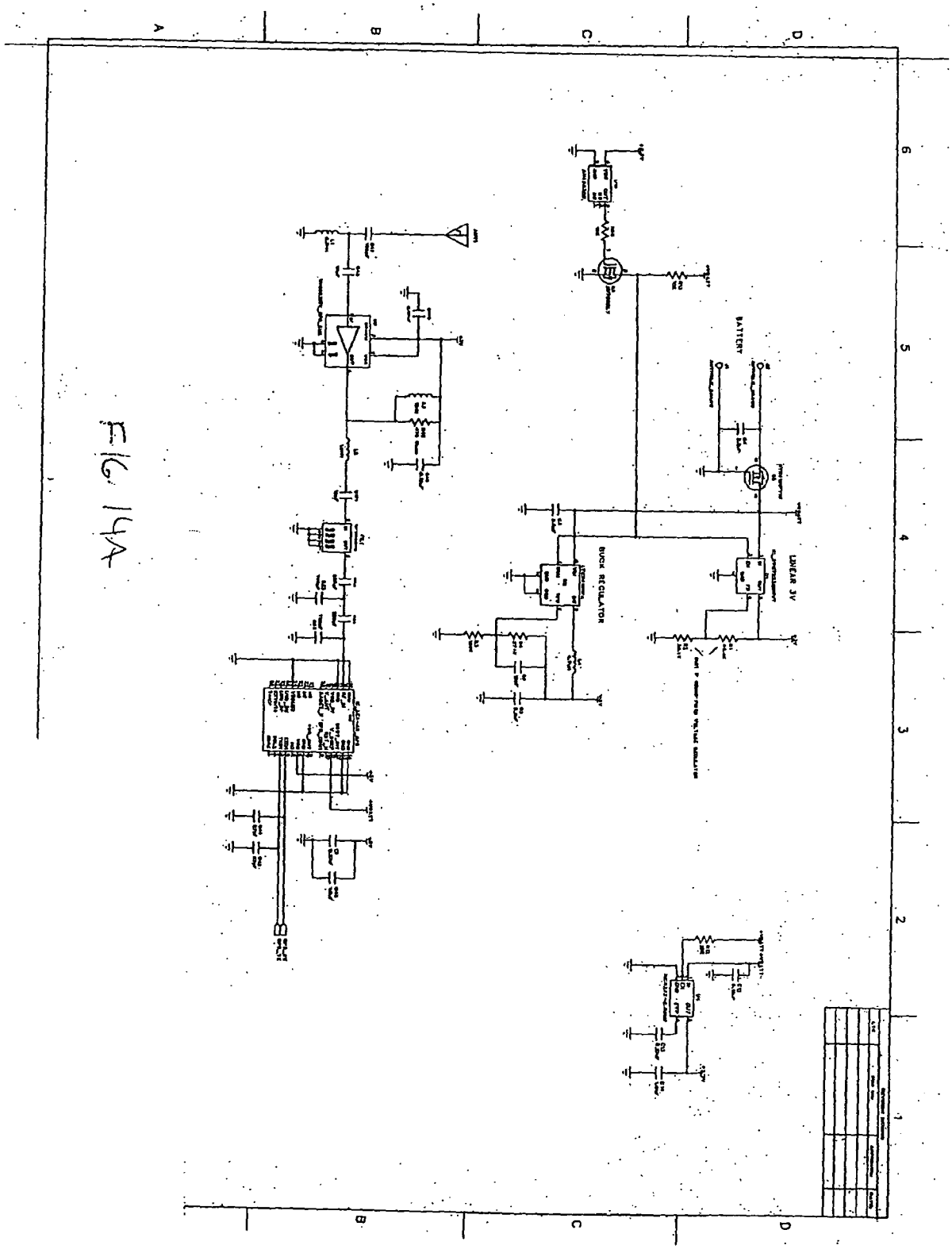

FIG. 14A

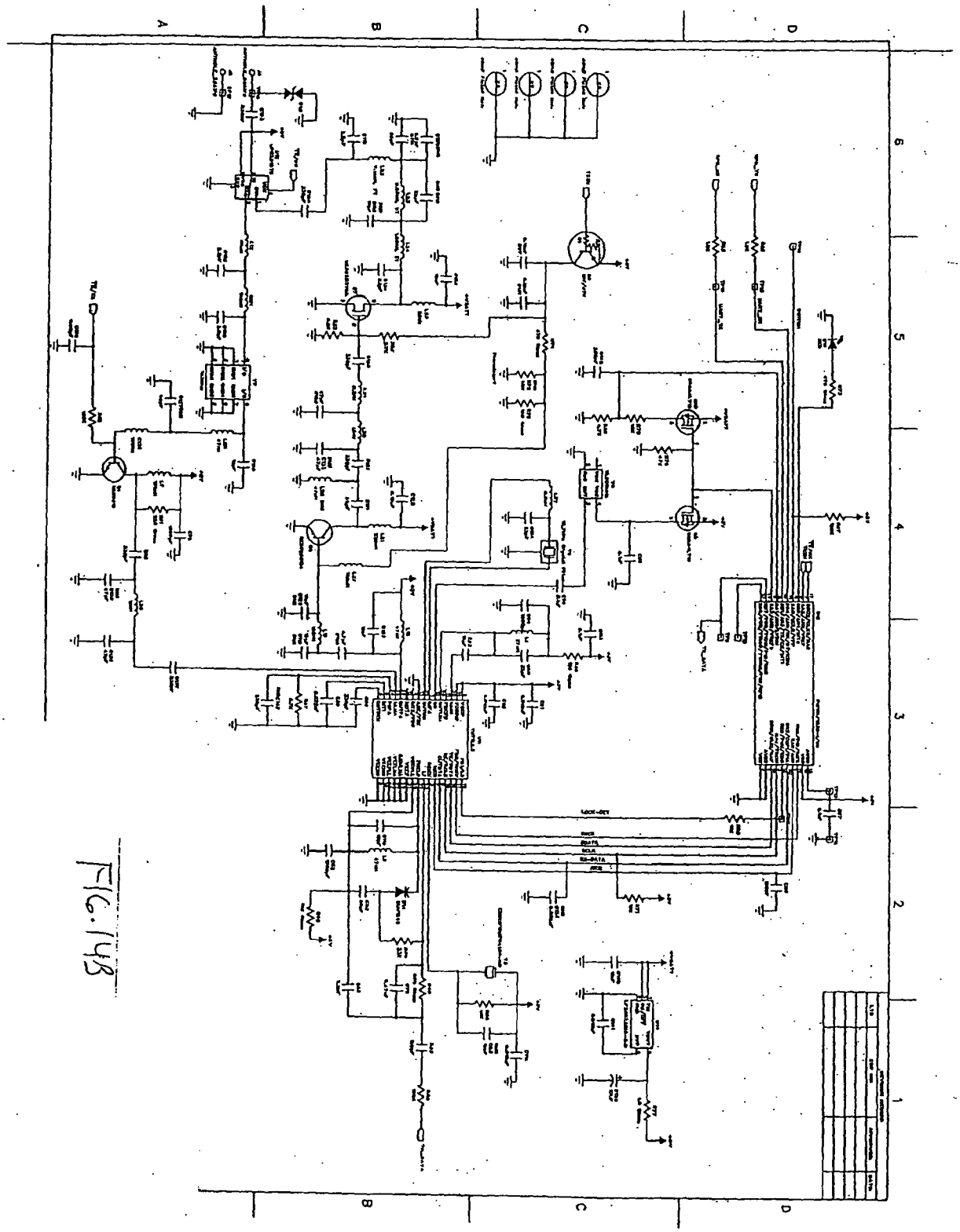

FIG. 14B

Sheet1

Item	Reference	Stuff	Manufacturer	PART NUMBER	PART DESC	VALUE	QTY
1	J1			NOT A PART	ANTENNA MOUNTING HOLE	ANTHOLE	1
2	Q1		California Eastern Laboratories (CEL)	NE85619-T1-A	NPN RF Transistor	NE85619	1
3	Q5		California Eastern Laboratories (CEL)	NESG250134-T1-AZ	NPN Medium Power RF Transistor	NESG250134	1
4	Q6		ON Semiconductor	DTA114YET1G	PNP with Bias R's	10K/47K	1
5	C7 C23 C34 C58	DNS	NIC Components Corp.	NMC0402NPO100JTRP****F	Capacitor, 0402, NPO	10pF	4
6	C32		NIC Components Corp.	NMC0402NPO100JTRP****F	Capacitor, 0402, NPO	10pF	1
7	C16 C31		Venkel LTD	C0402C0G500-100JNP	Capacitor, 0402, C0G	10pF	2
8	C8		Venkel LTD	C0402C0G500-101JNP	Capacitor, 0402, C0G	100pF	1
9	C18 C25-26		NIC Components Corp.	NMC0402X7R102KTRP****F	Capacitor, 0402, X7R	1000pF	3
10	C5		Venkel LTD	C0402C0G500-102JNP	Capacitor, 0402, C0G	1000pF	1
11	C73	DNS	Venkel LTD	C0402C0G500-102JNP	Capacitor, 0402, C0G	1000pF	1
12	C2		Venkel LTD	C0603C0G500-102JNP	Capacitor, 0603, C0G	1000pF	1
13	C11		NIC Components Corp.	NMC0402X7R103KTRP****F	Capacitor, 0402, X7R	0.010uF	1
14	C52 C70		Venkel LTD	C0402X7R500-103KNP	Capacitor, 0402, X7R	0.010uF	2
15	C15 C19-21		NIC Components Corp.	NMC0402X7R104KTRP****F	Capacitor, 0402, X7R	0.1uF	4
16	C1 C49-50 C57 C60		Venkel LTD	C0402X7R160-104KNP	Capacitor, 0402, X7R	0.10uF	5
17	C43		Venkel LTD	C0402X5R6R3-105KNP	Capacitor, 0402, X5R	1.0uF	1
18	C48	DNS	Venkel LTD	C0603X5R6R3-106KNP	Capacitor, 0603, X5R	10.0uF	1
19	C45		Venkel LTD	C1206X5R250-106KNP	Capacitor, 1206, X5R	10uF	1
20	C14 C68				10UF TANT CAP, 6.3V, A CASE	10UF	2
21	C64		Venkel LTD	C0402C0G500-150JNP	Capacitor, 0402, C0G	15pF	1
22	C56	DNS	Venkel LTD	C0402C0G500-1R0CNP	Capacitor, 0402, C0G	1.0pF	1
23	C22	DNS	Venkel LTD	C0402C0G500-220JNP	Capacitor, 0402, C0G	22pF	1
24	C63		Venkel LTD	C0402C0G500-220JNP	Capacitor, 0402, C0G	22pF	1
25	C46	DNS	NIC Components Corp.	NMC0402X5R223KTRP****F	Capacitor, 0402, X5R	0.022uF	1
26	C10		Venkel LTD	C0402X7R250-223KNP	Capacitor, 0402, X7R	0.022uF	1
27	C3		Venkel LTD	C0603X5R160-225KNP	Capacitor, 0603, X5R	2.2uF	1
28	C41-42		Venkel LTD	C0402C0G500-270JNP	Capacitor, 0402, C0G	27pF	2
29	C28		Venkel LTD	C0402C0G500-2R2CNP	Capacitor, 0402, C0G	2.2pF	1
30	C17		NIC Components Corp.	NMC0402NPO330JTRP****F	Capacitor, 0402, NPO	33pF	1
31	C24 C29-30 C71		NIC Components Corp.	NMC0402NPO331JTRP****F	Capacitor, 0402, NPO	330pF	4
32	C72	DNS	NIC Components Corp.	NMC0402NPO331JTRP****F	Capacitor, 0402, NPO	330pF	1
33	C9 C44 C86		Venkel LTD	C0402C0G500-331JNP	Capacitor, 0402, C0G	330pF	3
34	C54		Venkel LTD	C0402C0G500-3R9CNP	Capacitor, 0402, C0G	3.9pF	1
35	C59 C65		Venkel LTD	C0402C0G500-470JNP	Capacitor, 0402, C0G	47pF	2
36	C61 C67	DNS	Venkel LTD	C0402C0G500-470JNP	Capacitor, 0402, C0G	47pF	2
37	C4		Venkel LTD	C0402X5R6R3-474KNP	Capacitor, 0402, X5R	0.47uF	1
38	C12-13 C51 C69		Venkel LTD	C0603X5R100-475KNP	Capacitor, 0603, X5R	4.7uF	4
39	C47 C53		AVX	TAJB476K010R	47uF, Tantalum, 10V, 10%	47UF	2
40	C33		Venkel LTD	C0402C0G500-4R7CNP	Capacitor, 0402, C0G	4.7pF	1
41	C6		NIC Components Corp.	NMC0402NPO680JTRP****F	Capacitor, 0402, NPO	68pF	1
42	C27	DNS	Venkel LTD	C0402C0G500-680JNP	Capacitor, 0402, C0G	68pF	1
43	C37 C40		Venkel LTD	C0402C0G500-680JNP	Capacitor, 0402, C0G	68pF	2
44	C35		Venkel LTD	C0402C0G500-6R8CNP	Capacitor, 0402, C0G	6.8pF	1
45	C36	DNS	NIC Components Corp.	NMC0402NPO8R2DTRP****F	Capacitor, 0402, NPO	8.2pF	1
46	Y1		Murata Electronics North America, Inc.	CDSCB10M7GA136-RO	10.7MHz CER PIEZO DISCRIM	CDSCB10M7GA136-RO	1
47	Y4		Murata Electronics North America, Inc.	SFECF10M7HA00-R0	10.7MHz SMT Ceramic Filter	10.7MHz, 180kHz BW	1
48	J4 J6			NOT A PART	ANTENNA MOUNTING HOLE	ANTHOLE	2
49	J5			NOT A PART	SMT COAX CENTER MOUNTING POINT	COAX CENTER	1
50	J7			2-Pos	2-POS Wirepoint	2-pos	1
51	J3			52207-0417	3-POS FLEX CONNECTOR	3-pos 52207-0417	1
52	J2		JST	SM02B-GHS-TB	2-POS	2-pos	1

FIG 14C

Sheet1

53	Q4		California Eastern Laboratories (CEL)	NE5520379A-T1A-A	NCHANNEL MOSFET RF Transistor	NE5520379A	1
54	Q7		ON Semiconductor	BSS84LT1G	BSS84LT1G MOSFET PCHANNEL	BSS84LT1G	1
55	U9		NXP	74AHC1G00GW-G	IC, 2-input NAND Gate		1
56	U10		NXP	74AHC1G08GW-G	IC, 2-input AND Gate		1
57	U2		UBLOX	LEA-5S	UBLOX LEA-5S GPS Module	UBLOX LEA-5S GPS Module	1
58	U20		Linear Technology	LTC4055EUF	IC, USB Power Controller and Li-Ion charger		1
59	L12		Venkel LTD	LMCI1005-10NJT	Inductor, 0402, Multilayer	10nH	1
60	L6		Venkel LTD	LMCI1005-R10JT	Inductor, 0402, ML	100nH	1
61	L21		Venkel LTD	LMCI1005-R10JT	Inductor, 0402, Multilayer	100nH	1
62	L3		Venkel LTD	LMCI1608-R10JT	Inductor, 0603, Multilayer	100nH	1
63	L19		Venkel LTD	LMCI1005-15NJT	Inductor, 0402, Multilayer	15nH	1
64	L9 L18		Venkel LTD	LMCI1608-R18JT	Inductor, 0603, Multilayer	180nH	2
65	L1	DNS	CoilCraft	0603CS-1N6XJL*	Wirewound Chip Inductor, 0603	1.6nH	1
66	L15		CoilCraft	0906-2KLC	Wirewound SMT Microspring Inductor	1.65nH, 2T	1
67	L10		CoilCraft	1206CS-221XJL*	Wirewound Chip Inductor, 1206	220nH	1
68	L5		Venkel LTD	LMCI1005-27NJT	Inductor, 0402, ML	27nH	1
69	L2	DNS	CoilCraft	0603CS-3N3XJL*	Wirewound Chip Inductor, 0603	3.3nH	1
70	L8 L17		Venkel LTD	LMCI1005-47NJT	Inductor, 0402, Multilayer	47nH	2
71	L11	DNS	Venkel LTD	LMCI1005-47NJT	Inductor, 0402, Multilayer	47nH	1
72	L4		CoilCraft	0603CS-47NXJL*	Inductor-WW	47nH	1
73	L16		CoilCraft	1206CS-560XJL*	Wirewound Chip Inductor, 1206	56nH	1
74	L7		Venkel LTD	LMCI1005-68NJT	Inductor, 0402, Multilayer	68nH	1
75	L13		CoilCraft	1606-7JLC	Wirewound SMT Microspring Inductor	7.15nH, 7T	1
76	L20		Venkel LTD	LMCI1005-8N2JT	Inductor, 0402, Multilayer	8.2nH	1
77	L14		CoilCraft	1606-9JLC	Wirewound SMT Microspring Inductor	9.85nH, 9T	1
78	D4		Harvatek	HT-210SD/YG	Dual red/green LED, com anode	HT-210SD/YG	1
79	D3		Harvatek	HT-110YG	SMT GRN LED, Side-Look	HT-110YG	1
80	R34 R36	DNS	Venkel LTD	CR0402-16W-000T	Resistor, 0402, 5%	0 Ohms	2
81	R1		Venkel LTD	CR1206-8W-100JT	Resistor, 1206, 5%	10 Ohms	1
82	R4 R9			RK73B1ETT*101J	Resistor, 0402, 5%	100 Ohms	2
83	R20-21 R30		KOA Speer Electronics, Inc.	RK73B1ETT*102J	Resistor, 0402, 5%	1.0K	3
84	R24	DNS	KOA Speer Electronics, Inc.	RK73B1ETT*102J	Resistor, 0402, 5%	1.0K	1
85	R6		Venkel LTD	CR0402-16W-103JT	Resistor, 0402, 5%	10K	1
86	R13 R26 R28 R33		KOA Speer Electronics, Inc.	RK73B1ETT*103J	Resistor, 0402, 5%	10K	4
87	R11 R14 R23 R27 R35		Venkel LTD	CR0402-16W-104JT	Resistor, 0402, 5%	100K	5
88	R31 R25		KOA Speer Electronics, Inc.	RK73B1ETT*104J	Resistor, 0402, 5%	100K	2
89	R7		Venkel LTD	CR0402-16W-153JT	Resistor, 0402, 5%	15K	1
90	R19		KOA Speer Electronics, Inc.	RK73B1ETT*153J	Resistor, 0402, 5%	15K	1
91	R22 R32		Venkel LTD	CR0402-16W-181JT	Resistor, 0402, 5%	180 Ohms	2
92	R10		KOA Speer Electronics, Inc.	RK73B1ETT*221J	Resistor, 0402, 5%	220 Ohms	1
93	R17		Venkel LTD	CR0402-16W-272JT	Resistor, 0402, 5%	2.7K	1
94	R5 R12		KOA Speer Electronics, Inc.	RK73B1ETT*333J	Resistor, 0402, 5%	33K	2
95	R15 R29		Venkel LTD	CR0402-16W-471JT	Resistor, 0402, 5%	470 Ohms	2
96	R8		Venkel LTD	CR0402-16W-472JT	Resistor, 0402, 5%	4.7K	1
97	R18		KOA Speer Electronics, Inc.	RK73B1ETT*472J	Resistor, 0402, 5%	4.7K	1
98	R2		Venkel LTD	CR0402-16W-4993FT	Resistor, 0402, 1%	49.9k	1
99	R3		Venkel LTD	CR0402-16W-681JT	Resistor, 0402, 5%	680 Ohms	1
100	R16		KOA Speer Electronics, Inc.	RK73B1ETT*682J	Resistor, 0402, 5%	6.8K	1
101	U5		California Eastern Laboratories (CEL)	uPG2010TB-E3-A	RF Switch, SPDT	uPG2010TB	1
102	U3		Melexis Microelectronic Systems	TH71221.2	RF Tranceiver IC	TH71221.2	1
103	Y3		Sunny Electronics Corporation USA	P532x-1000	10MHZ TCXO SMT	10.000MHz	1
104	Y6		World Technologies	WSF153AC3	SAW Filter, 153MHz, SMT	153MHz	1
105	D2		ON Semiconductor	BAT54SWT1G	Dual Schottky, series connected	BAT54SWT1G	1

FIG 14D

Sheet1

106	D8	ON Semiconductor	MBR120VLSFT1G	Schottky Power Diode	MBR120VLSFT1G	1
107	TP8-9		NOT A PART	60-MIL ROUND TESTPOINT		2
108	TP1-2 TP5-7		NOT A PART	60-MIL ROUND TESTPOINT, BOTH SIDES		5
109	U6	Microchip Technology Inc.	PIC18LF1220-I/SS	8-Bit Flash uP, Low Voltage, nano-watt	PIC18LF1220-I/SS	1
110	D1	Skyworks Solutions, Inc.	SMV1249-079LF	SMV1249-079 VARACTOR DIODE	SMV1249	1
111	U7	National Semiconductor	LP2982AIM5-3.0	IC REG 3V LDO SOT23-5		1
112	U1	Microchip Technology Inc.	MCP1700-3002E/TT	LDO Regulator	3 Volt	1
113	U4	TI	TPS79330DBVR	IC REG 3V LDO SOT23-5		1

FIG. 14E

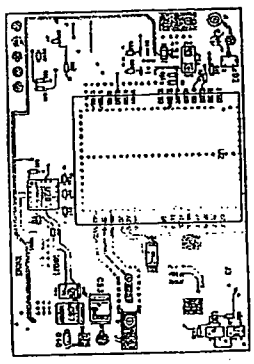

Fig. 14

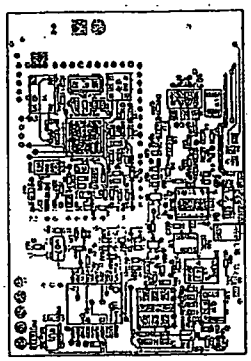

FIG. 19

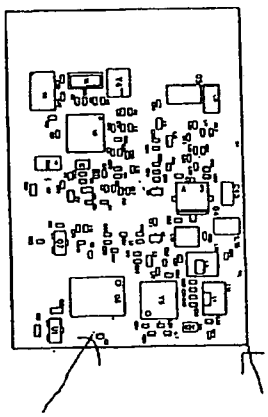

Fig. 11

Radio Size

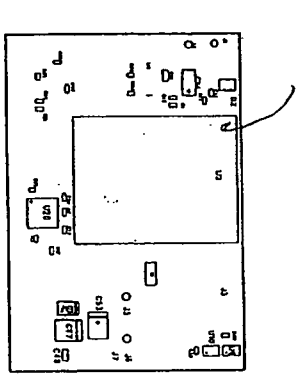

FIG. 4D.

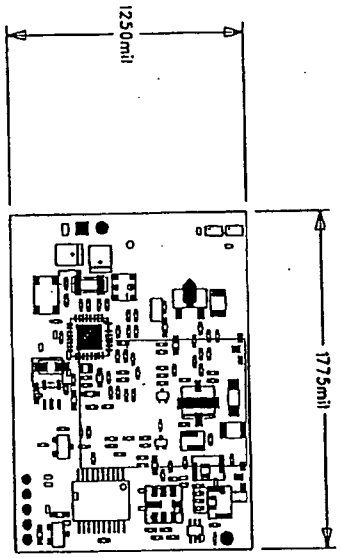

FIG. 14

VIEWED FROM COMP. SIDE

NOTES:

1) MATERIAL: CID OR EQUV., .062" THICK, 1 Oz. Cu.
2) TOLERANCE: PROFILE SIZE +OR- .005".
HOLE DIA. +OR- .003".
3) FINISH: SOLDER MASK OVER BARE Cu. HASL
4) 10 mil prepreg between Layers 1 and 2, 3 and 4