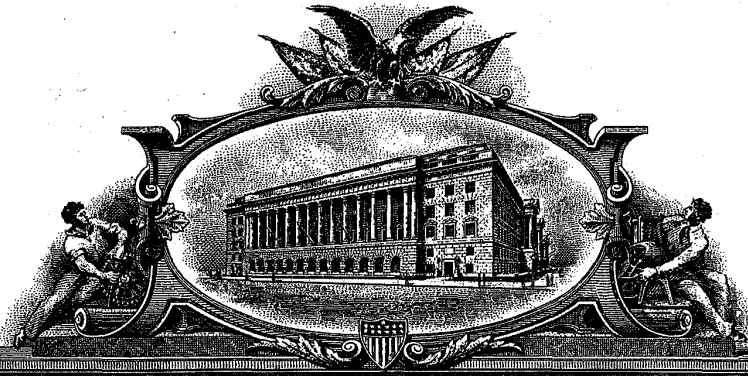


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November 2, 2023

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OF:

APPLICATION NUMBER: 09/753,178

FILING DATE: December 30, 2000

PATENT NUMBER: 6,441,752

ISSUE DATE: August 27, 2002

By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office



W. Montgomery
Wanda Montgomery
Certifying Officer



340	988
Class	Subclass
ISSUE CLASSIFICATION	

5. U

PATENT NUMBER

6441752



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APPLICATION NO. 09/753178	CONT/PRIOR	CLASS ~~701~~ 760	SUBCLASS 988	ART UNIT ~~366T~~ 263L	EXAMINER TRIGU
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TITLE	APPLICANTS
1. Chairman	1. Mr. J. H. ...
2. Vice Chairman	2. Mr. J. H. ...
3. Secretary	3. Mr. J. H. ...
4. Treasurer	4. Mr. J. H. ...
5. Member	5. Mr. J. H. ...
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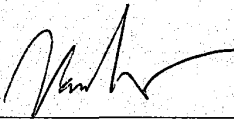
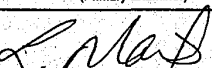
Mundi Fomukong

Method and apparatus for locating mobile units tracking another or within a prescribed geographic boundary

PTO-2040
12/99[illegible]

7-24-02 Formal Drawings (7 sheets) set 1

2-30-00

☐ TERMINAL DISCLAIMER	DRAWINGS			CLAIMS ALLOWED	
	Sheets Drwg. 7	Figs. Drwg. 7	Print Fig. 5	Total Claims 18	Print Claim for O.G. 1
☐ The term of this patent subsequent to _____ (date) has been disclaimed. ☐ The term of this patent shall not extend beyond the expiration date of U.S. Patent. No. _____ _____ _____	_____ (Assistant Examiner) (Date)			NOTICE OF ALLOWANCE MAILED 2. 1. 5-16-02	
	_____  (Primary Examiner) 5/7/02 (Date)			ISSUE FEE	
				Amount Due \$640.00	Date Paid 7.11.02
☐ The terminal _____ months of this patent have been disclaimed.	_____  (Legal Instruments Examiner) 5.22.02 (Date)			ISSUE BATCH NUMBER	

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Bib Data Sheet

CONFIRMATION NO. 2194

SERIAL NUMBER 09/753,178	FILING DATE 12/30/2000 RULE	CLASS 701 340	GROUP ART UNIT 3661 2632	ATTORNEY DOCKET NO.
APPLICANTS Mundi Fomukong, West Los Angeles, CA;				
** CONTINUING DATA *****				
** FOREIGN APPLICATIONS *****				
IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 02/15/2001				
** SMALL ENTITY **				
Foreign Priority claimed ☐ yes ☒ no 35 USC 119 (a-d) conditions met ☐ yes ☒ no ☐ Met after Allowance Verified and Acknowledged ☒		STATE OR COUNTRY CA	SHEETS DRAWING 7	TOTAL CLAIMS 19
ADDRESS MUNDI FOMUKONG 10853 ROSE AVE, #49 WLA, CA 90034		INDEPENDENT CLAIMS 7		
TITLE Method and apparatus for locating mobile units tracking another or within a prescribed geographic boundary				
FILING FEE RECEIVED 515	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit	



PTO/SB/17 (11-00)
Approved for use through 10/31/2002. OMB 0651-0032
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FEE TRANSMITTAL for FY 2001

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT

(\$) 515

Complete if Known

Application Number

Filing Date

First Named Inventor

Examiner Name

Group Art Unit

Attorney Docket No.

METHOD OF PAYMENT

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit
Account
Number

Deposit
Account
Name

- ☐ Charge Any Additional Fee Required
Under 37 CFR 1.16 and 1.17

- ☒ Applicant claims small entity status.
See 37 CFR 1.27

2. ☐ Payment Enclosed:

- ☐ Check ☒ Credit card ☐ Money
Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
101 710	201 355	Utility filing fee	355
106 320	206 160	Design filing fee	
107 490	207 245	Plant filing fee	
108 710	208 355	Reissue filing fee	
114 150	214 75	Provisional filing fee	

SUBTOTAL (1) (\$) 355

2. EXTRA CLAIM FEES

Total Claims	Extra Claims	Fee from below	Fee Paid
19	-20** =	X	
7	-3** =	4	160
Multiple Dependent			

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description
103 18	203 9	Claims in excess of 20
102 80	202 40	Independent claims in excess of 3
104 270	204 135	Multiple dependent claim, if not paid
109 80	209 40	** Reissue independent claims over original patent
110 18	210 9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$) 160

**For number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105 130	205 65	Surcharge - late filing fee or oath	
127 50	227 25	Surcharge - late provisional filing fee or cover sheet	
139 130	139 130	Non-English specification	
147 2,520	147 2,520	For filing a request for ex parte reexamination	
112 920*	112 920*	Requesting publication of SIR prior to Examiner action	
113 1,840*	113 1,840*	Requesting publication of SIR after Examiner action	
115 110	215 55	Extension for reply within first month	
116 390	216 195	Extension for reply within second month	
117 890	217 445	Extension for reply within third month	
118 1,390	218 695	Extension for reply within fourth month	
128 1,890	228 945	Extension for reply within fifth month	
119 310	219 155	Notice of Appeal	
120 310	220 155	Filing a brief in support of an appeal	
121 270	221 135	Request for oral hearing	
138 1,510	138 1,510	Petition to institute a public use proceeding	
140 110	240 55	Petition to revive - unavoidable	
141 1,240	241 620	Petition to revive - unintentional	
142 1,240	242 620	Utility issue fee (or reissue)	
143 440	243 220	Design issue fee	
144 600	244 300	Plant issue fee	
122 130	122 130	Petitions to the Commissioner	
123 50	123 50	Processing fee under 37 CFR 1.17(q)	
126 180	126 180	Submission of Information Disclosure Stmt	
581 40	581 40	Recording each patent assignment per property (times number of properties)	
146 710	246 355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149 710	249 355	For each additional invention to be examined (37 CFR § 1.129(b))	
179 710	279 355	Request for Continued Examination (RCE)	
169 900	169 900	Request for expedited examination of a design application	

Other fee (specify)

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$)

SUBMITTED BY

Name (Print/Type)	MUNDI FOMUKONG	Registration No. (Attorney/Agent)	Telephone	310 5598133
Signature	[Signature]	Date	12/29/00	

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THE UNIVERSITY OF CHICAGO

BACKGROUND OF THE INVENTION

The wireless industry is currently gearing towards the provision of a wide range of location based services to the general public. Such services will include utilizing the location of a subscriber's portable remote unit to channel a wide range of location-based services to the subscriber. For such a service to be successful, the remote unit must be able to obtain and relay its location information to other communication targets of the network requesting such information.

In Bird, US 5,418,537, a missing vehicle is located through the use of a GPS receiver mounted on the vehicle. When the vehicle is missing, a paging request is broadcast by the vehicle location center. Upon receiving the broadcasted message, the vehicle resolves and conveys its location to the service center.

1

In Chapman, US 5,504,491, a global status and positioning reporting system is described. A remote unit obtains its global location and updates the network with status information and location information as required. Such status information may include an emergency condition or relevant condition of the remote unit required by the network.

In Fomukong and al, US 5,918,159 a location reporting satellite paging system with optional blocking of location reporting is disclosed. In that invention, a remote mobile unit obtains its location information and provides that information via the network to other network units requesting the information. The provision of such location information is done based on authorization information provided and routinely updated by the remote unit.

In all of the above-disclosed inventions, the location of the remote unit is utilized by the system. The deployment of location services could be quite beneficial to the general public if safely implemented. In today's market, such mobile units are usually small, compact and lightweight. These devices could easily be concealed to reveal the location of a mobile user without the user knowing or authorizing the disclosure of their location. Most wireless consumers might not want their location disclosed to the network or general public and the thought of being tracked by a clandestine unit concealed in an object such as a car or luggage to reveal the location of an individual would be unacceptable by the general public. The risk of abuse clearly exists and must be handled appropriately by wireless vendors. In U.S patent 5,918,159 that provides authorization for location reporting, it would be almost impossible for the network to prevent a concealed location-reporting unit to provide the location of an individual being tracked, given an abuse is occurring. A need therefore exists for location reporting devices in a specific geographic region to reveal their location upon request. In situations where a user is being tracked, the network would be able to determine which units are tracking the user by querying for the location

of remote units within a specified radius of the user or tracked unit. The techniques required to provide the above result are described in the invention.

Whenever a mobile user is stranded and requires immediate help, another mobile party may exist not too far from the location of the user. The mobile user may not be aware of the presence of the other mobile party at that geographic location. By paging for the location of portable remote units (PRU) within the stranded area, a distressed subscriber might immediately sought help at that location. If the prescribed boundary specified by the mobile user exceeds pre-specified limits, the network may split that geographic area as described hereinafter. Pages may then be sent to specific areas in order to obtain the location of portable remote units in that geographic area. The location of any mobile location-reporting unit in a geographic area that is closest to the user will be revealed to the user.

Lots of other uses exist for such a service to be lucrative to a service provider. A wireless subscriber may opt to participate in the program and users of the system may be charged a fee each time the location of another PRU at a requested geographic boundary is provided to the user. Also, users in possession of portable remote units may be charged whenever they invoke the tracking mode in their PRU. To improve subscriber enrollment in the program, subscribers may also received benefits each time their location is provided to a distressed individual. Subscribers not requiring their locations disclosed at any time may block such information at the network. In situations where a PRU user is being tracked by another, the network will only reveal the location of the tracking unit only after both units have traveled a certain distance over a pre-specified period of time with the tracking unit maintaining proximity to the source during that period. Such distances and elapse times could be set as a standard by the industry to clearly define tracking.

From the above there is clearly a need for a system whereby a remote unit should be able to request for the location of other remote units within a specific geographic area. The components of such a system are described hereinafter.

OBJECTS OF THE INVENTION

It is an objective of the present invention to provide a mobile telecommunication system, method and technique that could facilitate the secure provision of location information pertaining to one or more mobile communication targets that are tracking another.

It is an objective of this invention to provide a mobile telecommunication system whereby a communication source residing in a geographic location may poll for the location of communication targets that are present in another geographic area.

It is an objective of this invention to provide a technique to report the location of communication units within a pre-specified boundary.

It is an objective of the current invention to provide adequate technology that would facilitate the disclosure of location information of communication units that are present in a wider than normal geographic area.

It is an objective of this invention to provide a remote unit that could provide location information and geographic boundary information where a search could be initiated for the presence of one or more location reporting communication targets.

SUMMARY OF THE INVENTION

The aforementioned objectives and others are achieved by a telecommunication system that can provide location information pertaining to other communication targets that are present within a pre-specified geographic boundary.

In the system, a communication source may query for the location of communication targets at a specified geographic boundary. The communication source may also enter into a mode to determine if another communication unit is tracking it. Communication sources and targets of the system should be able to obtain their location using any relevant location determination technique. This information is conveyed securely across the network based on system and subscriber requirements. When a communication source requires the location information of communication targets in a specific geographic area, the source obtains its location and may determine if the geographic boundary of the required targets is within its querying radii. Although the design could also be such that the network handles all queries, a communication source may poll directly for the location information of targets in a specified geographic boundary. This could happen if the communication targets are within the source's querying radii; preventing unnecessary overloading of shared network resources. For more complex and distant queries, the source may simply provide its location and geographic boundary information where targets should be interrogated for location disclosure. The network utilizes its resources and determines where and how a search for relevant communication targets should be initiated. Once the search for possible communication targets within the specified geographic boundary is completed, the network provides the communication source with information pertaining to communication target(s) closest to the source and in the geographic region specified by the source.

DECEMBER 11, 1944

Figure 1 shows a general schema depicting the invention.

Figure 2 shows a diagram of a mobile portable remote unit employed by the system.

Figure 3 shows a diagram indicating how a wider than normal geographic area is divided

Figure 4 shows a diagram that is employed to determine if a remote unit is within a

Figure 5 shows a flow chart illustrating the steps that a communication unit may employ to

Figure 6 is a flow chart illustrating the steps utilized by a communication unit to disclose a

Figure 7 is a flow chart illustrating how a search for the location of mobile communication

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A general overview of the present system in accordance with the invention is depicted in FIG. 1. The system consists of a network of portable remote units (PRU) 501-510 scattered throughout a wide geographic area. Mobile Users 701-709 are in possession of the portable remote units 501-509, respectively. Geographic regions 201-204 are standard geographic areas that may have present, one or more portable mobile users 701-709 as shown in FIG. 1. Mobile user 701 is in geographic region 201 and mobile users 502-506 are in geographic regions 202. Other mobile portable users exist in the system and are scattered as shown in FIG. 1. Geographic location 201-204 may simply be defined by their latitude, longitude and radii information or simply by points defining their geographic boundary as illustrated in FIG. 3. The terrestrial network center (TNC) FIG. 1, 801 is used to control the actions of the mobile system. The TNC communicates with ground based transmitters (GBT) 401-404 and earth based satellite transmitters 301-302 to relay information pertaining to the mobile system across the network. Other functionalities of the terrestrial network center may include determining which transmitters to employ to complete a call and how to prevent portable remote units from receiving calls when they are out of jurisdiction. Multiple terrestrial control or network centers may be employed as required by the system. Ground based transmitter stations (GBT) FIG. 1, 401-404 are employed to relay mobile information to and from the portable mobile units of the network. Interface to a fixed telephone network such as home telephone or other communication units such as the personal computer could be achieved through the public telephone switching network (PTSN). Satellites 101-102 are employed by the system to relay information to remote areas and also to provide referenced signals, which ground base communication units, may utilize in establishing

their geographic location. Communication between the satellites and the ground network is achieved through earth based satellite transmitters 301-302.

A general internal circuitry of a portable remote unit or PRU, FIG 1, 501-510 is shown in FIG. 2. The portable remote unit consists of an antenna 20 and a transceiver circuitry 21. The transceiver circuitry receives and transmits portable remote unit information via the antenna 20. On receipt, this information is processed and the intelligence portion is extracted and sent to the control unit 22 for further processing. The transceiver also receives portable remote unit information from the control unit 22, processes it, and forwards it as required to the network via the antenna 20. The control unit 20 controls the action of the PRU. Relevant information pertaining to the PRU could be stored in the allocated memory means 26. The memory means may include a Random Access Memory, a Read-Only Memory and additional memory to store PRU data. Input panel 25 is employed to take user instructions and the display 23 is used to present PRU information to a user. The audio means 24 is used for annunciation of voice messages. A PRU may be able to assist the network in determining its global location or use any location determination technique to resolve and provide its location to the network. As a PRU is carried from one location to the other it may obtain and provide information concerning its current location to the network

As stated in one of the objectives of the invention and illustrated in FIG. 1, a portable remote unit 501, utilized by a subscriber 701, in a moving vehicle 601, could be tracked by a clandestine unit 510, such unit concealed in vehicle 601. A subscriber – let say 704 in region 202- in another geographic region trying to keep track of the whereabouts of user 701 may have concealed unit 510 in vehicle 601 to track subscriber 701. As most portable remote units are small and compact they could easily be hidden without subscriber 701 knowing of such activity. As

vehicle 601 travels from one location to the next, authorized users will be able to receive location information from PRU 510 whenever they poll for it. As PRU 510 discloses its location to the authorized party, the party may obtain the location of subscriber 701 without their authorization. It is of utmost importance that a subscriber in possession of unit 501 should be able to determine if they are being tracked by another unit. In the current invention subscriber 701 will at any point in time activate the tracking feature provided in PRU 501. This could be achieved by invoking the appropriate function through the input panel, FIG. 2, 25 of the PRU. In tracking mode, a tracked PRU, FIG. 1, 501, may simply alert a user in possession of the tracked PRU with the location information of any tracking device - PRU 510 - that has resided within a pre-specified radius of the tracked PRU, with both units having traveled a minimum distance. Parameters such as elapse time, minimum distance traveled and tracking radii could be set as a standard by the industry. The tracking feature could be invoked by the tracked PRU or a request could simply be forwarded to the closest ground control station so that the operation is performed for the tracked PRU. In tracking mode the geographic location of the tracked unit, FIG. 1, 501, is utilized to determine the geographic boundary where a search for possible tracking units 510 could be initiated. Over a period of time and at pre-determined time intervals a page is sent to the geographic location 201 where the tracked unit 501 resides for all location-reporting units within that geographic boundary to disclose their location. The geographic boundary required to establish tracking could be set as a standard by the industry. For instance, it could be agreed upon that a unit could be deemed as tracking another if it stays within a 5 meter radius of the tracked unit over a 1 mile stretch. As the tracked unit 501 is moving, that unit or an appropriate network unit, may page for the location of other communication units within the tracking boundary of the tracked unit to disclose their location. Only communication units within that geographic boundary would disclose their

location. Timing information could also be included in the disclosed information to help eliminate errors that may occur when a tracked unit, FIG. 1, 501, is in a vehicle 601 that is moving at a high velocity. This exercise could be done at fixed time intervals and over a pre-determined time period. At the first time interval, a list could be maintained of all the PRUs that responded within the specified geographic boundary defined for tracking. At subsequent time intervals, PRUs that were in the list at the first tracking interval and not responding in later intervals could be eliminated as possible tracking units. At the end of the tracking period, if there are any units in the tracking list and the minimum tracking distance was covered, such communication units are deemed to be tracking another and are reported to the requested party. The minimum traveling distance must be maintained to eliminate the risk of identifying communication units that reside in a fixed geographic boundary over the tracking period as possible tracking units. Also, a maximum time limit must be set for the tracking exercise such that if the minimum distance is not traveled within that time period the tracking process is aborted. If such a time is not maintained a PRU could be in the tracking mode indefinitely. The steps for this process are shown in FIG. 5.

According to FIG. 5, once the tracking mode is invoked at a search unit, tracking is initialized, FIG. 5, 1. Note that the search unit could be any relevant mobile communication unit trying to identify possible mobile communication units that are tracking another. The search unit then operates repeatedly over pre-defined time intervals 2 until the end of the tracking period 9, 13. At each tracking interval 2, the location of the tracked unit is obtained 3. Possible tracking units within a specified geographic boundary of the tracked unit are paged to reveal their location 4. For the first tracking interval 5, all tracking units that provided their location at that interval are stored in a list 7. At subsequent tracking intervals, a tracking unit that responded in the first tracking interval and not responding in a subsequent tracking interval is eliminated 6 as a possible

tracking unit. If the tracking list is empty at any tracking interval 8, the tracking process is aborted 9. A test 10 is next performed to verify that the tracking units in the list traveled the minimum pre-defined distance. If it is determined that the tracking units traveled the minimum distance 10, they are reported as tracking units to the network 11. If it is determined that the tracking units have not yet traveled the minimum distance 10, a check is done to establish if the maximum tracking time has elapsed 12. If no time is left to establish tracking 12, the process is aborted, 13, otherwise it is repeated 2. A maximum time must be set for the tracking process to ensure that a PRU is not in tracking mode indefinitely.

As previously indicated, a PRU may invoke this method directly to determine if other units residing in its immediate geographic area have been tracking it. This would help reduce network overload and, at the end of the tracking period, a status signal may simply be forwarded to the network. In circumstances where a tracked PRU cannot perform this operation, a ground control unit may be employed to carry out the tracking operation for the PRU and report any findings to the PRU. Maintaining a list of all tracking units at the first tracking interval is efficient as it reduces storage space and processing time. It is also possible to maintain a list of all units that are within a pre-defined geographic boundary of the tracked unit throughout the entire tracking process. At the end of the process, the list could be used to determine which units reported their location over a pre-specified distance traveled by the tracked unit.

For a unit to report a global location within a specified geographic boundary, the unit must be able to obtain geographic boundary information and further determine if its location is within the prescribed boundary. There are several techniques well known in the art that a remote unit may employ to resolve its geographic location or assist the network in resolving its location. Once the PRU obtains its location from whatever technique, that information is utilized to perform the

functions in accordance with the invention. Apart from determining if a remote unit is being tracked, other uses exist for a remote unit to disclose its location at a particular geographic location. For instance a distress subscriber at a specific global location may simply want to know if there mobile users in the immediate geographic area. Furthermore, a subscriber might want to know if there are any individuals at their home, office or a specified geographic location. By specifying the required location and further information such as radii information, the network may provide a portable remote unit with the location portable remote targets that are closest to the PRU and in the geographic area specified by the PRU.

For a simple search where the geographic region does not exceed a pre-specified limit, a page may simply be sent to the required region for all units in the region to disclose their location. As it would be inefficient to page for portable remote units in wider geographic boundaries to reveal their location, searches in these areas could be managed differently by the network. In this situation, the network may simply split the wider area into sub regions and recursively query for the location of PRUs, starting in sub-regions that are close to the origin before extending to geographic regions that are further away.

To disclose a global location within a prescribed geographic boundary, a PRU at the geographic location picking up the request must determine if it is within that boundary before providing its location to the network. FIG. 3 shows a geographic location with mobile units M_1 - M_N . This location is divided into cells (C_1 - C_n) or grids (G_1 - G_N) where n is the total number of cells or grids, also known as region. Each region could be defined by its latitude, longitude and radii information or by distinct points that define the grid. Looking at FIG. 3, cell C_1 is defined by radius R and its latitude and longitude information is that of mobile user M_1 (x_o, y_o). Grid G_1 is defined by four points P_1 , P_2 , P_3 and P_4 . Subsequent cells and grids are defined in that fashion as

shown in FIG. 3. FIG. 3 depicts a wide geographic area. Ground stations and control centers, not shown, may also be available in that area. Such an illustration may also be seen in a general sense in FIG. 1.

As shown in FIG. 3, a distressed mobile user M_1 may need to find where another party might exist in that geographic region. The user could initiate a page from their PRU for the closest available PRUs that could be found in that geographic jurisdiction. Looking at FIG. 3, mobile user M_1 will provide its location, latitude and longitude (x_0, y_0) to the closest available ground station serving area C_1 or grid G_1 . As stated earlier, appropriate terrestrial technology will be scattered in that region to serve the PRUs in that area as shown in FIG. 1. Once a ground station picks up this signal, it sends a page for all location reporting devices in the specified boundary surrounding mobile unit M_1 , FIG. 3 to disclose their location. Such boundary information could simply be specified by the latitude and longitude of unit M_1 and appropriate radii information. For the very first request, such radii information would be the distance R as shown in FIG. 3. A PRU within that area will pick up the signal and determine if it is within the specified radii. Also, if the ground station specifies grid information for the first cell, G_1 , a PRU will have to determine if it lies within the grid G_1 boundary, P_1, P_2, P_3 and P_4 . According to FIG. 3, when a ground station sends a page for the location of PRUs in cell C_1 or grid G_1 only mobile unit M_1 may respond. As M_1 is the PRU that initiated the search, the ground control station would make the determination and obtain the next region – radii or grid- information for a possible search. The geographic boundary information of cell C_2 or grid G_2 will be provided for the next search. Subsequent searches will include incrementing the radii information to from $C_1 \dots C_N$ or grid boundary information from $G_1 \dots G_N$ until a PRU within that geographic boundary responds or system limitations are encountered. A possible limitation may be the size of a geographic

boundary to page for remote unit locations. According to FIG. 3, the radius of each cell is from the origin of mobile unit M_1 , (x_o, y_o) . The radii of subsequent cells is a factor of the radius of the first cell, C_1 . The grid is usually the tightest rectangular boundary defining the cell. As the grid or cells become larger, exclusion zones, as described hereinafter, may also be specified if it is required that PRUs in certain areas should not disclose their location. Another possibility might be not to increase the next geographic area on a subsequent page but split the entire geographic boundary into small regions of about the same size. Each region could then be paged, starting in areas that are closed to the origin. This could be done until a PRU at a region discloses their location.

Considering that mobile unit M_1 is initiating a search for possible portable remote units in its immediate area, a relevant ground control station will send three pages. The first page will cover cell C_1 or grid G_1 . As no units are available in the area a second page will be sent to cover cell C_2 or grid G_2 . Examining FIG. 3, the next PRUs exist only in cell C_3 or grid G_3 . Once a page is sent out for cell C_3 , PRU, M_2 and M_3 will respond. If grid G_4 is specified PRU M_2, M_3, M_4 and M_5 will respond. The ground control station will next select the unit closest to PRU M_1 , which is M_2 , in this instance. The location of PRU M_2 will then be forwarded to PRU M_1 . M_1 may also choose to request for the number of PRUs in its area and the ground control station would respond again, based on system requirements. Using the system, a user in possession of a PRU may check for the existence or other PRUs at another geographic location. A user may select a geographic area from a map presented by the PRU. In FIG. 1, a mobile user 709 at location 204 may utilize this system to request for the location of mobile units in another geographic region such as 202 or 203. This could be for instance, checking to see if there are PRUs at the office or house or any location of interest. The system would simply return the appropriate information

such as number of PRUs responding, location of PRUs and relevant information requested. In such a system, subscribers may choose to participate to have their location disclosed when a search is initiated. Subscribers may also opt to block or activate this feature at any time at the network. A subscriber to the service may be charged a fee each time the system is used. A possible technique utilized to implement the above is shown in FIG. 7.

According to FIG. 7, the geographic information of the area where a search for possible remote targets sought is first obtained 1. This information could be provided by a PRU to the network. This information may simply be the latitude and longitude of the area where the search would be performed and other relevant information to assist the network with the search. A PRU may display a map where a user may select a specific geographic area. From this information the next geographic region where a possible search for PRUs is estimated 2. This could be the latitude longitude and radii information of the searched area. Also, the tightest rectangular grid surrounding the cell having that radii information could also be calculated and utilized. Once that information is obtained a page is sent out to that geographic region for remote units in the region to reveal their location 3. If remote units are identified in the paged area 4, that information is forwarded to the network 5 and the process is aborted 7. If no remote units are identified in the area 4, a check is done to establish if there are any remaining cells or grids higher up in the chain to be searched 6. If no regions exist for a possible search, the process is aborted, otherwise, the process is repeated until all geographic cells or grids have are searched for the existence of portable remote units

Whenever a portable remote unit receives a page to disclose its location within a specified geographic boundary, the PRU obtains its location and attempts to determine if it is within that boundary. As mentioned before, the PRU may employ any relevant location determination

technique well known in the art to obtain its geographic location. If the boundary information specified by the network contains a well-defined set of points - latitude and longitude for that region - defining the geographic region, the PRU will simply establish if its location is within the geographic boundary and provide its location to the network based on that. The points may simply define the minimum and maximum latitude and longitude values within which a PRU should respond. Such a procedure would be stored in the memory means, FIG. 2, 26 of the PRU and invoked by the control unit FIG. 2, 22 of the PRU as required. If the network simply provides the origin - latitude and longitude- and radii information of the region where a search is to be performed, the PRU will utilize these values to establish if it is within the area defined by the network as shown in FIG 4.

FIG. 4 shows four mobile objects, Object₀, Object₁, Object₂ and Object₃. Considering that Object₀ is the source and needs to know if any portable remote units are available in the geographic region of radius R. The location of Object₀ is the origin of the region and the radii information provided by the network for that region is R. All objects within that radius must respond upon receiving the signal requesting for their location in the specified radii. Looking at FIG.4, only Object₃ and Object₂ exist in the region specified and would respond to the page. If all the mobile objects are served by the same ground station they will all receive the signal for location disclosure if in the region. To establish if they are within the region specified, each mobile object will obtain its location and calculate its tangential information from the specified geographic origin (x_0, y_0) defined by the source, Object₀. The tangent of an angle is usually the opposite/hypotenuse. Looking at FIG 4, the tangent is between the origin of Object₀ and Object₁, and that angle is θ . As Object₃ lie on the same line as Object₁ the tangent between the origin of Object₀ and Object₃ is also θ . The tangent between the origin of Object₀ and Object₂ is α . Standard

trigonometric equations dictate that the tangent of an angle is the opposite / hypotenuse.

According to FIG. 4, $\tan \theta = (y_1 - y_0) / (x_1 - x_0)$ for Object₁ and $(y_3 - y_0) / (x_3 - x_0)$ for Object₃. For Object₂ $\tan \alpha = (y_2 - y_0) / (x_2 - x_0)$. Once the inclination or tangent of the object to the origin is calculated, the distance of the object to the origin could easily be calculated by using the sine formula – $\text{Sine } \theta = \text{opposite} / \text{hypotenuse}$ where the opposite is $(y_1 - y_0)$, $(y_3 - y_0)$ for Object₁ and Object₃ respectively. The hypotenuse is the distance from the mobile object to the origin; R_{01} and R_{03} for Object₁ and Object₃ respectively. For Object₂, the distance from the origin $R_{02} = (y_2 - y_0) / \text{Sine } \alpha$. Once the distance from the origin (x_0, y_0) is calculated for each mobile object, an evaluation could easily be made as to whether the mobile object lies within the specified boundary and the location of the mobile object could be provided to the network based on that. Furthermore, the network may choose to provide an exclusion region or regions to the portable mobile remote units or PRUs. A PRU in that exclusion region will not disclose its location to the network even if it lies in the network's specified geographic boundary. This exclusion zones may be specified simply as grid points anywhere in the paged region or as a direction aft the origin. A direction aft the origin contains information that will indicate to PRUs in the region not to disclose their location if they are East, West, North or South of the origin. Considering FIG. 3 as a further example, if a request is received in that region for the location of mobile units in G_4 or C_4 and the origin is the location of M_1 , with the exclusion zone specified as East, all the mobile units in G_4 or C_4 will receive the request to disclose location in that area. Upon detecting the exclusion zone information in the signal only the mobile units to the West of M_1 will reveal their location. Again, such exclusion zone information may simply specify sub region(s), where PRUs should not reveal their location.

FIG. 6 shows the steps utilized by a remote unit to reveal its location if it is within the geographic boundary specified by the network. The unit first obtains geographic boundary information specified by the network 1. This information may consist of latitude and longitude information defining the regions origin and radii information. The unit next obtains its location 2. This could be done in association with the network or by using any remote unit location determination techniques such as GPS. The next step is to determine if the unit is within the boundary prescribed by the network 3. Such a technique has already been described in the invention. Further checks are carried out to ensure that remote unit is not in a location reporting exclusion zone defined by the network 4. The location of the remote unit is provided to the network 7 once it is established at the remote unit that the subscriber 6 authorized such an action.

It could be made mandatory that all PRUs reveal their location once they receive a request to establish tracking. A PRU may not respond to any tracking establishing routines if it is at a fixed location. Tracking is only possible when the tracking and tracked unit are in motion. If a network's request is just to establish if a PRU is within a geographic location, the PRU's response could be based solely on the requirements of the subscriber – whether such action is authorized or not. A PRU may choose to instruct the network to relay certain information to mobile units in a specific geographic region. That information would then be appended to the geographic boundary information and beamed in the specified geographic region. The target PRUs would determine if they are in the specified boundary before alerting a subscriber as to the content of the message. In circumstances where a subscriber in possession of the PRU is in motion and a request is received for the location of the PRU if within a specified region, the PRU may provide this information and also provide additional information such as its velocity to the network. This might help a party seeking help to establish if they would be able to catch up with another subscriber in the region

which help was sought. Also, a party requesting for the location of remote units in a geographic boundary may also forward maximum velocity information. If a PRU is in the region and establishes its velocity is above what is specified, no response is sent to the network. A PRU may calculate its velocity by using the equation, $\text{velocity} = \text{distance} / \text{time}$. At time intervals T_1 and T_2 , a PRU may obtain its location, Y_1 and Y_2 and calculate the distance between these two points, as previously disclosed. The velocity is given by $(\text{distance between } Y_2 \text{ and } Y_1) / (\text{Time at } Y_2 - \text{Time at } Y_1)$. Such information could then be provided to the network. In situations where a PRU cannot perform any of the tasks described herein, the network may obtain its location information and the required functions performed at the network and forwarded to the appropriate communication target on completion.

What is claimed is:

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1. A method for providing the location of a portable remote unit associated with a network comprising:

obtaining the location of the remote unit;

obtaining at the network geographic boundary information within which the location of the remote unit should be disclosed;

determining whether the remote unit is within the said geographic boundary obtained at the network;

forwarding the location of the remote unit to the network upon determination that the remote unit is within the said geographic boundary.

Sub
B1

2. The said technique employed by the method of claim 1 to determine if a remote unit is within a prescribed geographic boundary comprising:

obtaining radii information of the said geographic boundary from the network;

obtaining geographic information describing the origin of the said geographic boundary;

calculating the angle of inclination of the said remote unit to the said geographic boundary origin;

calculating from the said angle of inclination the distance between the remote unit and the said geographic boundary origin.

comparing the said radii of the geographic boundary to the said calculated distance to establish if the remote unit lies in the said geographic boundary.

3. A technique employed by the method according to claim 1 to determine if a remote unit is within a specified geographic boundary comprising:

obtaining from the network geographic information describing the said geographic boundary;

estimating at the remote unit if the current location of the remote unit is within the said geographic boundary obtained at the network;

b.12 4. A method employed in 1 to further limit the provision of remote unit location comprising to the network comprising:

obtaining at the network, exclusion region information within which the remote unit should not provide its location the network;

determining that the remote unit is not in the said exclusion region before providing the location of the remote unit to the network;

Sub 7 5. A method for providing the location of portable remote units that exist within a prescribed geographic boundary comprising:

re-defining at least a geographic region in the said prescribed geographic boundary;
requesting in the said re-defined geographic region(s), the location of remote units that are present in the region;

verifying after each request in a re-defined region whether a portable remote unit disclosed a global location in the region;

providing to the network upon said verification, the location of at least a remote unit that revealed its location in the said re-defined region.

6. A technique according to claim 5, utilized to terminate a request for the location information of remote units in the said prescribed geographic boundary comprising:
checking to establish that a request for remote unit location information was undertaken in all re-defined regions of the said prescribed boundary or a portable remote unit in a defined region responded with location information.

7. In a communication system comprising:
at least a first communication unit able to provide location information to the network;
at least a second communication unit able to request for the location of a first communication unit present within a geographic boundary prescribed by the at least second communication unit;
the system able to obtain and provide the location information of the at least first communication unit that is within the prescribed geographic boundary defined by the at least second communication unit.

8. The system of claim 7 the at least first communication unit, able to provide first communication unit location information if it is within a geographic boundary prescribed by the at least second communication unit;

9. A method for determining that a portable remote unit associated with a network is being tracked comprising;
obtaining the location of the said portable remote unit or tracked unit;

obtaining the location of at least a second communication unit or tracking unit that is within proximity or a pre-specified radius of the said tracked unit;
verifying whether the tracking and tracked unit have traveled a minimum pre-specified distance;
forwarding the result of the said verification to the network at the end of the tracking period.

10. The verification technique employed in the method of claim 9 comprising:

6.13 retaining a tracking list of all tracking units that are within a pre-specified radius or region of the said tracked unit at the first tracking interval;

eliminating or removing at subsequent tracking intervals, all tracking units in the said tracking list that do not report their location during a subsequent tracking interval.

validating at the end of the tracking period that at least a tracking unit exist in the tracking list and a minimum distance was traveled by the tracked unit.

11. Another verification technique employed in the method of claim 9 comprising:

maintaining a list of all tracking units that are maintaining a close distance to the tracked unit over the said period of time.

searching the tracking list at the end of the tracking period to obtain tracking units that traveled a minimum pre-specified distance with the tracked unit.

Sub 7 12. A communication system comprising:

A5 a network of communication units;

at least a first communication unit and at least a second communication unit able to provide location information to the said network;

the system able to determine that the at least second communication unit maintained a close distance from the at least first communication unit while traveling a minimum pre-specified distance.

sub. 12 13. The system of claim 12, the at least first communication unit able to invoke a tracking mode at the at least first communication unit in order to determine if a clandestine unit is tracking it.

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sub. 14 14. A portable mobile remote unit associated with a network comprising:
means to obtain the location of the portable mobile remote unit;
means to obtain geographic boundary information in order to disclose a global location at the network;
means to provide the location of the portable mobile remote unit to the network upon determination that the portable mobile remote unit is within the said geographic boundary obtained at the network;

sub. 15 15. The portable mobile remote according to claim 14, having means to further determine if location disclosure for the remote unit is prohibited at a specific geographic boundary before sending its location to the network;

ABSTRACT OF THE DISCLOSURE

A mobile location reporting communication system consists of a network of communication sources and targets managed by one or more control stations. In the system, a communication source may request for the location of a mobile communication target from the network. The target conveys its location to the network and that information is provided to the source. In the invention a mobile communication source request for the location of mobile communication targets that are present in a prescribed geographic boundary. The network provides to the source only remote targets that are present in the prescribed boundary. Also in the invention, a concealed or clandestine mobile portable target, close to the mobile portable source, may be tracking the source. The source may invoke a method that may result in the disclosure of mobile targets that have traveled a pre-specified distance with the source while maintaining proximity to the source.

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PTO/SB/01 (10-00)
Approved for use through 10/31/2002. OMB 0651-0032

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**DECLARATION FOR UTILITY OR
DESIGN
PATENT APPLICATION
(37 CFR 1.63)**

☐ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number

First Named Inventor

COMPLETE IF KNOWN

Application Number

Filing Date

Group Art Unit

Examiner Name

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**METHOD AND APPARATUS FOR LOCATING MOBILE
UNITS TRACKING ANOTHER OR WITHIN A PRESCRIBED
GEOGRAPHIC BOUNDARY.**

(Title of the Invention)

the specification of which

☒ is attached hereto

OR

☐ was filed on (MM/DD/YYYY)

as United States Application Number or PCT International

Application Number

and was amended on (MM/DD/YYYY)

(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
			☐	YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

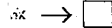
I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

[Page 1 of 2]

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR:

☐ A petition has been filed for this unsigned inventor

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(first and middle [if any])

MUNDI

Family Name
or Surname

FOMUKONG

Inventor's
Signature

[Signature]

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City WLA

State CA

ZIP 90034

Country U.S.

NAME OF SECOND INVENTOR:

☐ A petition has been filed for this unsigned inventor

Given Name
(first and middle [if any])

Family Name
or Surname

Inventor's
Signature

Date

Residence: City

State

Country

Citizenship

Mailing Address

Mailing Address

City

State

ZIP

Country

☐ Additional inventors are being named on the _____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

000027" BATES 60

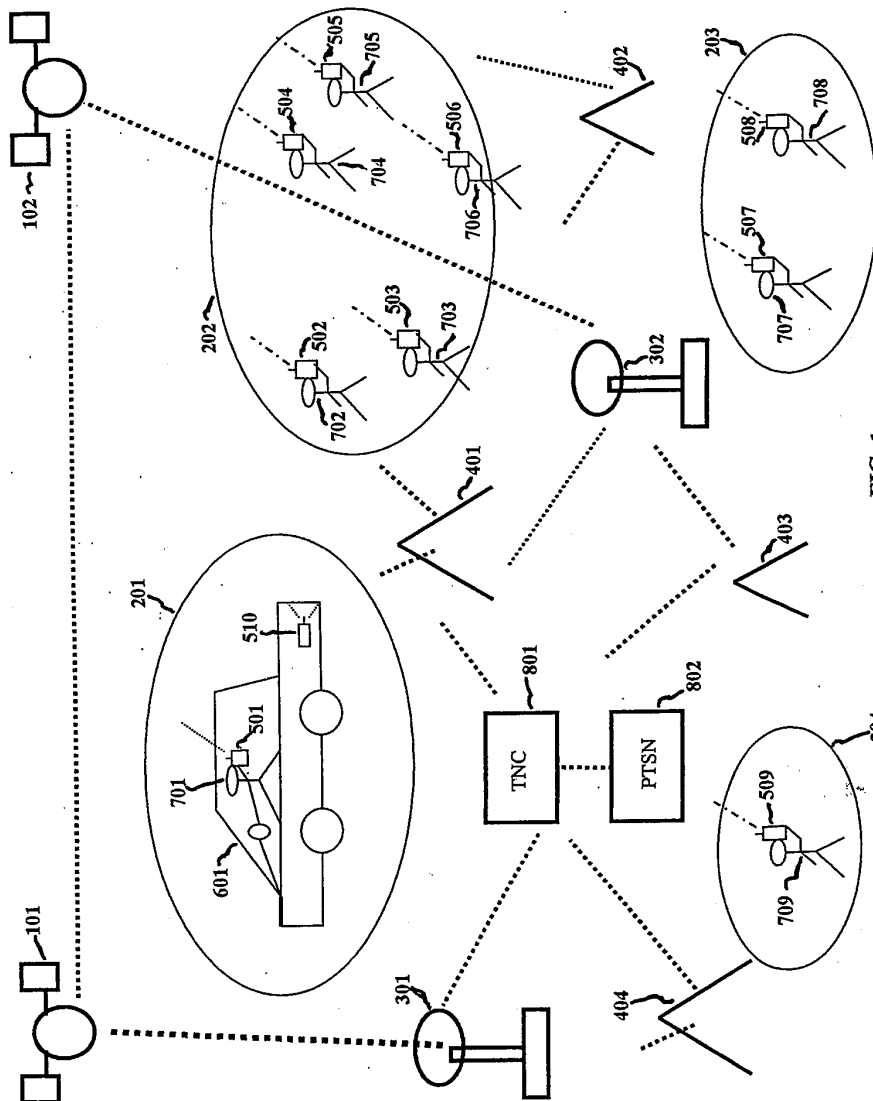


FIG. 1

000027-84TES60

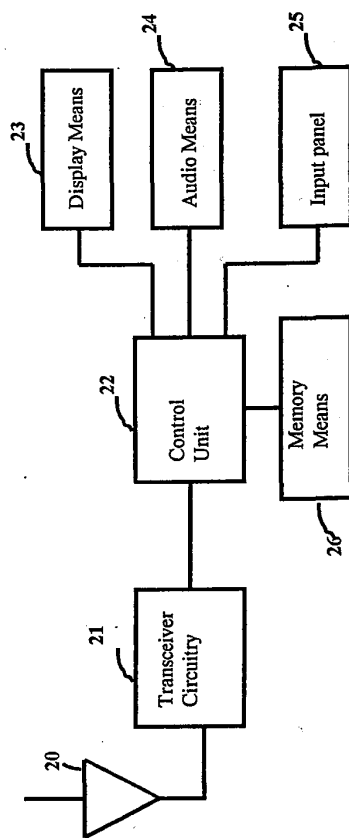


FIG. 2

00027-8475260

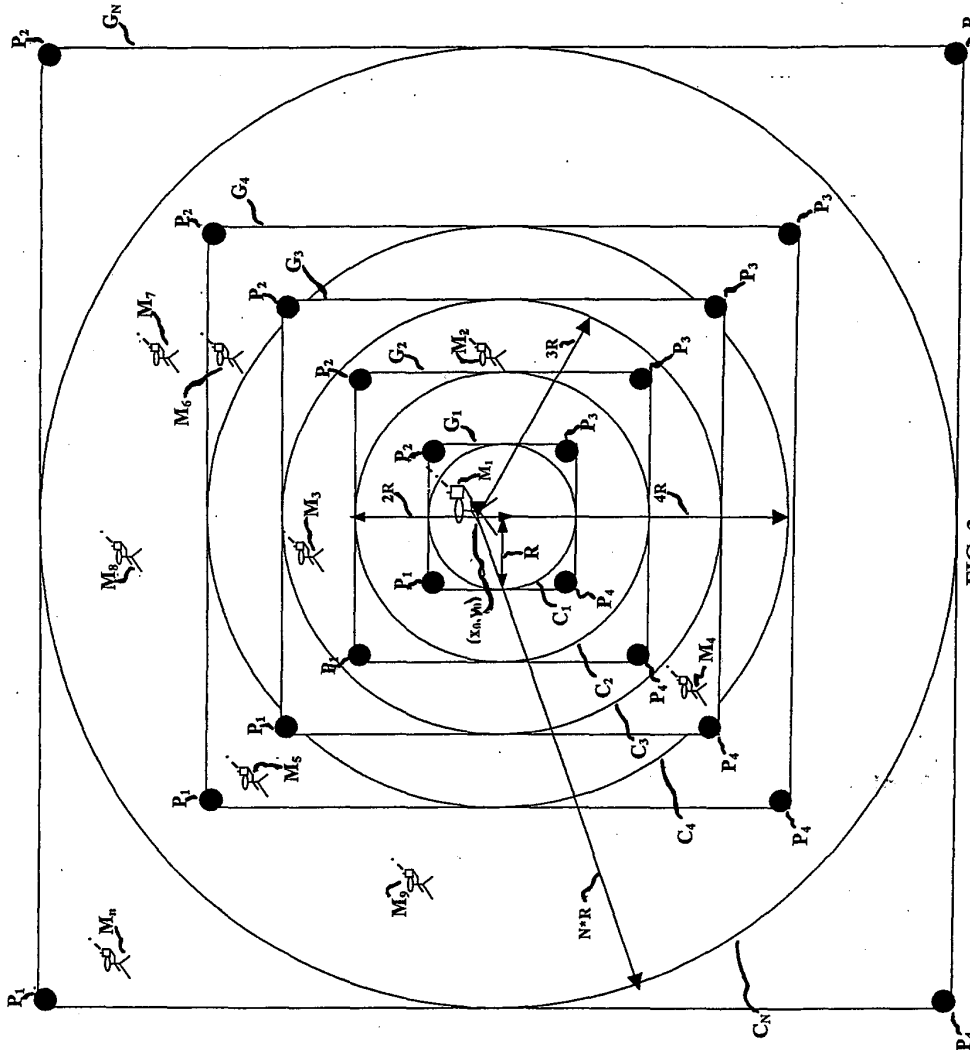


FIG. 3

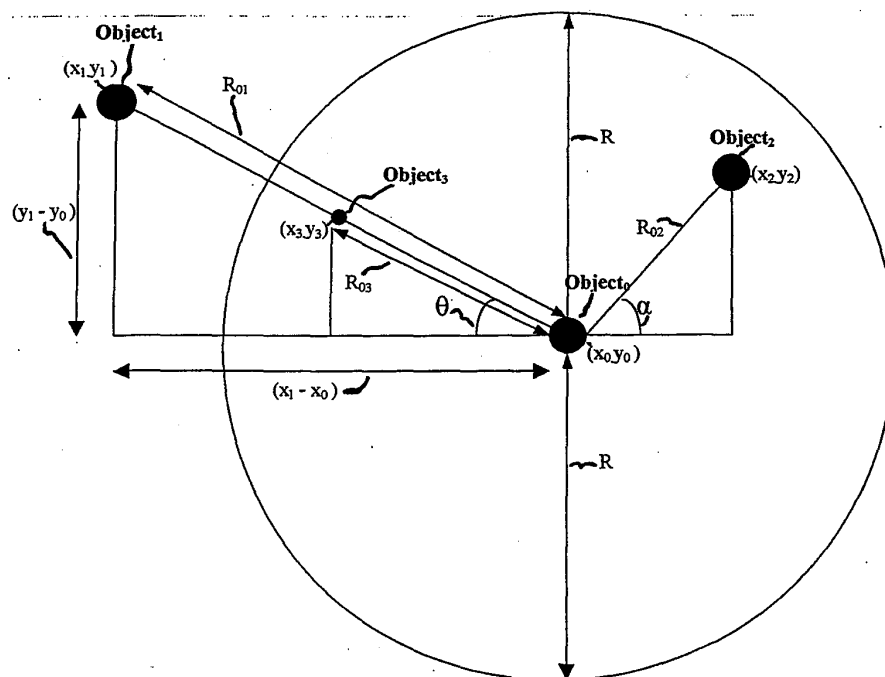


FIG. 4

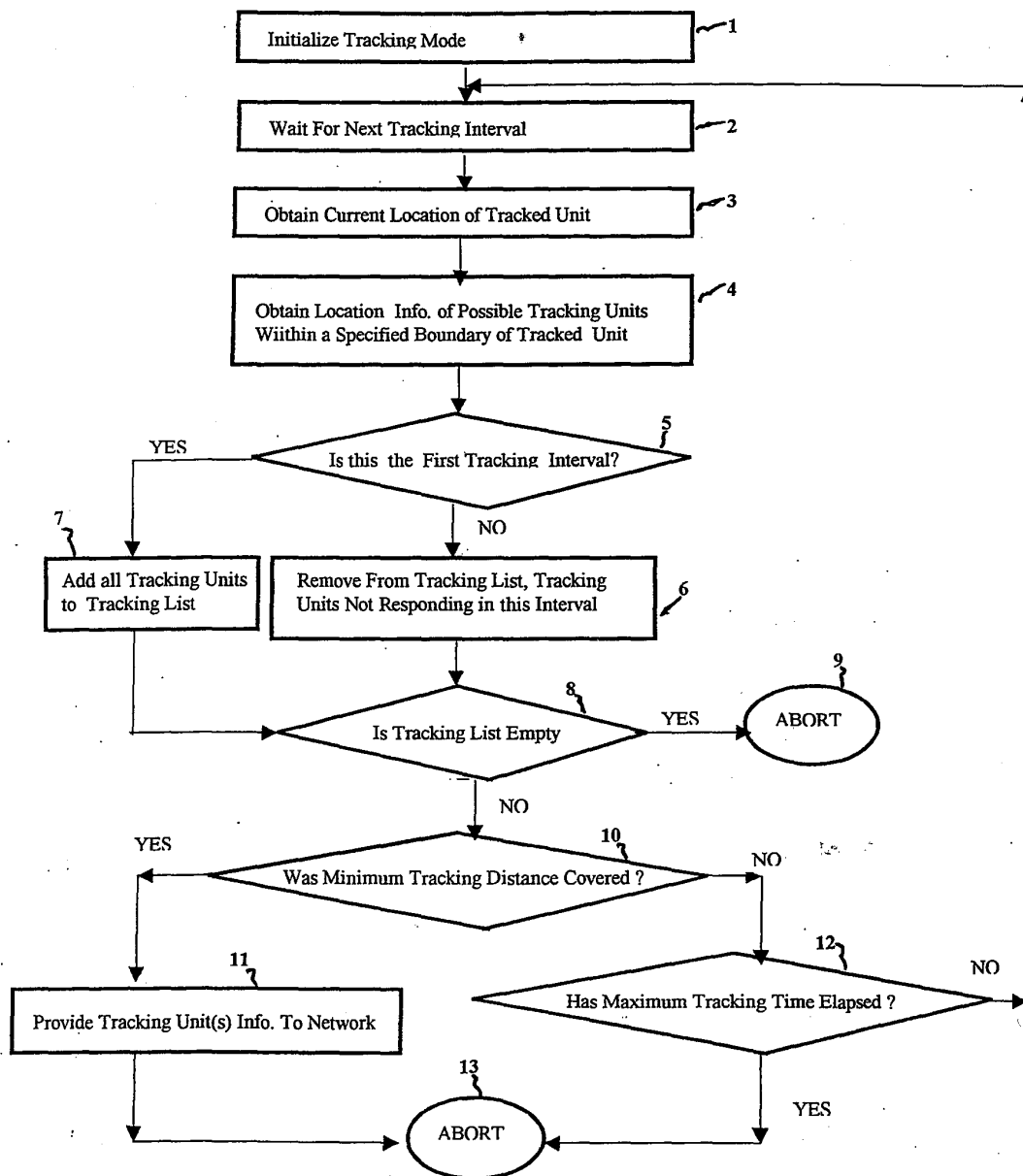


FIG. 5
5/7

00021-8715560

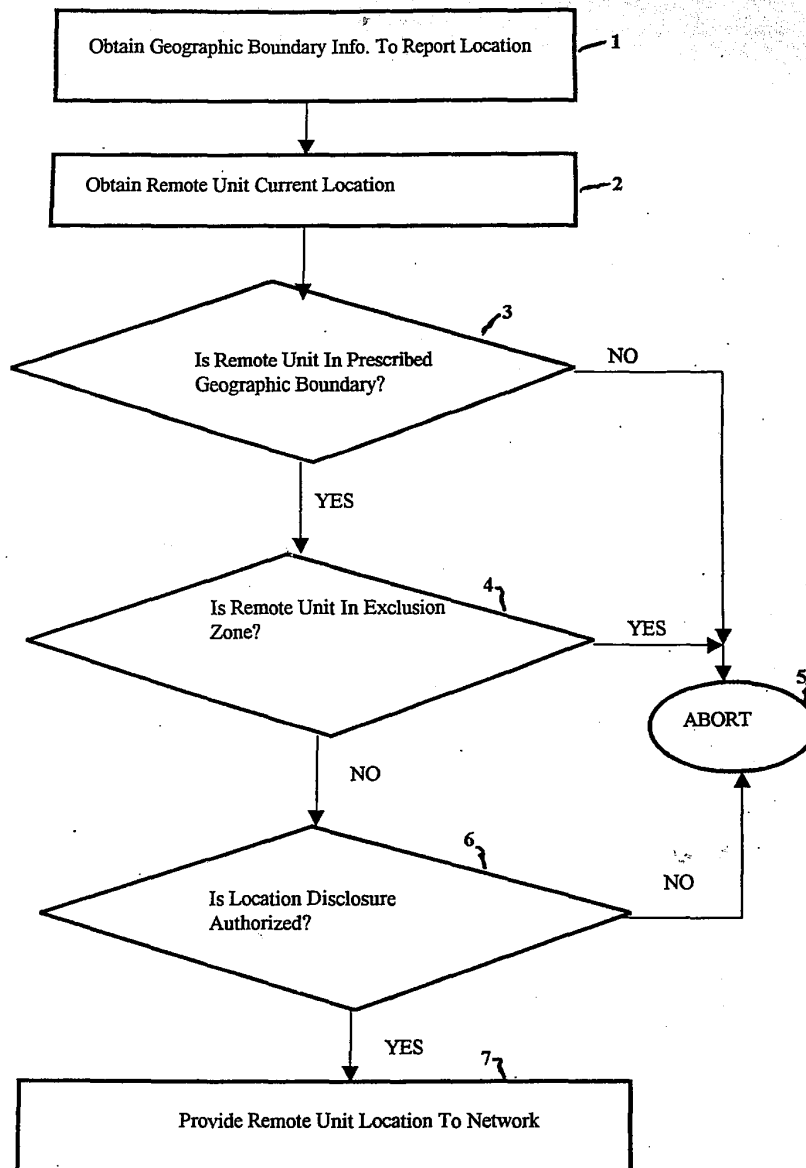


FIG. 6
6/7

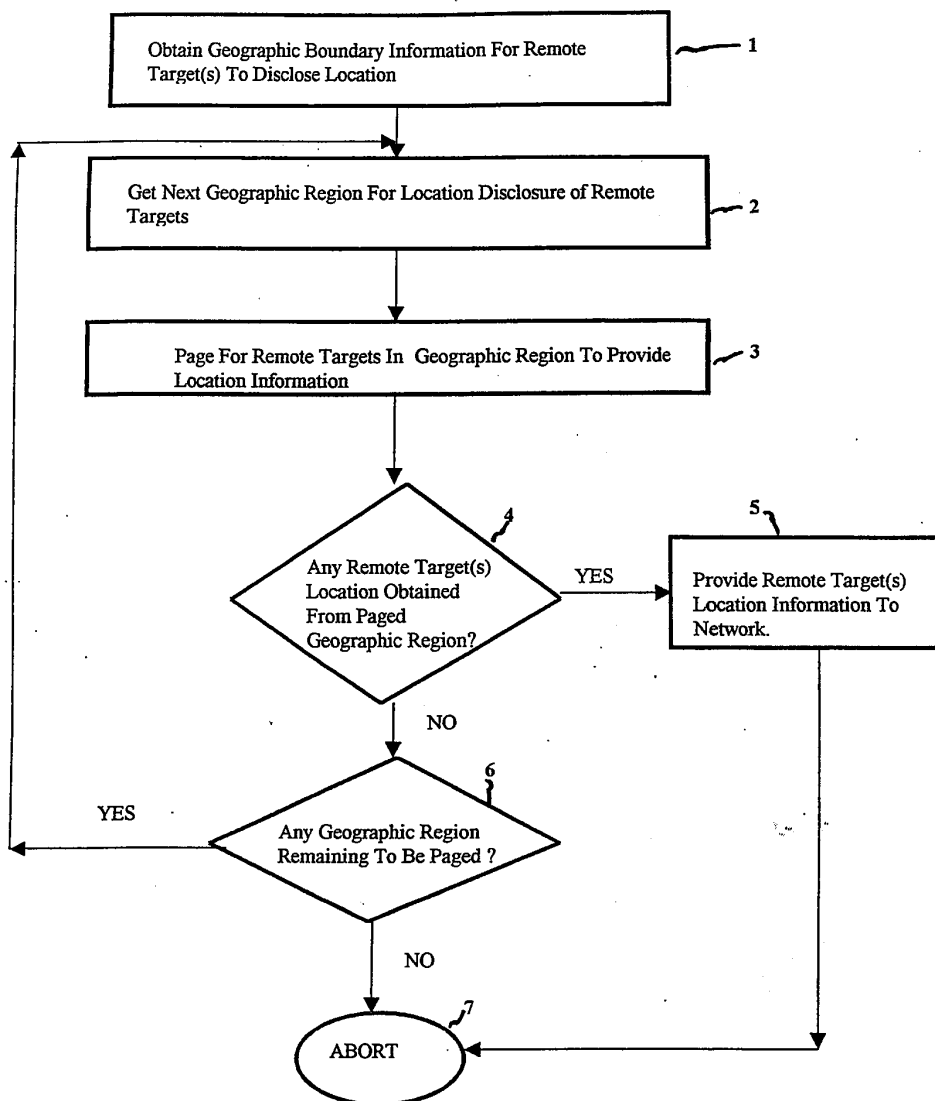


FIG. 7

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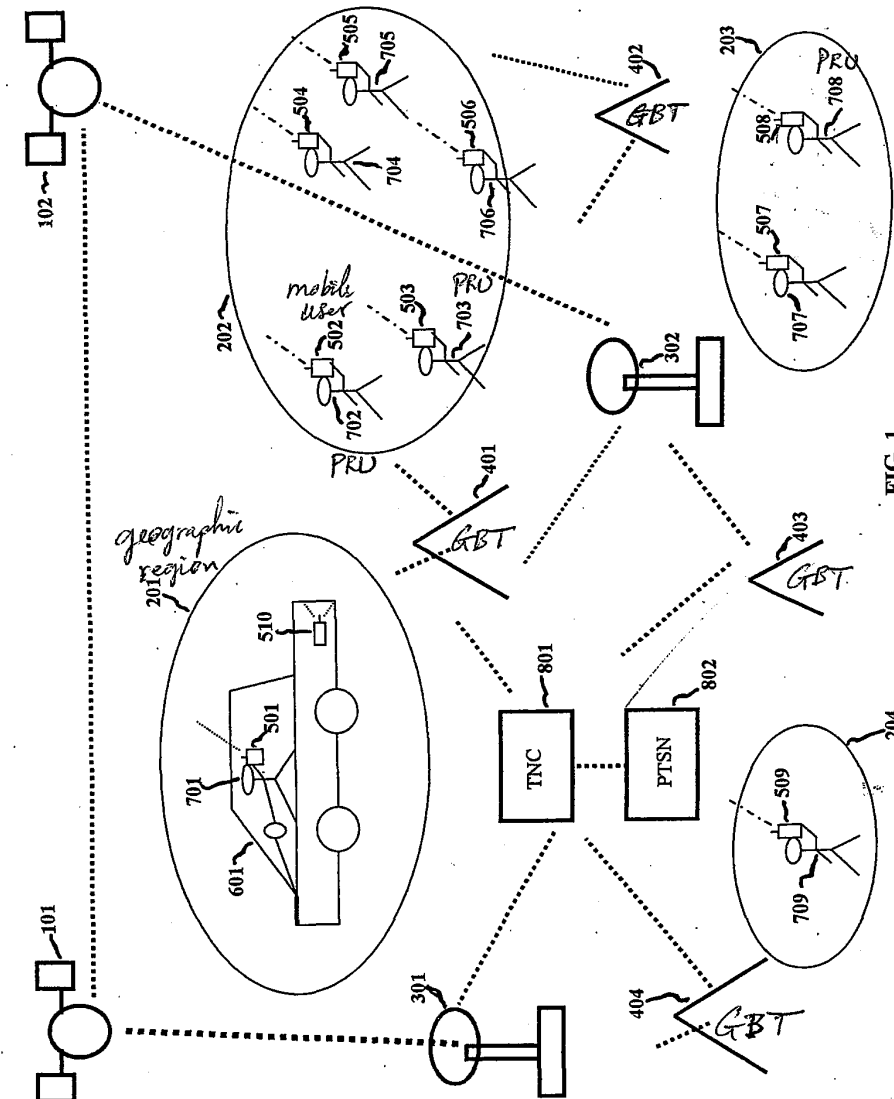


FIG. 1

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✓

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5,870,029
6,333,703
5,944,659

000021" 84TES460

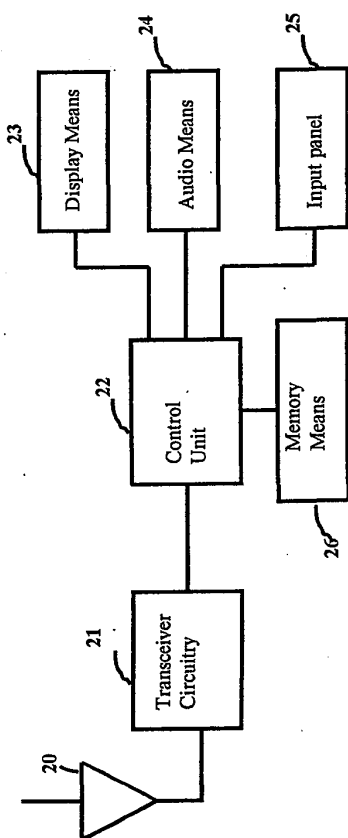


FIG. 2

PRU

000221-84TES460

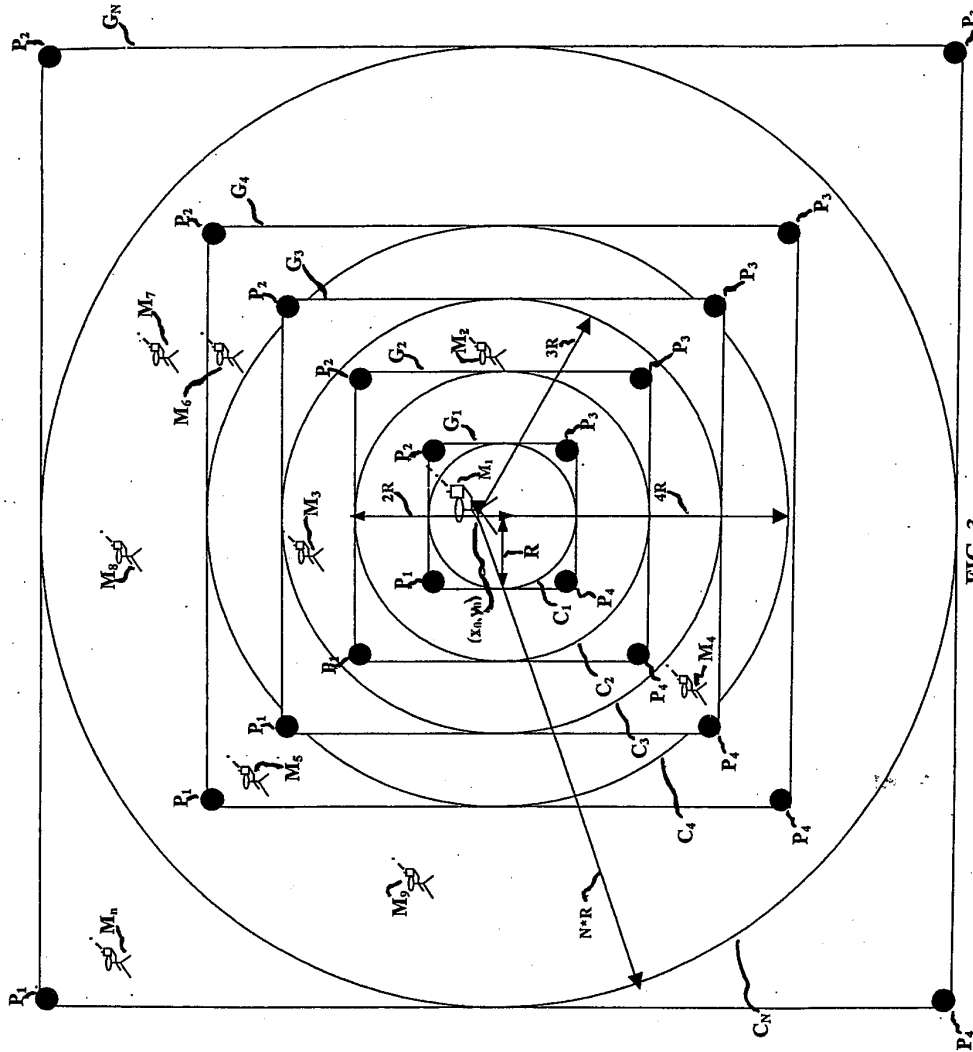


FIG. 3

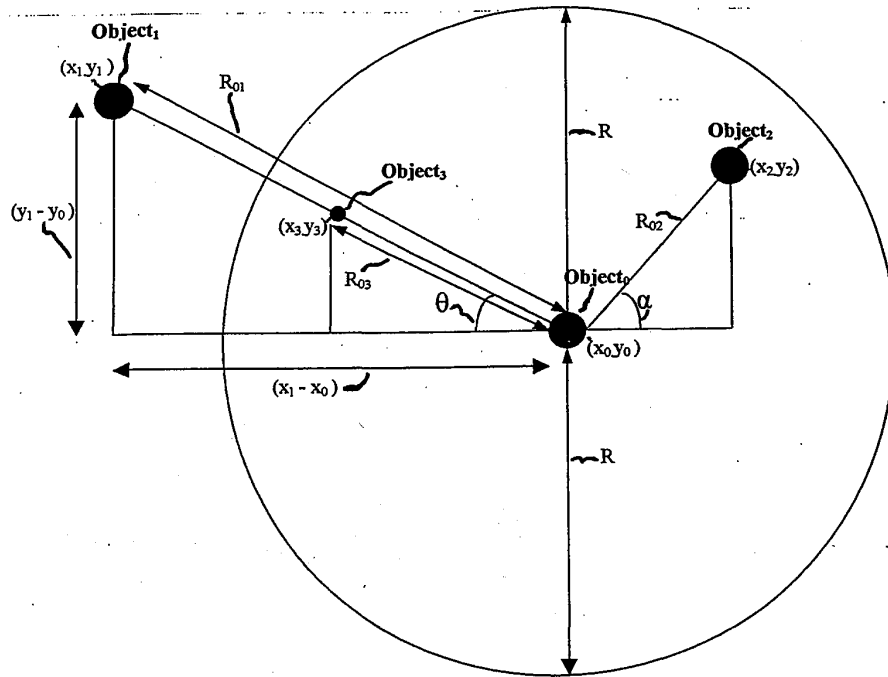


FIG. 4

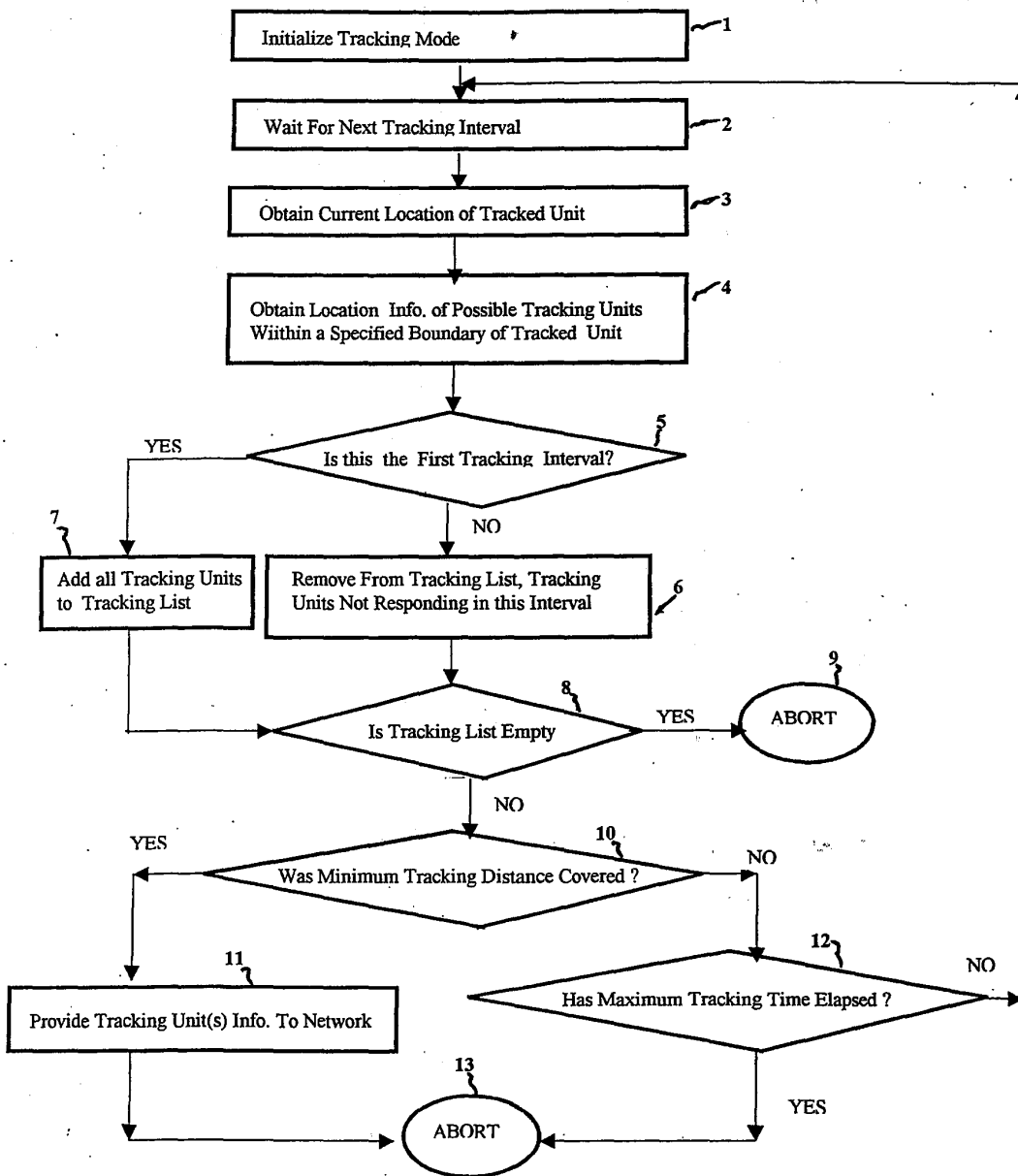


FIG. 5
5/7

000021 84TES260

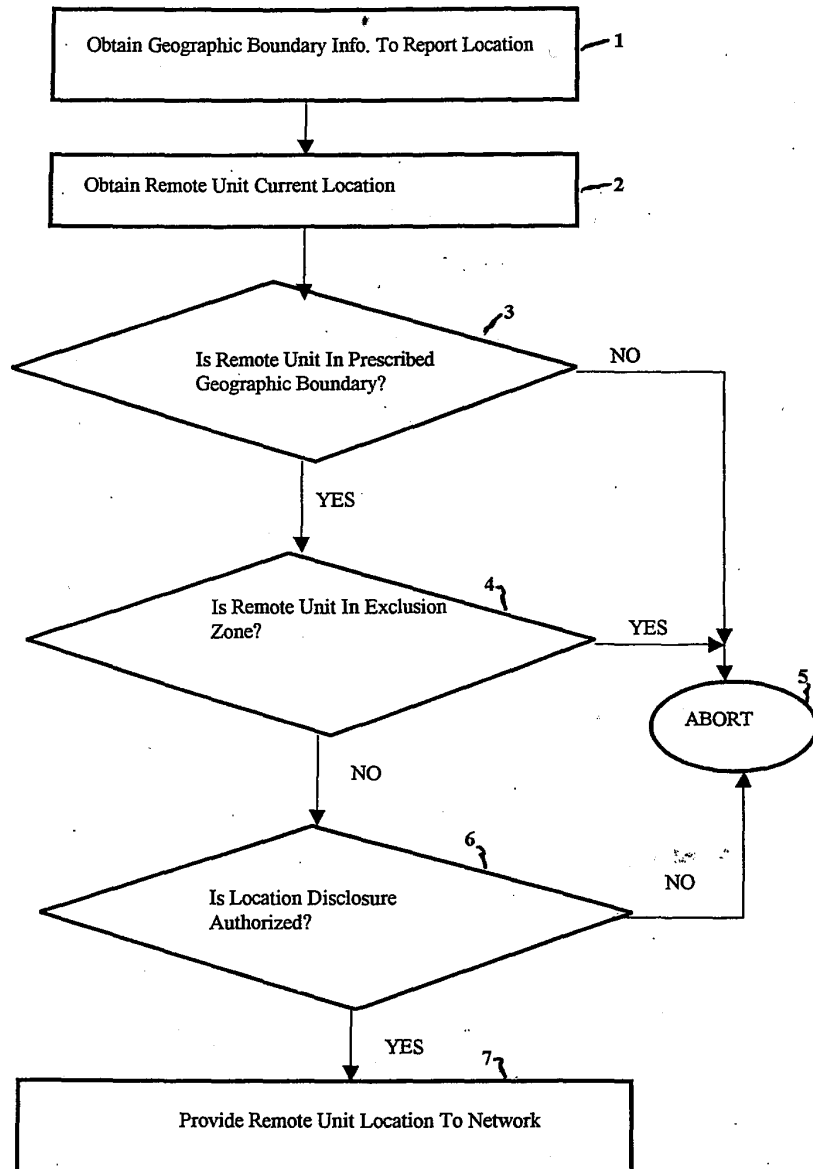
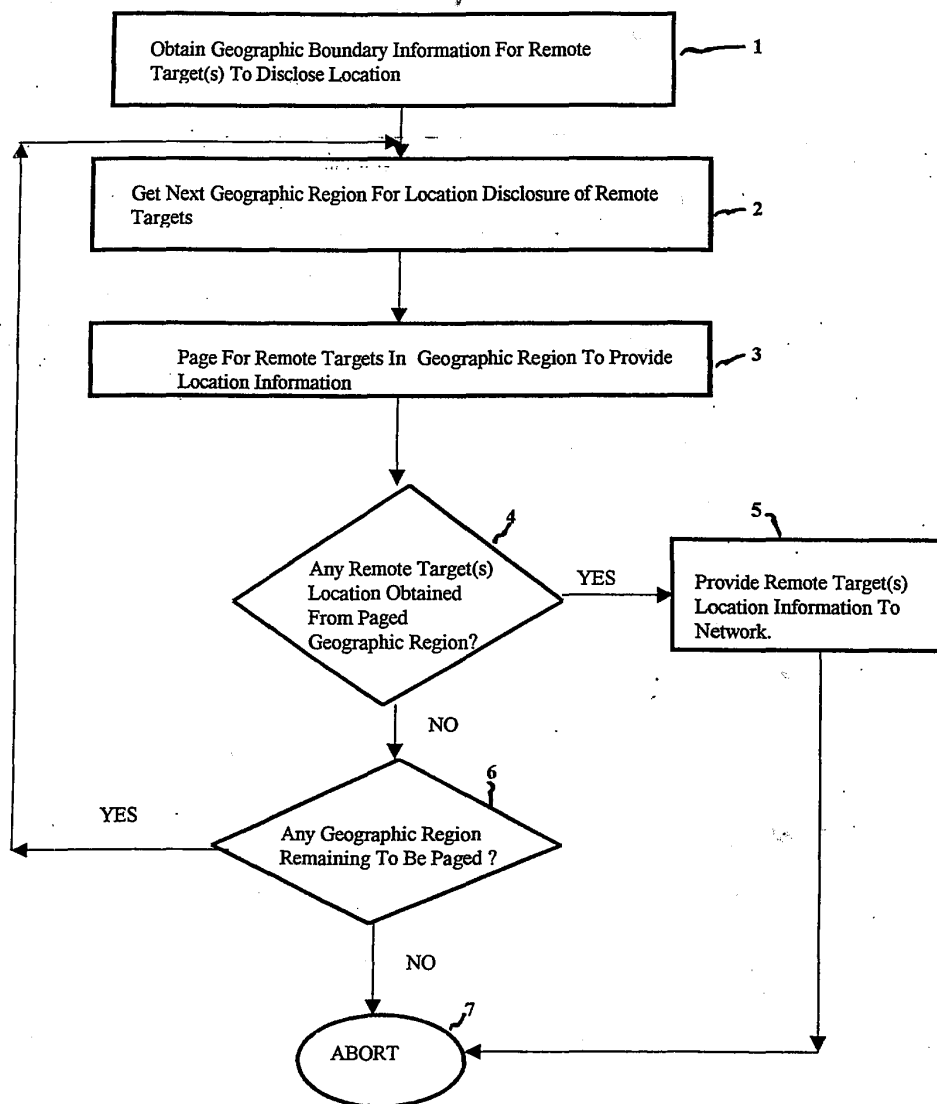


FIG. 6

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APPROVED	O.G. FIG.	
BY	CLASS	SUBCLASS
DRAFTSMAN	340	988

L/I

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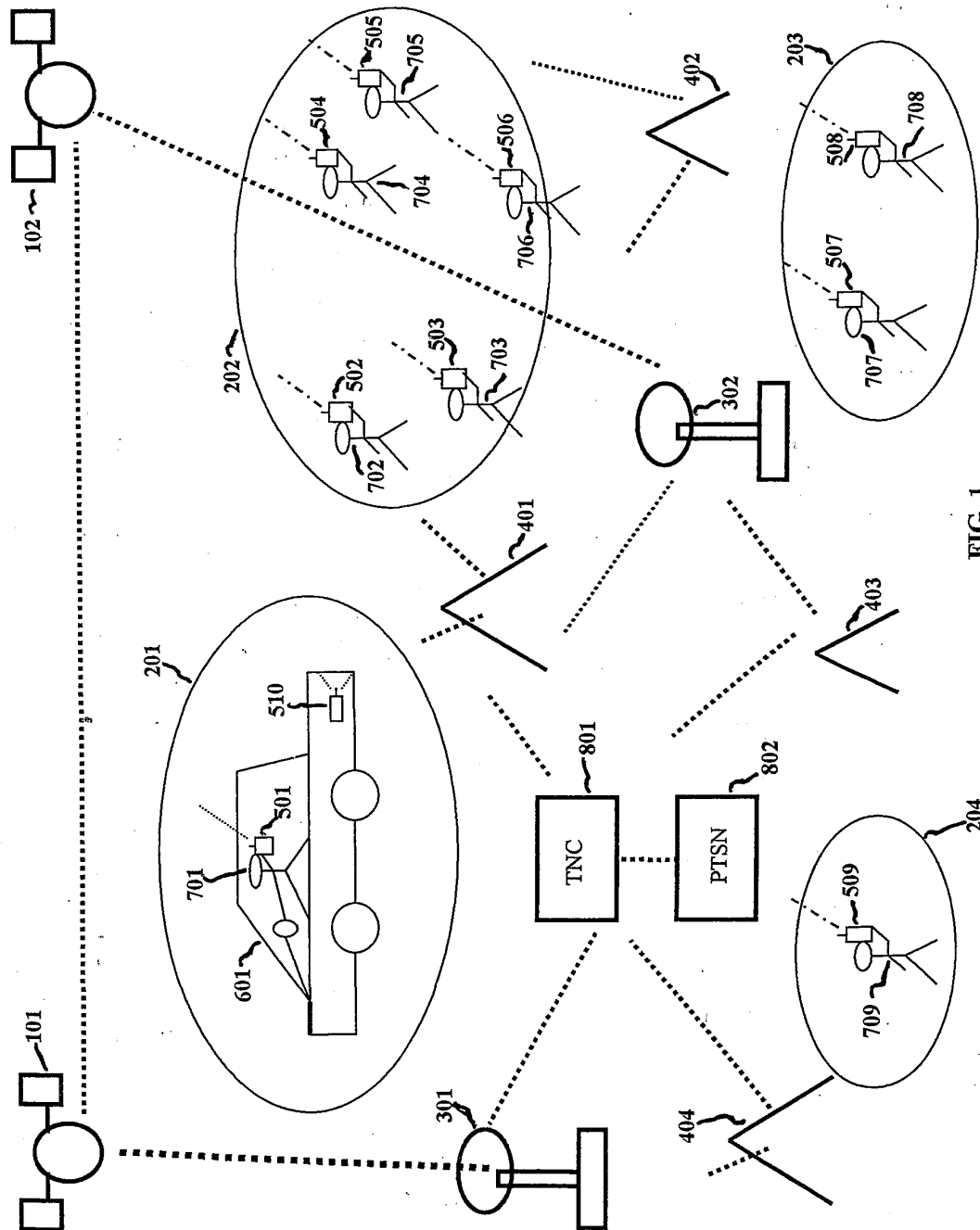


FIG. 1

(7)

APPROVED	O.G. FIG.	
BY	CLASS	SUBCLASS
DRAFTSMAN		

2/7

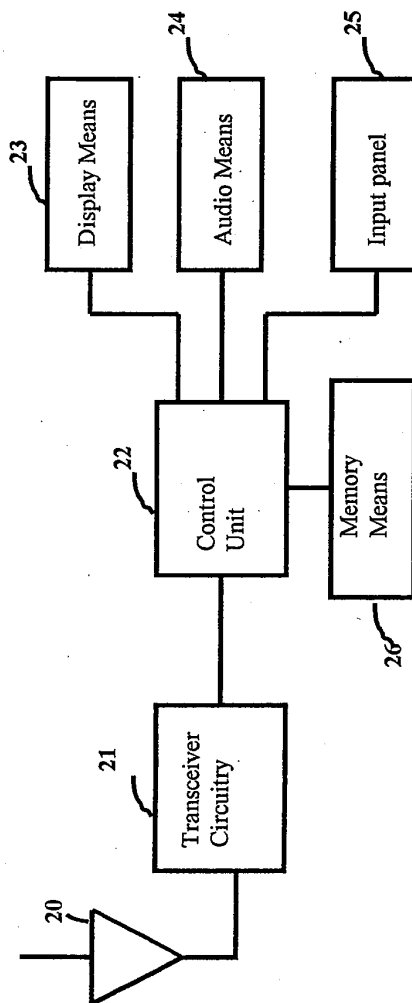


FIG. 2

000001" 84T5260

APPROVED	O.G. FIG.
BY	CLASS
DRAFTSMAN	SUBCLASS

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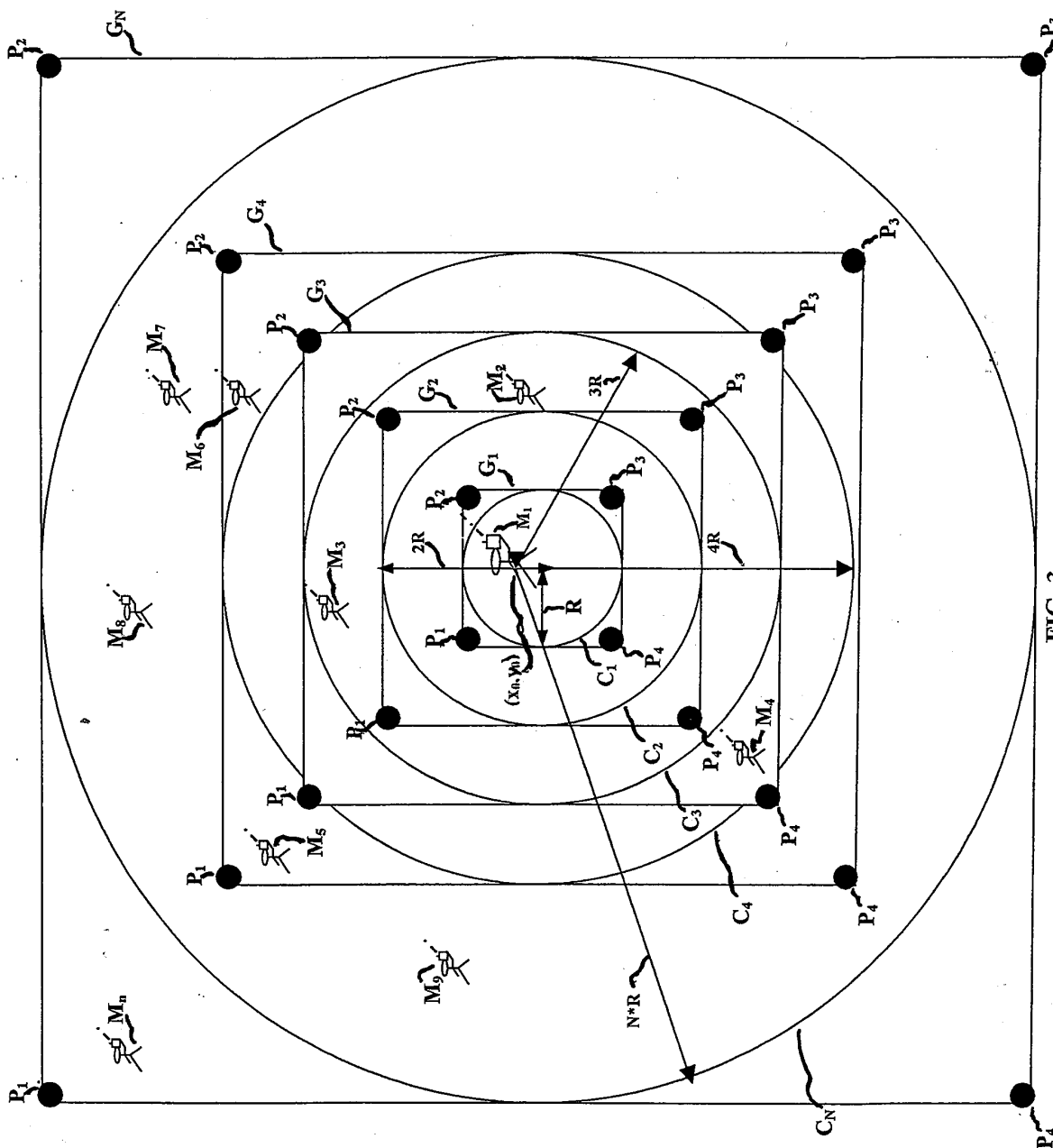


FIG. 3

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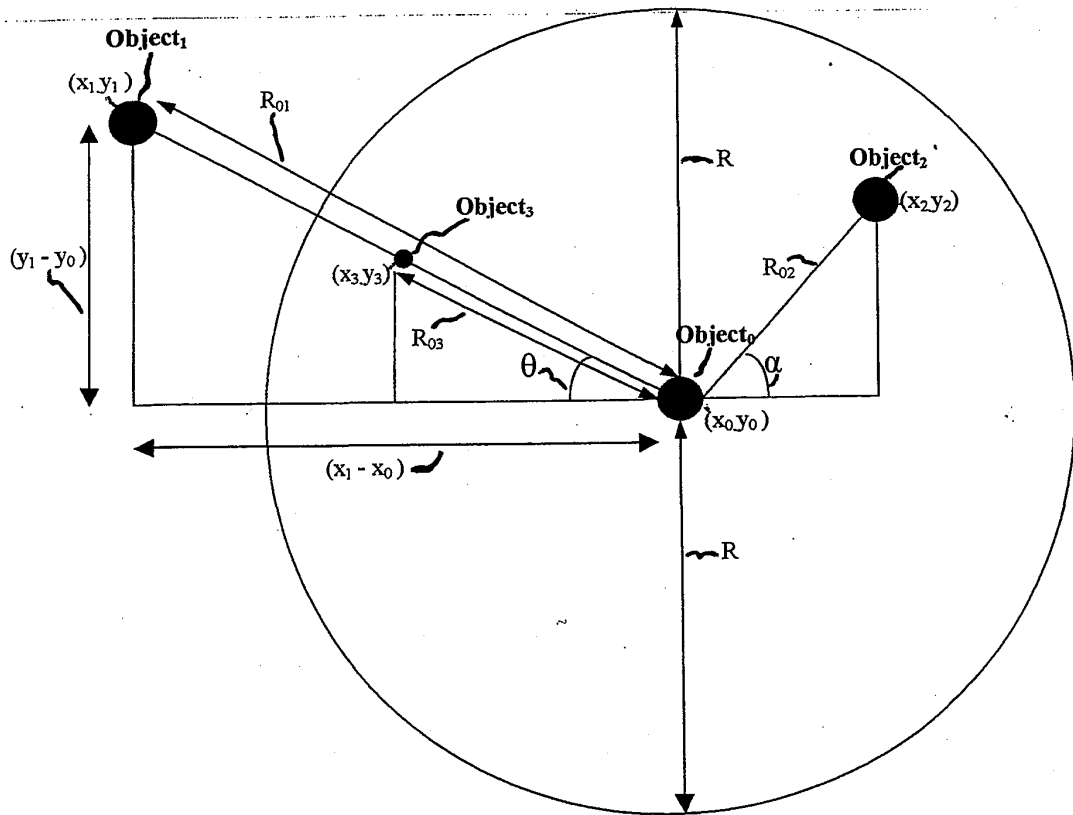


FIG. 4

APPROVED	O.G. FIG. 5	
BY	CLASS	SUBCLASS
DRAFTSMAN	340	988

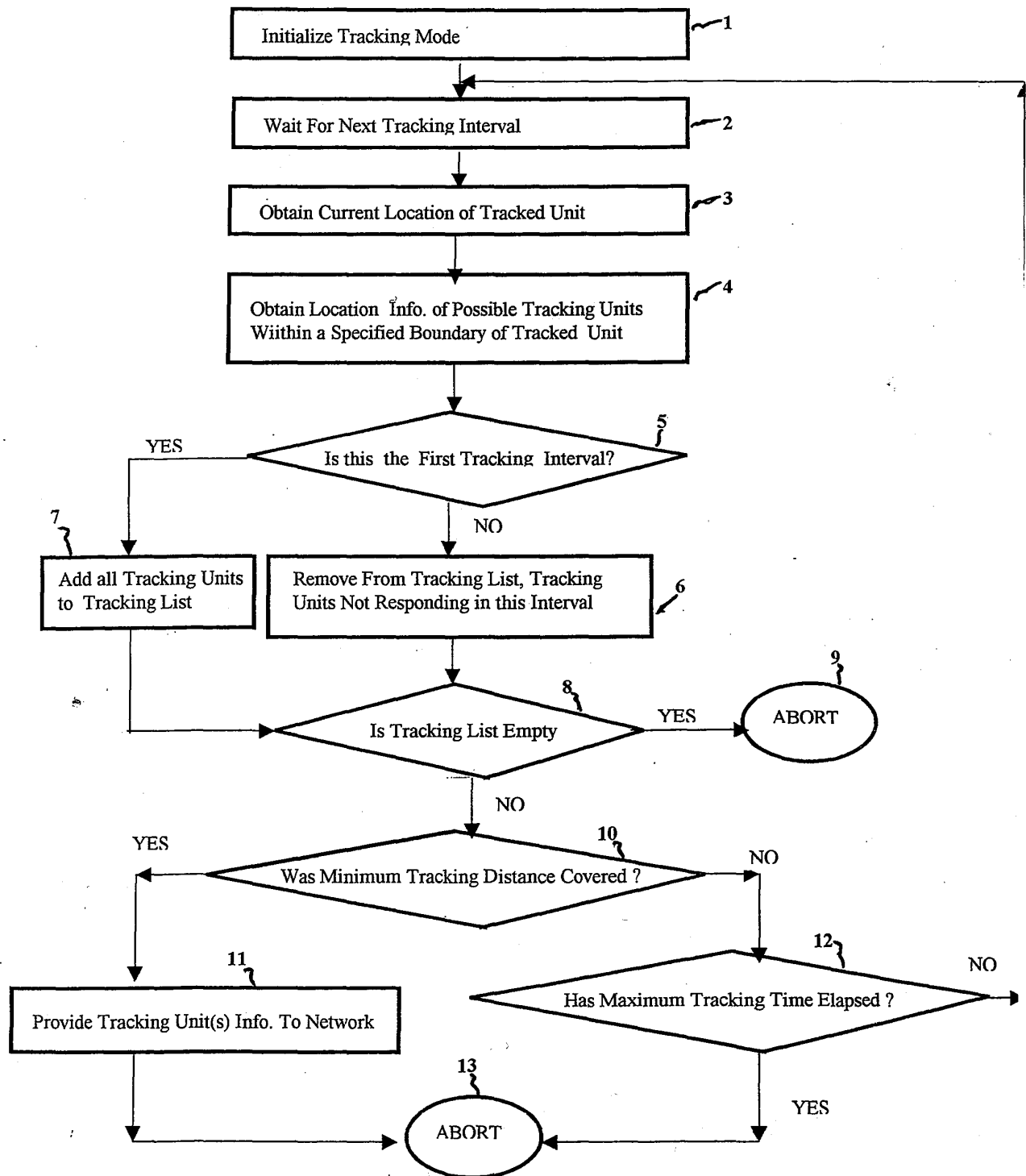


FIG. 5
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APPROVED	O.G. FIG.	
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DRAFTSMAN		

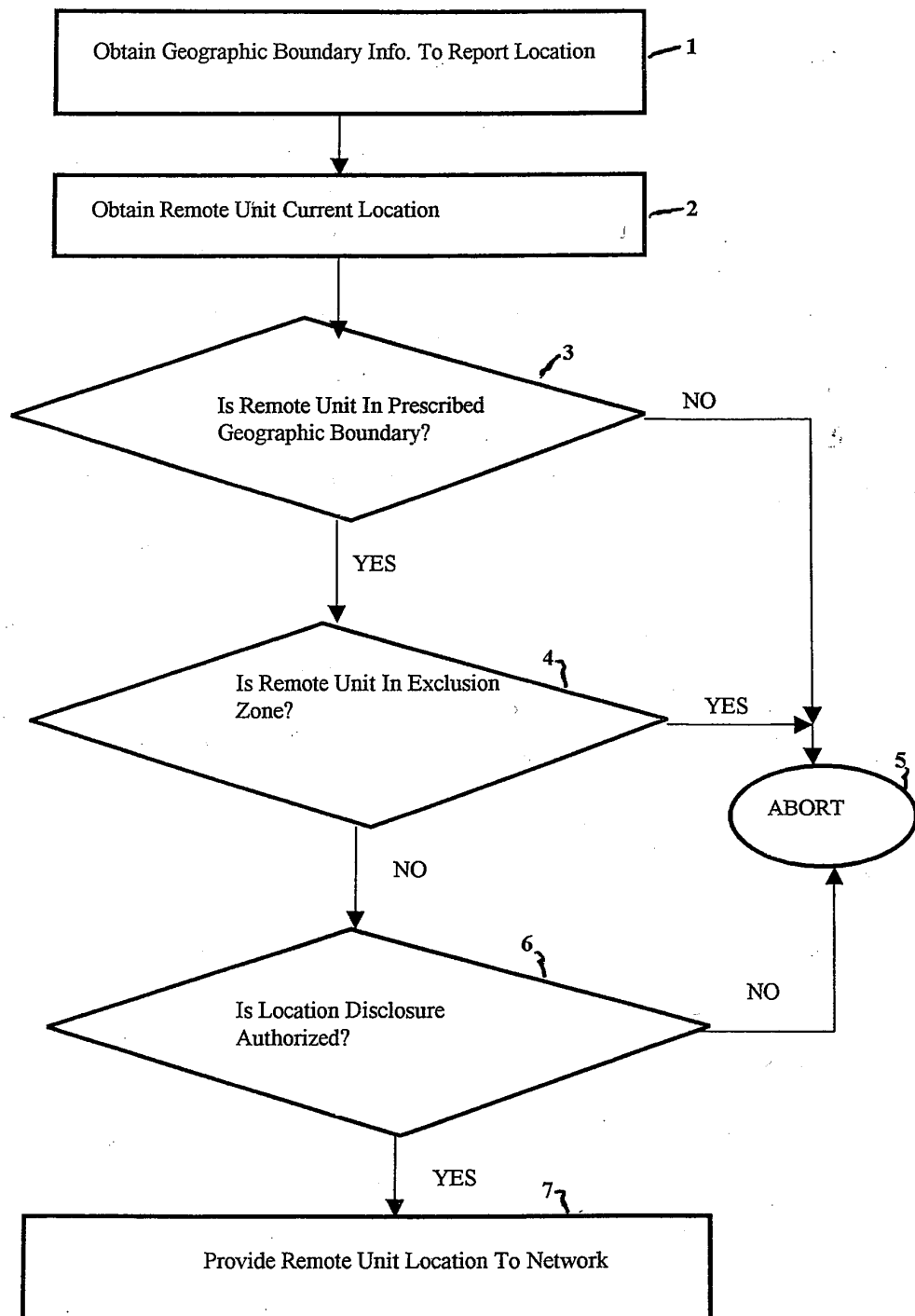


FIG. 6
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APPROVED	O.G. FIG.	
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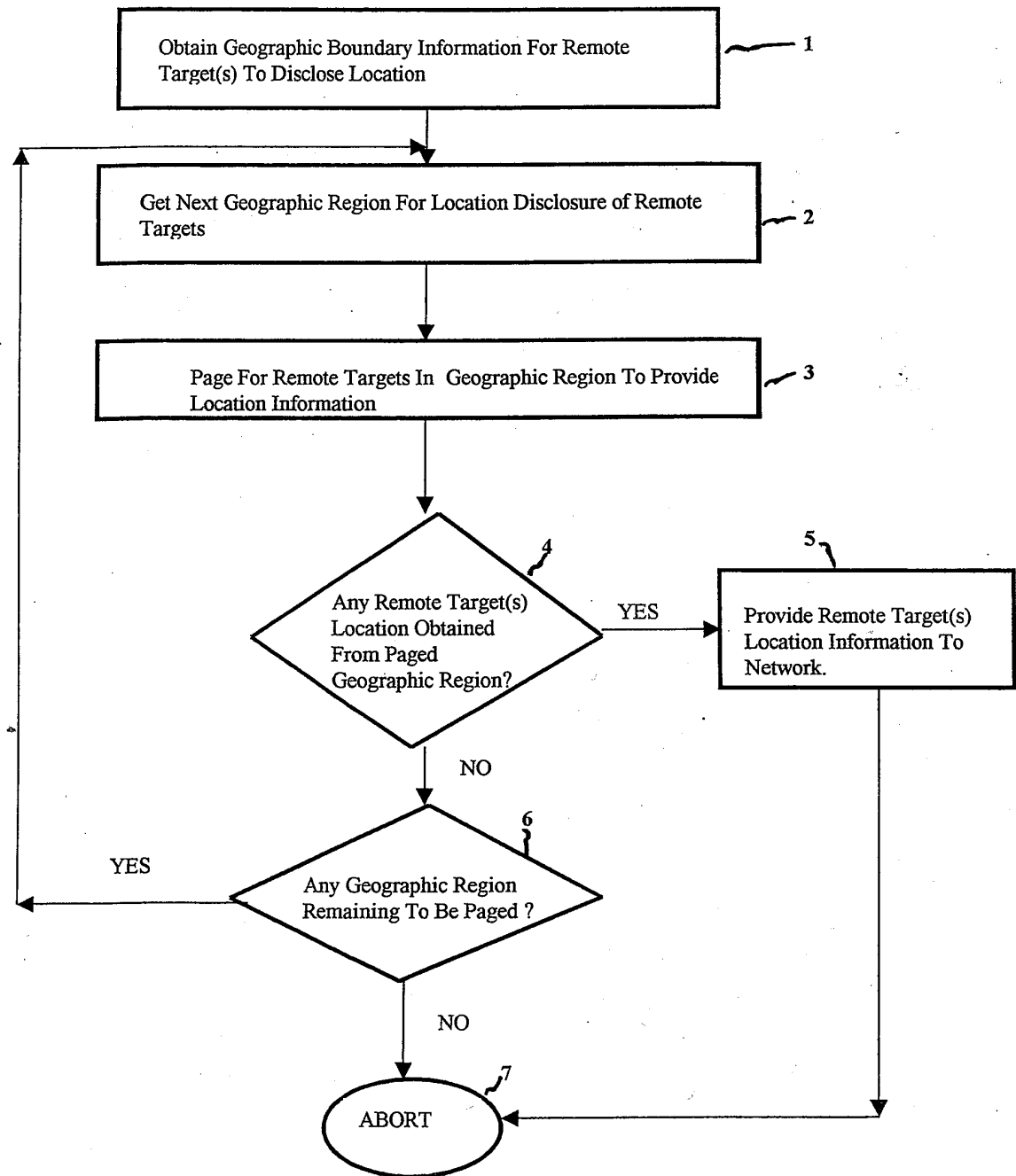


FIG. 7

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Application Number	09/753,178
Filing Date	12/30/2000
First Named Inventor	MUNDI
Group Art Unit	2632
Examiner Name	VAN FRIED
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09/753178
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U.S. PATENT DOCUMENTS						
Examiner Initials*	Cite No.1	U.S. Patent Document		Name of Patentee or Applicant of Cited Document	Date of Publication of Cited Document MM-DD-YYYY	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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✓		5,689,245		Norreen et al.	11-18-1997	340/825.49
✓		5,418,537		Bird	05-23-1995	340/357.09
✓		5,539,395		BMSS	07-23-1996	340/7.43
✓		5,504,491		Chapman	04-02-1996	342/357.09
✓		5,918,159		Fornukong et al	08-26-1997	340/7.21

[illegible]

Van Tine

10/18/07

¹ Unique citation designation number. ² See attached Kinds of U.S. Patent Documents. ³ Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. * Applicant is to place a check mark here if English language Translation is attached.

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Ref: RB 7704750

US005689245A

United States Patent [19]

[11] Patent Number: 5,689,245

Noreen et al.

[45] **Date of Patent:** Nov. 18, 1997

[54] **INTEGRATED COMMUNICATIONS
TERMINAL**

[75] Inventors: **Gary Noreen**, La Cañada Flintridge, Calif.; **Theodore R. Harper**, Apex, N.C.; **Ken Renshaw**, Manhattan Beach, Calif.

[73] Assignee: **Radio Satellite Corporation.** La
Canada Flintridge. Calif.

[21] Appl. No.: 469,608

[22] Filed: Jun. 6, 1995

4,837,786	6/1989	Gurantz et al.	370/20
4,852,090	7/1989	Borth	370/104
4,868,811	9/1989	Suzuki	370/50
4,870,660	9/1989	Keate	375/88
4,882,730	11/1989	Shinmyo	370/95.2
4,903,320	2/1990	Hanawa	455/34
4,914,517	4/1990	Duffield	358/191.1
4,951,279	8/1990	Hotta	370/75
5,027,400	6/1991	Baji et al.	380/20
5,036,389	7/1991	Morales	358/84
5,057,915	10/1991	Von Kohorn	358/84
5,134,719	7/1992	Mankovitz	455/154.1
5,161,019	11/1992	Emanuel	358/183
5,539,395	7/1996	Buss	340/825.44

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 963,233, Oct. 19, 1992, Pat. No. 5,455,823.

[51] **Int. Cl.⁶** **H04Q 1/00**

[52] U.S. Cl. 340/825.49; 370/329; 340/825.44

[58] **Field of Search** 340/825.44, 825.49:
370/328, 329

References Cited

U.S. PATENT DOCUMENTS

3.683,116	8/1972	Dill	179/15
4.178.476	12/1979	Frost	340/825.44
4.425.639	1/1984	Acampora et al.	370/50
4.437.183	3/1984	Profet	370/110.1
4.470.788	9/1984	Konneker	340/825.49
4.501.002	2/1985	Auchterlonie	375/86
4.599.734	7/1986	Yamamoto	375/40
4.625.235	11/1986	Watson	358/86
4.635.247	1/1987	Tejima	370/13
4.635.285	1/1987	Coombs	379/63
4.660.196	4/1987	Gray et al.	370/109
4.706.121	11/1987	Young	358/142
4.720.873	1/1988	Goodman et al.	455/2
4.742.512	5/1988	Akashi et al.	370/96
4.752.951	6/1988	Konneker	340/825.49
4.754.465	6/1988	Trimble	375/1
4.759.016	7/1988	Otsuka	370/95

FOREIGN PATENT DOCUMENTS

60-261232 12/1985 Japan H04B 7/15

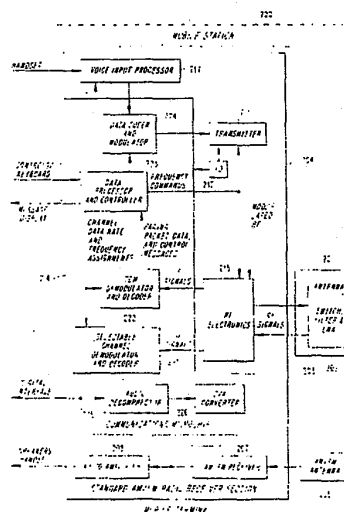
Primary Examiner—Brian Zimmerman

Attorney, Agent, or Firm—David Newman & Associates.
P.C.

[57] **ABSTRACT**

An electronic device for use as a communications terminal including means for determining a location of the electronic device, means for storing that location in the electronic device, means for receiving a wide-area broadcast, and means for executing location-specific instructions contained within the wide-area broadcast, responsive to the stored location. The invention further comprises a method for delivering a data channel signal having a plurality of location-dependent instructions, from a transmitter to a plurality of receiving units. The method comprises the step of transmitting the data channel signal to the plurality of receiving units. Once received by a particular receiving unit, the particular receiving unit identifies and executes location-dependent instructions within the data channel signal which correlate with the location of the particular receiving unit as stored in that receiving unit. The location of the particular receiving unit may be determined internal or external to the particular receiving unit and may be transmitted to the particular receiving unit as part of the data channel signal.

22 Claims, 8 Drawing Sheets



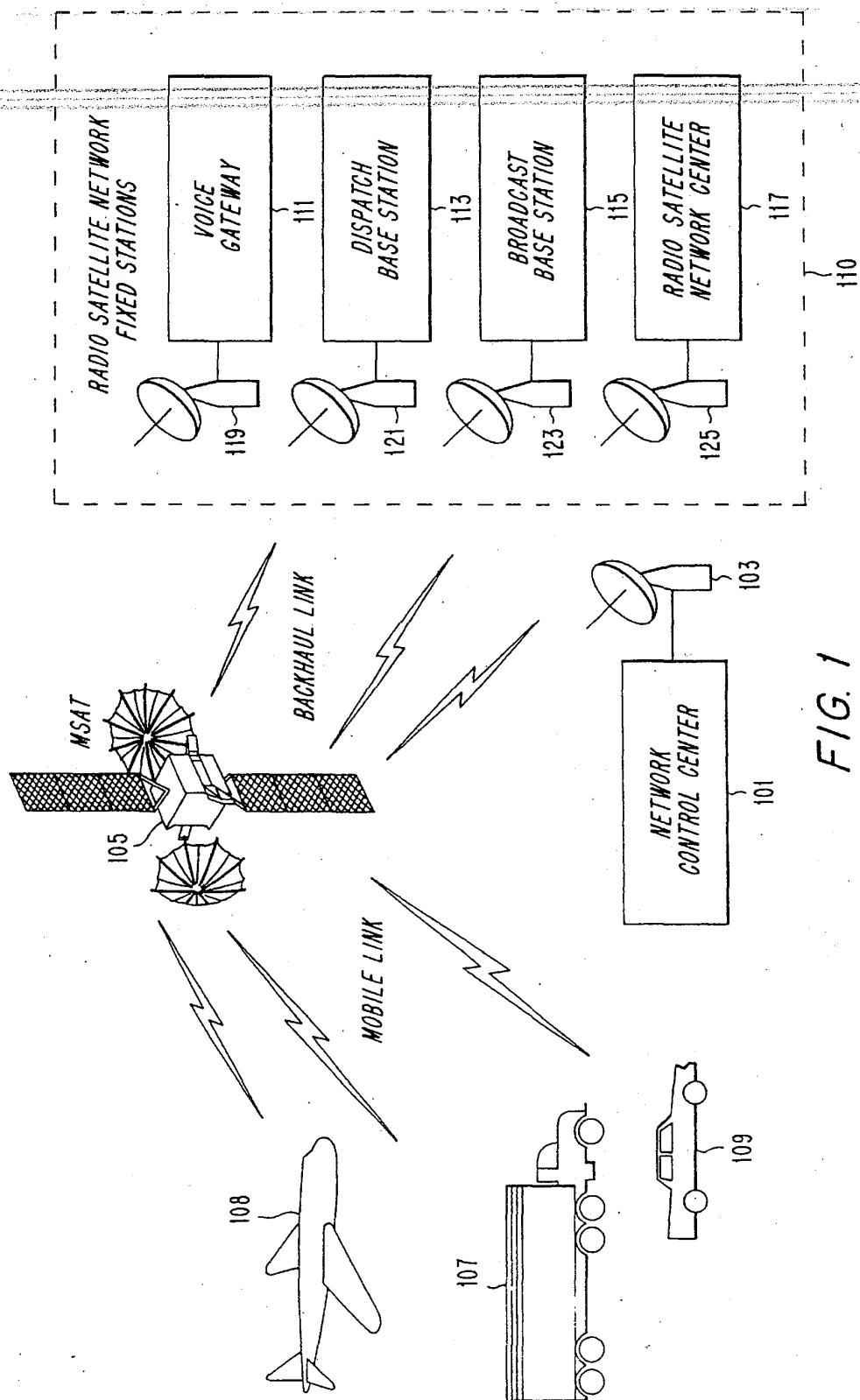


FIG. 2

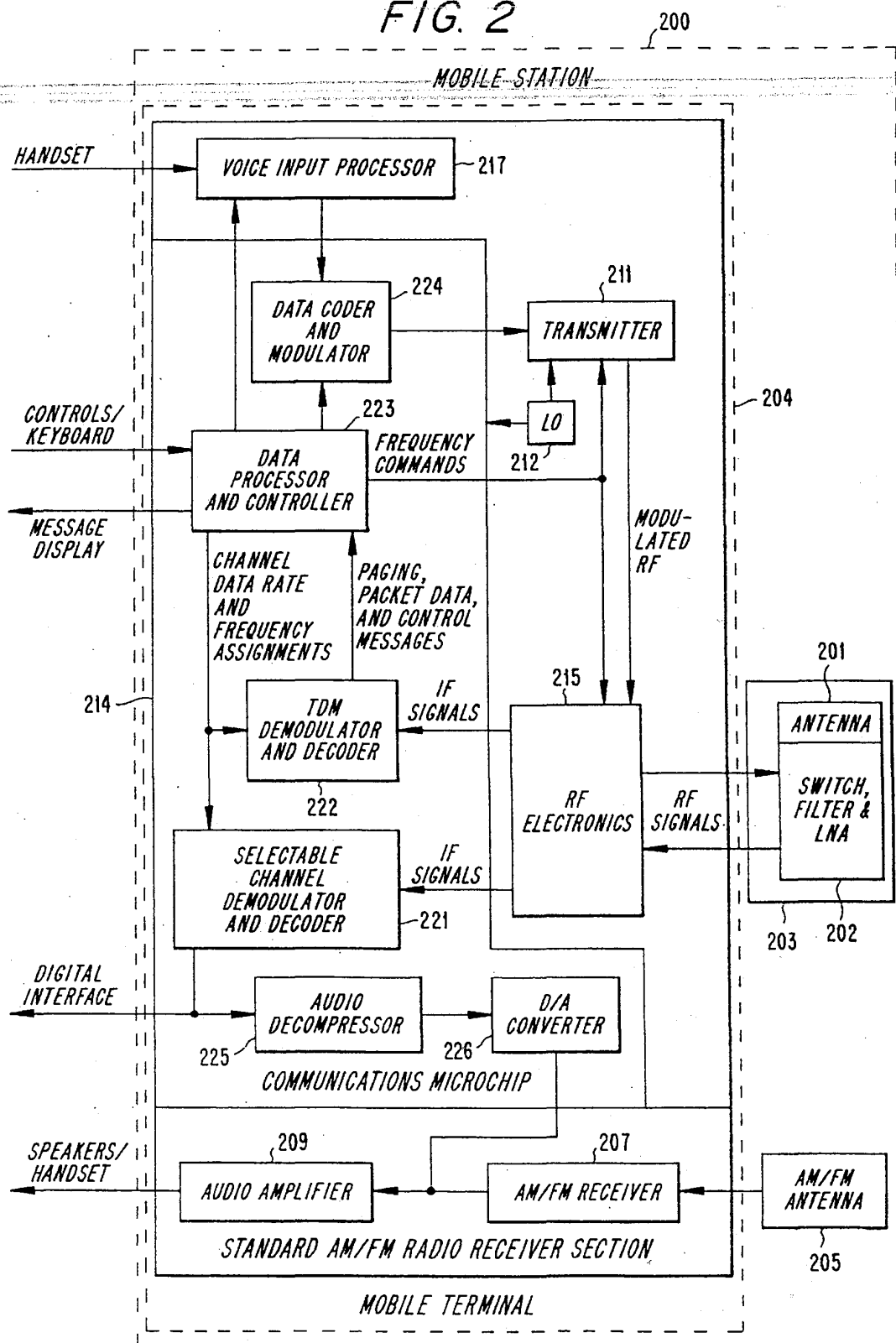


FIG. 3

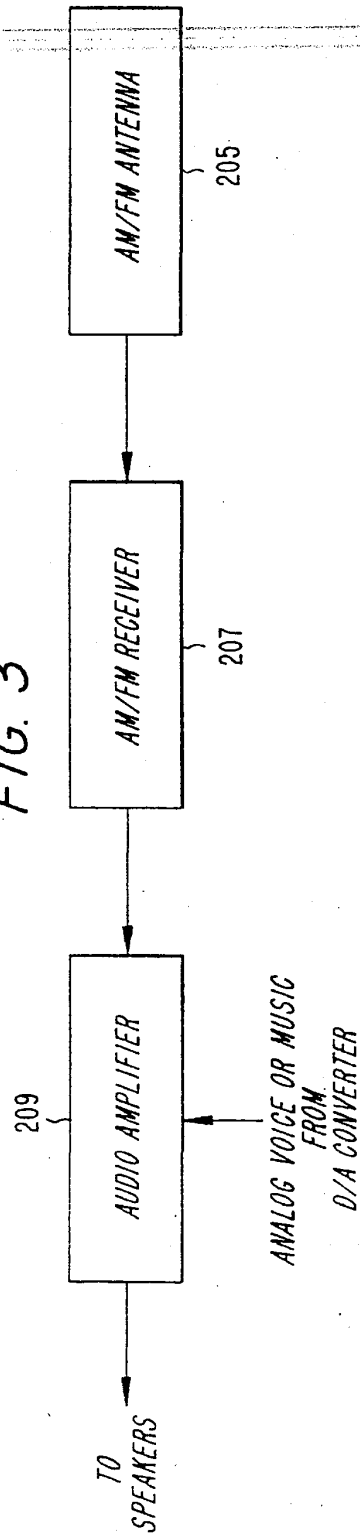


FIG. 4

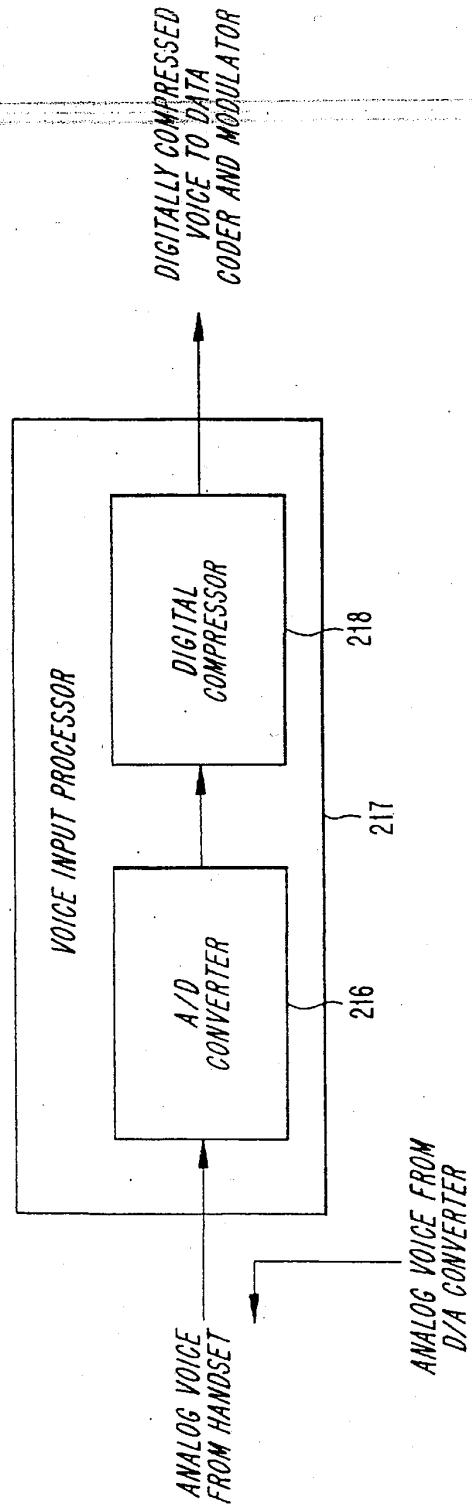


FIG. 5

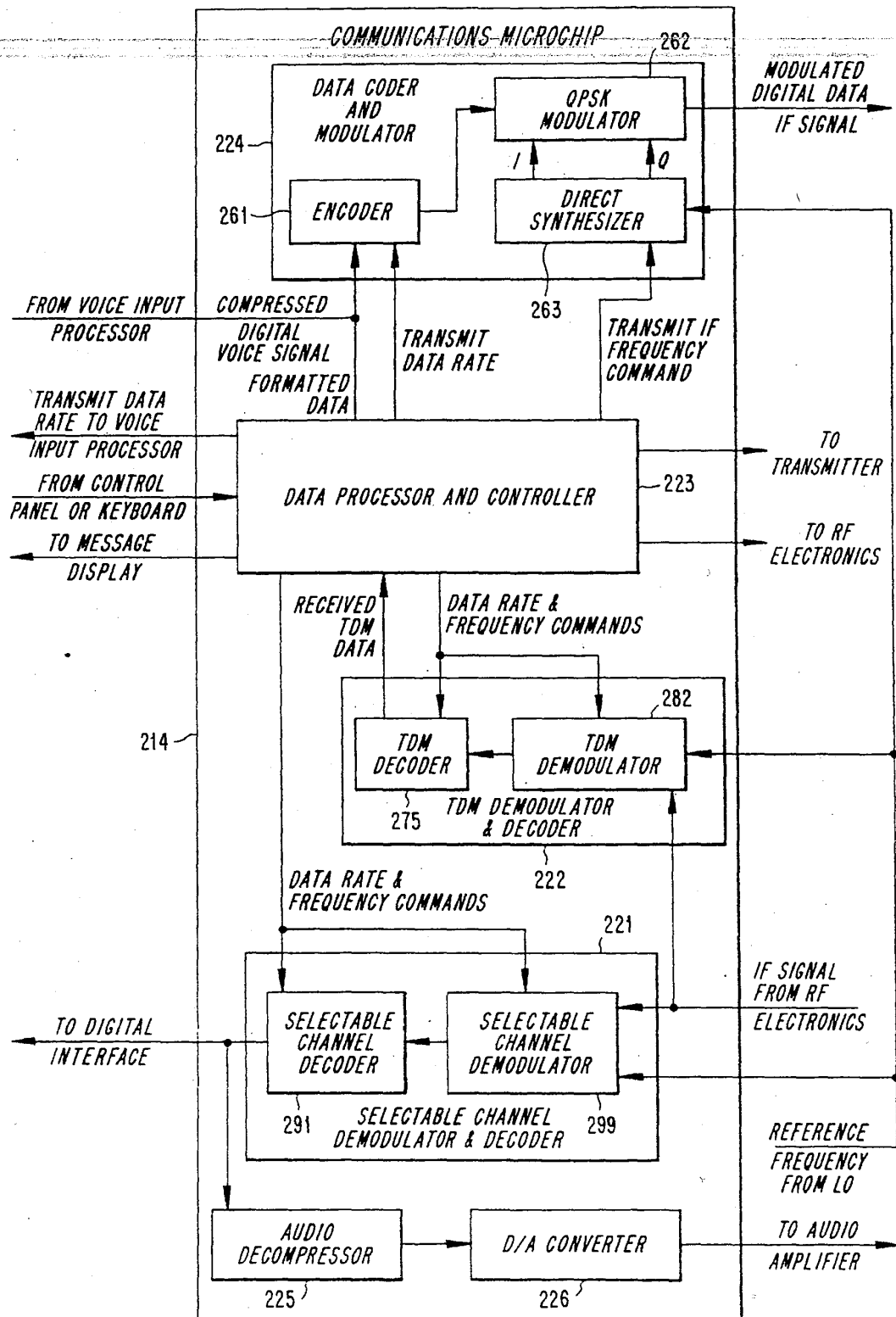


FIG. 6

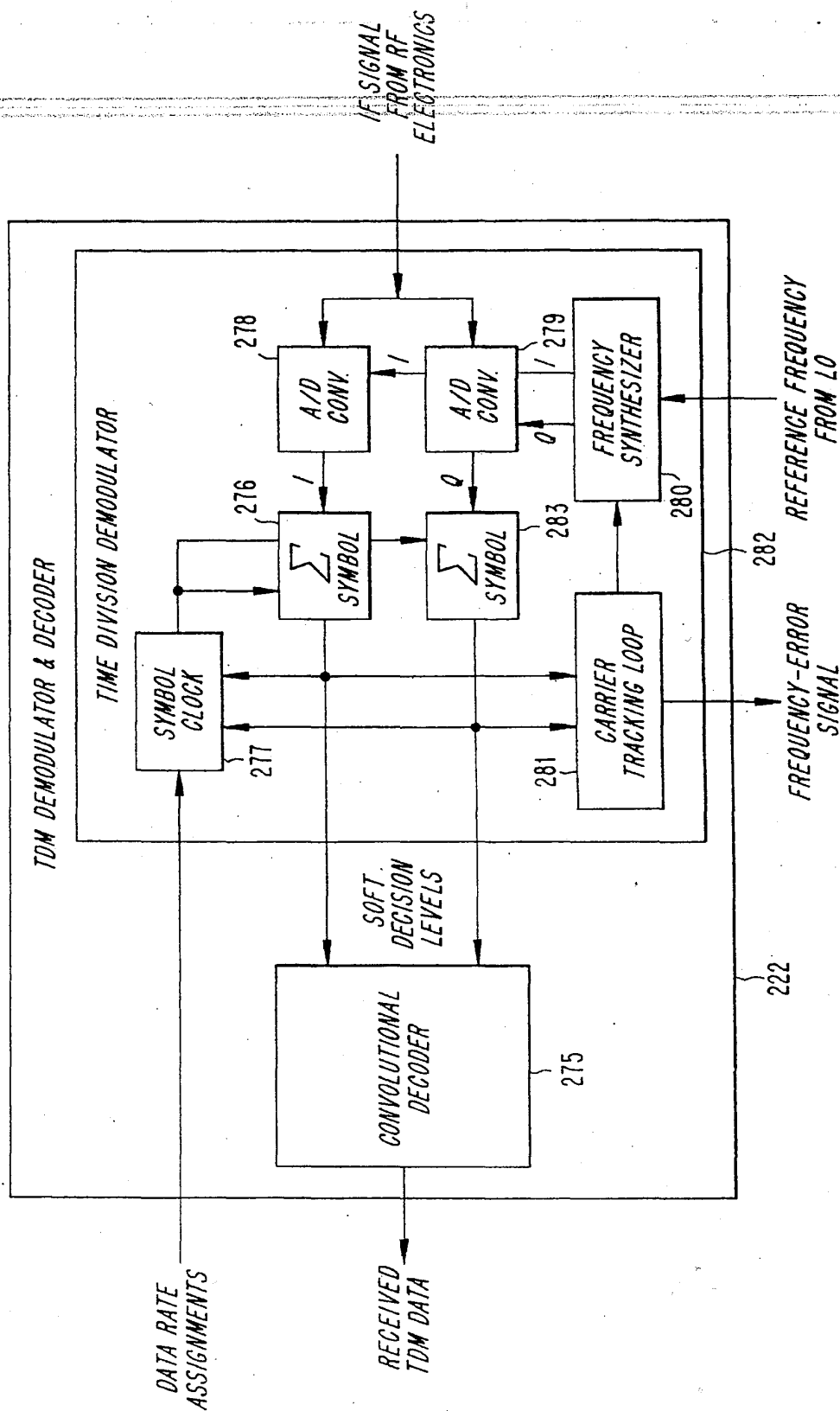


FIG. 7

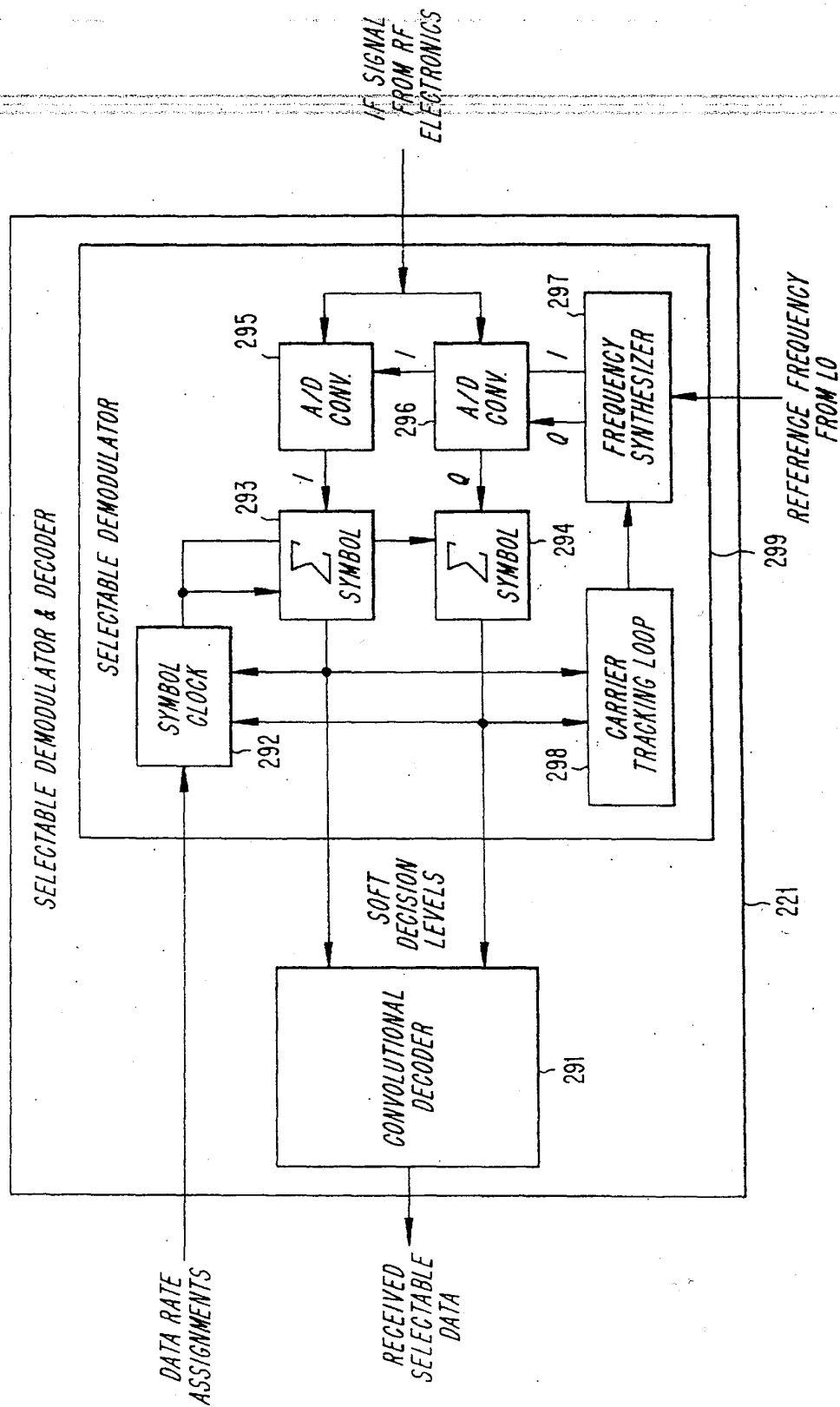


FIG. 8

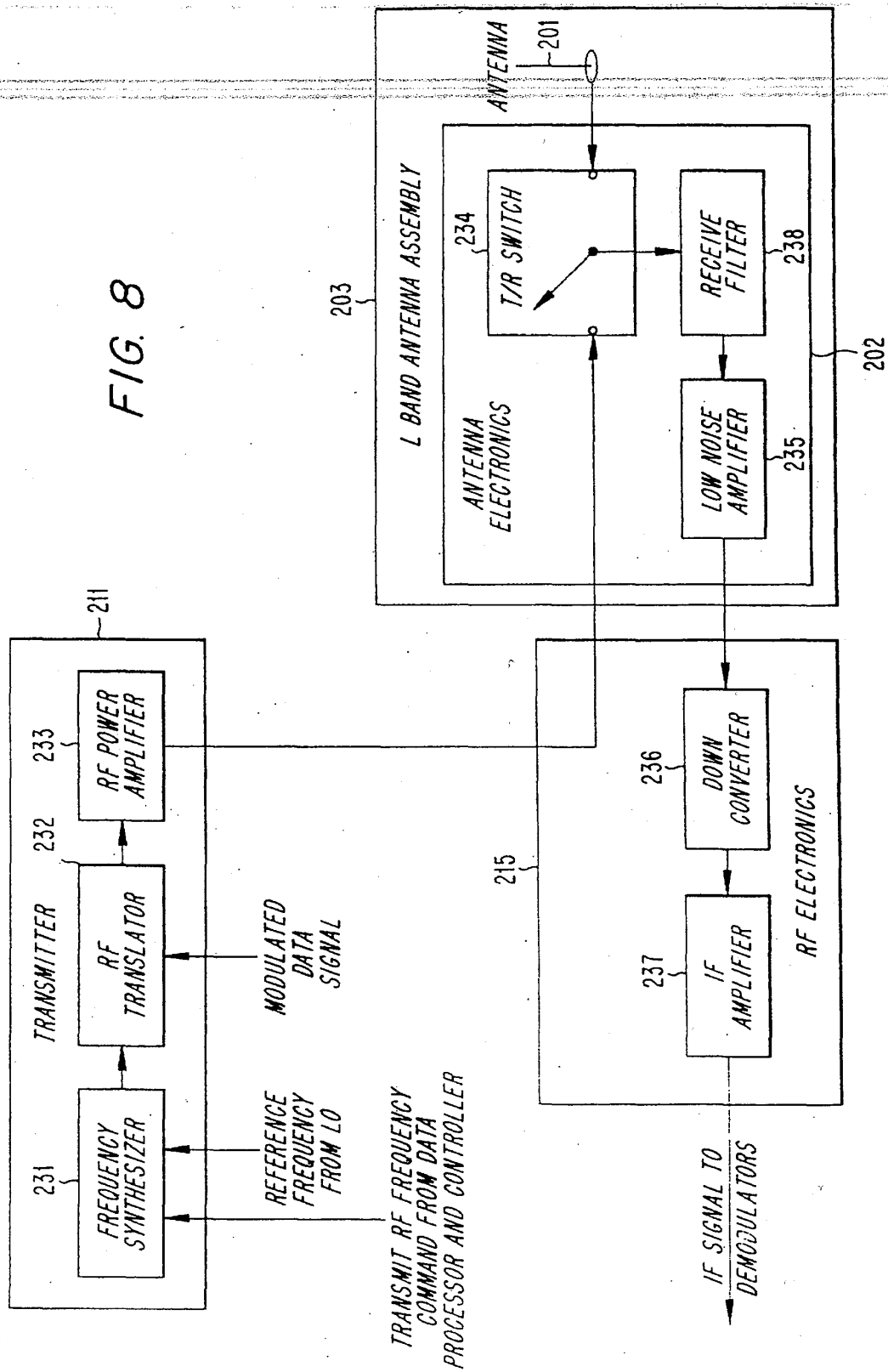


FIG. 9

<i>BEAM</i>	<i>FREQUENCY, MHz</i>	<i>DATA RATE, kbps</i>
1	1559.000	60
2	1559.200	20
3	1559.400	40
4	1559.600	70

FIG. 10

<i>NAME</i>	<i>FREQUENCY, MHz</i>	<i>DATA RATE, kbps</i>
CLASSICAL	1555.100	60
COUNTRY	1554.750	60
CSN	1555.350	16
EDUCATIONAL	1556.400	16
JAZZ	1557.200	60
KIDS	1553.800	16
NEWS	1556.250	16
ROCK	1558.050	60
SPORTS	1558.200	16
TALK	1553.250	16

INTEGRATED COMMUNICATIONS TERMINAL

RELATED PATENTS

This patent is a continuation-in-part of patent application entitled, INTEGRATED COMMUNICATIONS TERMINAL, having Ser. No. 07/963,233 and filing date Oct. 19, 1992, now U.S. Pat. No. 5,455,823. The benefit of the earlier filing date of the parent patent application is claimed pursuant to 35 U.S.C. § 120.

BACKGROUND OF THE INVENTION

This invention relates to communications networks and more particularly to a mobile station for communicating through satellite networks which allows greatly expanded access by the travelling public, such as mobile radio users, to diverse audio programming sources, communication services, and navigation services. This invention is also applicable to digital mobile communications, subscriber radio communications, and similar systems.

DESCRIPTION OF THE RELEVANT ART

New communications satellites, capable of communicating with mobile stations through small, light-weight, inexpensive antennas, are under development and are planned for operation in the mid 1990's. These satellites are expected to provide mobile satellite services, including two-way mobile telephony and data services, to commercial users, such as truck drivers, and to government users, such as law enforcement and public safety organizations. The number of users served, particularly with two-way telephony service, is small due to economic, technical and regulatory limits on satellite capabilities and use of radio frequencies.

The new communications satellites would be of much greater benefit to the general public, and provide greater potential revenue to mobile satellite system operators, if mobile stations capable of communicating through the new communications satellites were compact, relatively inexpensive mass market consumer items, similar to AM/FM car radios, and capable of being used by a large percentage of the travelling public. This is possible only if there were widespread public demand for mobile satellite services.

At present, there is relatively little public demand for the telephony and data services planned with the new mobile satellite systems; however, significant public demand does exist for additional audio entertainment programming, such as radio music, talk shows, and programming that has wider geographic coverage which also does not fade or disappear during travel.

Mobile radio listeners generally have not received the benefits of diverse programming and narrowcasting alternatives available to television viewers and radio listeners in their homes through existing cable and satellite distribution networks. The prospect of additional, alternative programming beyond existing AM and FM units becoming available to the travelling public is poor. Terrestrial implementation of proposed new digital audio broadcasting systems, which face significant technical and regulatory barriers, still does not resolve problems relating to poor radio coverage of areas of low population density; however, such remote areas could be easily served by satellite. Proposed new satellites dedicated to radio broadcasting, if ever authorized and constructed, are many years away.

In addition to an earlier implementation, the use of currently authorized mobile satellites for audio broadcasting

has other distinct advantages over the use of proposed new satellites dedicated to radio broadcasting, since the L-band spectrum of mobile satellite systems is better for this purpose than the higher frequencies proposed for the broadcasting satellites. In addition, the proximity of radio frequencies involved allows audio programming through the mobile satellite systems to be easily and economically integrated with other communications features of the mobile satellite systems as well as navigation data broadcasts from the U.S. government Global Positioning System (GPS).

In spite of these advantages, the communications satellite industry has had the belief that continuous broadcasting of audio programming and high-rate digital data are not possible through the presently authorized mobile satellites for various reasons.

Principal among these reasons are the following:

1. All providers of services through the mobile satellite systems presently authorized are required by regulation to be capable of immediately vacating mobile satellite spectrum required for emergency communications. Consumer entertainment broadcast systems cannot meet this requirement, because broadcast channels could not be shut down or relocated in frequency without unacceptable disruption of service to listeners.

2. Since satellite capacity is limited, only a few entertainment channels could be broadcast through a mobile satellite, limiting the public appeal of a radio satellite broadcast system.

3. The broadcasting of enough high quality music entertainment programming to attract widespread public interest in the satellite service requires a significant portion of the capacity of a mobile satellite, resulting in high costs for such broadcasts. These high costs make the broadcasting of high quality music uneconomical.

4. To be readily accepted by the public, consumer mobile communications receivers must be compact and lightweight. Present mobile satellite receivers are generally too large and too heavy for consumer applications, because the limited production runs of these receivers do not justify the large initial costs of miniaturization of all components.

Prior art communications systems employing multiple channel receivers do not use separate control channels as well as selectable channels simultaneously received by communicating units, with such units being mobile or stationary, and the prior art does not use the control channel to convey information other than control information to communicating units. Some non-control information is more appropriately sent through a common message/control channel in order for such non-control information to be accessible to all communicating units or to communicating units that are tuned to different selectable channels, where such selectable channels are defined to be channels which may be assigned to an available frequency by the system controller or selected by the user. Also, prior art communications systems do not have a ground unit capable of receiving a message/control channel including various types of low data rate time-division-multiplexed information and, simultaneously, a second high-rate channel selected by the user from among a group of frequency-division-multiplexed high data rate channels identified by information delivered through the message/control channel. In addition, prior art communications systems do not include receiving units capable of storing location information and, responsive to that stored location information, of acting upon specific location-dependent instructions received as part of a wide-area broadcast.

microchips, is provided comprising a selectable channel demodulator; a selectable channel decoder; a time division multiplex (TDM) channel demodulator; a TDM channel decoder; control means that includes a programmable, non-volatile memory; an audio decompressor; a digital-to-audio (D/A) converter; and a data coder and modulator. The microchip processor is used with a mobile station having a message display, an input device, RF electronics, an antenna assembly, an audio amplifier and speakers, and, optionally, a transmitter for return link communications.

The RF electronics convert a received electromagnetic signal to a received intermediate frequency (IF) signal. The optional transmitter, in response to a transmitter frequency command signal generated by the control means, selects and adjusts a carrier signal frequency, amplifies a data-modulated signal as an amplified data-modulated signal, and transmits the amplified data-modulated signal.

The audio decompressor operatively is coupled to the selectable channel decoder. The audio decompressor decompresses the selectable-data signal as a digital audio signal.

The D/A converter is operatively coupled to the audio decompressor. The D/A converter converts the digital audio signal to an analog audio signal which is delivered to an audio amplifier and speakers, to a handset, or to a headset.

The TDM channel demodulator operatively is coupled to the RF electronics, to the control means, and to the local oscillator. Using a TDM data rate and frequency command signal generated by the control means and a frequency reference from the local oscillator, the TDM channel demodulator generates a demodulated TDM channel signal and a frequency-error signal. The TDM channel decoder, which is coupled to the TDM channel demodulator, decodes the demodulated TDM channel signal as a TDM-data signal.

The control means operatively is coupled to the TDM channel decoder, to the RF electronics, and optionally to the transmitter. The control means decommutates the TDM-data signal as a control signal, and as paging signals and other message or information signals. To commutate is herein defined to mean the same as to interchange and/or to assemble collected data, and to decommutate is herein defined to mean the same as to disassemble or to break apart a signal or collection of data into component signals or component groups of data.

The control signal includes data which constitute look-up tables broadcast periodically that identify the name, radio frequency location, and data rate of the selectable channels and the TDM channel. The look-up tables are stored by the control means, and the look-up tables are updated periodically. The control means uses the data in the look-up tables to identify and tune-in broadcasts to the selectable channels. The control means, in response to the control signal and/or memory, generates the selectable data rate and frequency command signals and the TDM data rate and frequency command signals that tune the selectable channel demodulator and the TDM channel demodulator, respectively. The control means outputs the message signals to memory for message storage and/or to the message display.

The control means is further coupled operatively with an input device, a data coder and modulator, and an optional transmitter. In response to data signals from the input device and/or in response to the control signal, the control means sends a formatted data signal to the data coder and modulator.

In response to formatted data signals from the control means, the data coder and modulator, coupled to the transmitter, encodes the formatted data signals and modu-

lated the transmit IF frequency to a data-modulated signal, and sends the modulated signal to the transmitter for amplification and transmission.

The selectable channel demodulator operatively is coupled to the RF electronics and to the control means. Using the selectable data rate and frequency command signal generated by the control means, the selectable channel demodulator demodulates the received IF signal for output as a demodulated selectable channel signal. The selectable channel decoder, which is coupled to the selectable channel demodulator, decodes and deinterleaves the demodulated selectable channel signal as a selectable-data signal. The selectable-data signal is delivered from the selectable channel decoder to either a digital interface or to an audio decompressor.

The mobile station may optionally include a voice input processor to provide for two-way voice conversations. The voice input processor is operatively coupled to the data coder and modulator, as well as coupled to a voice input device, such as a handset, a microphone, or a headset with a microphone. The voice input processor converts an analog voice signal from the voice input device to a compressed digital voice signal which is delivered to the data coder and modulator.

The present invention, when used with a satellite system capable of communicating with compact mobile stations, offers the benefits of integrated nationwide personal communications and navigation services. These services include paging, in both alphanumeric formats and voice formats; two-way voice and data communications; broadcast data and audio entertainment programming; and a low-cost navigation service and a precision navigation capability. The present invention is extraordinarily flexible in delivery of services.

With the integrated communications terminal of the present invention, consumers may listen to high quality audio entertainment broadcasts nearly everywhere that the consumers go, through a spectrum efficient system that can receive transmissions of different bandwidths and data content. The consumers may communicate while on the move from virtually anywhere in the country at low cost. They may obtain these and other services through low-cost, integrated car radios. The radio satellite system enabled by the present invention offers a revolution in mobile communications capability for consumers everywhere in the United States.

The utility of this invention is not limited to satellite communications. This invention could be incorporated into any communications system, whether originating from terrestrial, aircraft or marine sources, using radio, lasers, wire signal or other delivery systems, first, where it is desired that the mobile station receive simultaneously background messages and information stored in memory or displayed to the user as well as a foreground channel of entertainment or other communications selected by the user from among a group of available foreground channels; and second, the data rate, the frequency location, and/or the number of the available foreground channels may change over time.

The present invention also offers the capability of transmitting location-specific instructions through a determination of the location of receiving units and the transmission of a plurality of location-dependent instructions as part of a wide-area broadcast to a plurality of receiving units. As used in this patent, "wide-area" may be defined to include an area of sufficient geographic scope to legitimize the transmission

delivered through the TDM channel. This addressing may be accomplished by including location-dependent instructions which are executed by those mobile stations having locations, stored in mobile-station memory, corresponding to the specified location or geographic region associated with the location-dependent instructions. Selectable channels can include digital audio entertainment channels; facsimile broadcasts; a return link of two-way voice communication channels, with the return link being the link from the fixed station to the mobile station; or other data transmissions. Both the data rate and radio frequency location of each selectable channel can be changed relatively frequently.

The data rate and radio frequency location of each selectable channel that may be received by a plurality of mobile stations is sent periodically to all mobile stations in each MSAT beam through the TDM channel for the beam. This information is sent in a selectable channel look-up table; i.e. a data signal identifying data rates and radio frequency locations that also may include additional identifying information about each channel and about the contents of each channel, such as illustratively shown in FIG. 10. In particular, the selectable channel look-up table is sent through the TDM channel whenever there is a change in frequency or data rate of a selectable channel intended for reception by mobile stations. The selectable channel look-up table is stored in a programmable, non-volatile memory of a control means, embodied as a data processor and controller 223.

Each mobile station may simultaneously receive two channels: the TDM channel for the strongest MSAT beam in which the mobile station is located and one of the many selectable channels sent through MSAT that the mobile station is authorized to access. Both TDM channel and selectable channel transmissions are transmitted to all mobiles, where control information is sent over TDM channels for use to allow the selectable channels to be addressed to all mobile stations, to groups of mobile stations, or to individual mobile stations. This addressing may be accomplished by including location-dependent instructions which are executed by those mobile stations having locations, stored in mobile-station memory, corresponding to the specified location or geographic region associated with the location-dependent instructions.

This network architecture allows mobile stations simultaneous access to most services. For example, packet data and paging messages can be sent over the TDM channel. High rate data for such digital services as facsimile transmissions or high quality digital audio programming can be sent over the selectable channels.

The two-channel mobile station receiver design gives simultaneous access to all lower-data-rate services through the TDM channel while the mobile station is receiving one of many selectable channels. The design of the receiver also permits the radio satellite system operator to change the data rate and frequencies of selectable channels with great flexibility.

In the exemplary arrangement shown in FIG. 2, a mobile station 200 comprises a communications microchip 214; an audio amplifier 209; an optional voice input processor 217; an optional transmitter 211; RF electronics 215; local oscillator 212; and antenna assembly 203. The antenna assembly 203 includes an antenna 201 and a transmit/receive switch, receive filter, and low noise amplifier (LNA) 202. The antenna 201 is coupled through switch, filter and LNA 202 to the RF electronics 215. The antenna 201 typically is an

omnidirectional antenna, mounted on a vehicle roof, and is used for both transmitting and receiving. A mobile station 200 may include a conventional AM/FM receiver 207 connected to an AM/FM antenna 205. For optimum performance, the AM/FM antenna 205 and antenna 201 are separate and independent in use.

Mobile stations simultaneously receive two channels: a time division multiplex (TDM) channel and one of a plurality of selectable channels. Both TDM and selectable channel transmissions broadcast to all mobile stations; coding in the transmissions and in the received signals allows portions of broadcasts to be addressed to all mobile stations, to groups of mobile stations, or to individual mobile stations. This addressing may be accomplished by including location-dependent instructions which are executed by those mobile stations having locations, stored in mobile-station memory, corresponding to the specified location or geographic region associated with the location-dependent instructions. This architecture allows mobile stations simultaneous access to all services. For example, low rate data such as packet data and paging messages can be sent over the TDM channel, while high rate data for digital services such as facsimile machines or high quality digital program data such as music can be sent over the selectable channel. Broadcast transmissions can be interleaved to mitigate the effects of short-term fading.

As shown in FIG. 2, a user optionally can add transmitter 211 to the mobile station, providing the user with a two-way communications terminal. Low rate packet data messages may be generated automatically, such as by position reporting, or may be input from an input device, which may be embodied as an external keyboard or message generator. Such low rate packet data can be communicated back through MSAT 105. An optional voice input processor 217 may be included and may be embodied as a semiconductor chip. The voice input processor 217 digitizes and compresses voice signals to a selected bit rate, preferably in the 1200-9600 bps range, depending on the voice quality desired for transmission.

The voice input processor 217 is coupled to the data coder and modulator 224, with the data coder and modulator 224 being connected to the transmitter 211, and with the transmitter 211 being connected to the RF electronics 215, with the RF electronics 215, in turn, being connected to the antenna assembly 203.

A variety of peripheral devices may additionally be used with the mobile station. The basic configuration may provide compact disk quality program material through standard vehicle radio speakers, and may also display paging or other messages. Dispatch terminals, a handset for voice communications, or a headset and microphone for voice communication can also be added. A digital interface may also be included for facsimile machines or other functions.

The transmit/receive switch, filter and low noise amplifier (LNA) 202 isolates the transmitted RF signal from the mobile station. A signal from the receiver in the mobile station is received from MSAT 105 through antenna 201, and is amplified by LNA 202. Signals, including transmit/receive switch control signals, pass from the mobile terminal 204 mounted inside a vehicle to the antenna assembly 203 and from the antenna assembly 203 to the mobile terminal 204 by a common cable, with the common cable also providing power to the antenna assembly 203. Local oscillator (LO) 212 provides a frequency reference to transmitter 211 and communications microchip 214.

The communications microchip 214 includes a selectable channel demodulator and decoder 221, a TDM channel

TDM data rate and frequency command signal corresponds to one of the finite sets of frequencies and data rates at which the TDM channel can operate, identified in a TDM channel look-up table stored in the memory of the data processor and controller 223, with the TDM channel look-up table updated periodically through data signals sent through the TDM channel. The TDM channel look-up table contains data rates and radio frequency locations that also may include additional identifying information about the finite sets of frequencies and data rates at which the TDM channel can operate, as illustratively shown in FIG. 9. The TDM data rate and frequency command signal is passed to the TDM channel demodulator and decoder 222.

The data processor and controller 223 receives the TDM-data signal from TDM channel decoder 275, and decommutates the TDM-data signal as a control signal and as paging and other message or information signals. In the preferred embodiment, the decommutation of the TDM-data signal includes time-demultiplexing the TDM-data signal as the control signal and as paging and other message or information signals. The data processor and controller 223 sends the appropriate channel data rates and frequencies to the TDM channel demodulator and decoder 222 through the TDM data rate and frequency command signal, and the data processor and controller sends the appropriate channel data rates and frequencies to the selectable channel demodulator and decoder 221 through the selectable data rate and frequency command signal. The control signals specify the radio frequency location and data rate of each TDM channel and each selectable channel to which the mobile station is intended to have access, as well as the frequency, data rate and allowed time slot for any transmission by the mobile station. The control signals include look-up tables, including a selectable channel look-up table and a TDM channel look-up table, and the control signals also include information needed to set up and execute two-way data and voice communications using the mobile station. Control signals can include additional control information as well, such as location-dependent instructions which are executed by those mobile stations having locations, stored in mobile-station memory, corresponding to the specified location or geographic region associated with the location-dependent instructions. The look-up tables are broadcast periodically. The look-up tables may include the name, radio frequency location, and data rates of the selectable channels and of the TDM channels, and the look-up tables are stored by the data processor and controller 223 in the programmable, non-volatile memory, and the look-up tables are also updated periodically through data broadcasts on the TDM channels. The data processor and controller 223 uses the look-up tables to generate the TDM data rate and frequency command signal, the selectable data rate and frequency command signal, and the transmitter frequency command signal.

The data processor and controller 223 provides data rate information to the data coder and modulator 224, demultiplexes received TDM channel data streams, and sends and receives messages to and from an input device and a message display.

The transmitter frequency command signal includes frequency information for the transmitter 211, and the transmitter frequency command signal is used to select the carrier frequency of transmitter 211. The data processor and controller 223 generates the transmitter frequency command signal from information derived from the TDM channels.

The data processor and controller 223 also stores, in the non-volatile memory, data as needed, outputs message signals to the message display, and generates the selectable data

rate and frequency command signal and the TDM data rate and frequency command signal. The data processor and controller 223 may also store, in the non-volatile memory, information relating to the location of the mobile station, whether such information is received in a message or via the input device. The data processor and controller 223 uses data rate and frequency information from the input device or from received messages, including the periodically broadcast TDM channel look-up table, to assign the data rate and frequency to be used by the TDM channel demodulator 282 and TDM channel decoder 275. The data rates and frequencies for the TDM channel are passed from the data processor and controller 223 to the TDM channel demodulator 282 in the TDM data rate and frequency command signal. The data rate and frequency for a chosen one of the selectable channels are passed from the data processor and controller 223 to the selectable channel demodulator 299 in the selectable data rate and frequency command signal. The frequencies for the optional transmitter are passed from the data processor and controller 223 to the transmitter 211 in the transmitter frequency command signal.

The data processor and controller 223 uses the data rate and frequency assignments in the selectable channel look-up table updated periodically through the TDM channel, and uses an input of a selection by the user or automatic functions, to assign the data rates and frequencies to be employed by the selectable channel demodulator 299 and selectable channel decoder 291. These data rates and frequencies are passed from the data processor and controller 223 to the selectable channel demodulator 299 and the selectable channel decoder 291 in the selectable data rate and frequency command signal.

The transmitter frequency command signal is used to select the carrier frequency of the transmitter 211. The data processor and controller 223 also generates a Doppler-correction signal. The Doppler-correction signal includes information for correcting for Doppler shift of the transmitted waveform, which is referred to as the data-modulated signal. The correction for the Doppler shift is derived from analyzing GPS-derived mobile Doppler estimates generated at the mobile station and satellite oscillator drift and return link satellite Doppler compensation estimates generated by the radio satellite network center 117 and sent through MSAT 105 over the TDM channel to the mobile station.

The error can potentially be reduced still further through the use of GPS-derived mobile Doppler estimates generated at the mobile station and with satellite return link Doppler compensation estimates generated by a network center and broadcast to the mobile station. An optional GPS receiver in each of the mobile stations can be used to estimate individual vehicle velocity. The speed of the vehicle towards or away from MSAT 105 may be computed by the data processor and controller 223 using an approximate position of the satellite from information sent over the TDM channel. The calculated speed of a vehicle containing a mobile station 200 can be used by the data processor and controller 223 to calculate mobile Doppler effects on both the downlink and the uplink and to send appropriate adjustments to the TDM channel demodulator 282, to the selectable channel demodulator 299, and to the frequency synthesizer 231 to compensate for frequency errors caused by mobile Doppler effects.

In addition to the use of GPS for estimating vehicle velocity, GPS may also be used as a means of determining location of the mobile station. Location information may then be stored in the mobile station memory and used to identify specific location-dependent instructions, within a wide-area broadcast, relevant to the mobile station. Other

plurality of selectable channel signals, to which the electronic device is to be tuned, dependent on the stored location.

The radio satellite network center 117 can be used to estimate return link satellite oscillator drift and satellite Doppler effects using various techniques such as, for example, using a reference mobile station/terminal and satellite ephemeris data. The radio satellite network center 117 can then prepare and broadcast return link frequency compensation data over the TDM channel in each beam to each of the mobile stations. The mobile stations can then use the frequency compensation data to adjust transmitter frequency settings as appropriate using the transmitter frequency command signal.

The data processor and controller 223 stores data as needed, outputs message signals to the message display, generates the transmitter frequency command signal to control the carrier signal of the transmitter 211, and generates the selectable data rate and frequency command signal and the TDM data rate and frequency command signal. The data processor and controller 223 uses data rate assignments from the input device or from received messages, including the periodically broadcast look-up tables, to assign the data rate to be used by the TDM channel demodulator 282 and TDM channel decoder 275. The data rates are passed from the data processor and controller 223 to the TDM channel demodulator 282 in the TDM data rate and frequency command signal. The data rates determine the TDM channel demodulator 282 and TDM channel decoder 275 symbol clock rate. A tracking loop in a symbol clock synchronizes the timing signals with the arriving TDM signal, and a carrier tracking loop in the TDM channel demodulator 282 is commanded by the TDM data rate and frequency command signal to synthesize a clock that samples the arriving TDM signals at an appropriate rate.

The data processor and controller 223 also uses the data rate assignments to assign the data rates to be employed by the selectable channel demodulator 299 and the selectable channel decoder 291. These data rates are passed from the data processor and controller 223 to the selectable channel demodulator 299 in the selectable data rate and frequency command signal. The data processor and controller 223 sets the synthesized frequency to be used by the selectable channel demodulator 299 for demodulating the selectable-IF signal. Typically, the synthesized frequency is a harmonic of the symbol clock rate.

The data processor and controller 223 controls the transmission of data. Data from the input device, such as an input panel or a keyset, is formatted into the messages required by the network protocol by the data processor and controller 223 as a formatted data signal and the formatted data signal is provided to the data coder and modulator 224.

When the mobile station is turned on for the first time, the mobile station executes an initialization sequence. In a preferred embodiment of this initialization sequence, the data processor and controller 223 generates the TDM data rate and frequency command signal. The TDM data rate and frequency command signal corresponds to one of the finite sets of frequencies and data rates at which the TDM channel can operate, identified in a TDM channel look-up table held in memory, and passes this signal to the TDM channel demodulator and decoder 222.

The data processor and controller 223 then examines the output of the TDM channel demodulator and decoder 222 to determine if a TDM channel is present at the selected frequency and data rate. If after a predefined period of time

the channel has not been identified as a TDM channel, the data processor and controller 223 commands the TDM channel demodulator 282 to tune to another possible TDM channel frequency and again monitors the output of the TDM channel demodulator and decoder 222 to detect whether a TDM channel is present. The data processor and controller 223 continues the tuning and monitoring process until the data processor and controller 223 has detected a TDM channel or until the data processor and controller 223 has examined all possible frequencies and failed to detect a TDM channel.

If the data processor and controller 223 has failed to detect a TDM channel following an examination at all possible frequencies, the data processor and controller 223 sends the TDM data rate and frequency command signal to the TDM channel demodulator and decoder 222 to set the TDM channel demodulator and decoder 222 to another possible TDM data rate. The data processor and controller then sequentially examines all possible TDM frequencies to detect whether a TDM channel is present at the new data rate. This process is continued through all possible combinations of data rate and frequency.

TDM channel look-up tables are assembled periodically by the radio satellite network center 117, as shown in FIG. 1, and sent over the TDM channels in each beam through ground unit antenna 125 and MSAT 105 to all mobile stations. Each TDM channel look-up table contains the frequencies and data rates of the TDM channel of the beam in which the TDM channel is being sent and the TDM channels in each adjacent beam, as well as possible alternatives. Once the data processor and controller 223 determines that the mobile station is tuned to a TDM channel, the data processor and controller 223 monitors the output of the TDM channel demodulator and decoder 222 until a TDM channel look-up table is received. The data processor and controller 223 stores this TDM channel look-up table and then measures the received power of each TDM channel by sequentially tuning to each such channel and monitoring received signal level. Once the received signal levels of all operating TDM channels have been measured, the data processor and controller 223 sets the TDM data rate and frequency command signal so as to receive the strongest TDM channel.

The data processor and controller 223 always stores the most recently received TDM channel look-up table in non-volatile memory. Each time the mobile station is turned off, then back on again, the data processor and controller 223 once again commands the TDM channel demodulator and decoder 222 to tune in to each TDM channel, then compares the strengths of each TDM channel, and finally commands the TDM channel demodulator and decoder 222 to tune in to the strongest TDM channel. By this comparing of strengths of each TDM channel, the TDM channel can normally be selected without having to undergo the entire initialization process described above. TDM channel data rates and frequencies are expected to change infrequently. The carrier signal frequency of the transmitter 211 is set or adjusted by the transmitter frequency command signal from the data processor and controller 223.

While the signals received by the mobile station from satellites include frequency errors caused by Doppler effects from the mobile station, the received signals are much closer to the correct absolute frequency than the locally generated signals, so the frequency-error signal from the TDM channel demodulator can be used by the data processor and controller 223 to generate the transmitter frequency correction signal. The transmitter frequency correction signal is the

control two-way data and voice communications. The communications microchip 214 includes a data coder and modulator 224 for use with an optional data transmitter 211. An optional voice input processor 217 can be added for the two-way voice communications. The voice input processor 217 as a chip can include an analog-to-digital converter 216 and a digital compressor 218 as illustrated in FIG. 4.

An optional Global Positioning System (GPS) microchip and associated RF electronics can be added to the mobile station for processing navigation information. The radio satellite network center can insert GPS differential corrections and integrity information into TDM channel data broadcasts, which the communications microchip receives and forwards to the GPS microchip. With differential corrections, the GPS microchip can estimate mobile position to within two meters. GPS position estimates can be sent to dispatchers over the radio satellite system return link, i.e. mobile station to fixed station, data channels. GPS position estimates may also be used for mobile station location determination as discussed earlier relative to the location-determination capability of the present invention and the use of such location-determination capability to implement, at any given mobile station, location-dependent instructions contained within a wide-area broadcast.

The GPS L1 frequency at 1575.42 MHz is between the satellite-to-mobile band, 1529-1559 MHz, and mobile-to-satellite band, 1630.5-1660.5 MHz, of mobile satellite systems presently authorized by the Federal Communications Commission. This proximity to the receive frequencies for the present invention make it possible for a GPS receiver to share the antenna and front end with a radio satellite system mobile station, though some additional RF circuitry is required as well as a GPS microchip. Typical GPS microchips include all base band circuitry necessary for receiving and processing GPS transmissions.

Performance requirements are modest, consistent with mass production and distribution constraints. The antenna can be a small, simple cross-polarized drooping dipole on a microstrip patch. Two-way voice communications require a diplexer instead of switch in the antenna assembly and may require a mobile antenna with a 4 dBi gain rather than 3 dBi to counteract the higher loss through the diplexer.

Typically, the transmitter power radiates two watts, the antenna has a gain of 3 dBi, and the mobile EIRP is 3 dBW, with a mobile G/T=-20 dB/K.

The radio satellite network center 117 assembles control information and incoming data from numerous sources, including pages, differential GPS corrections, electronic device location information, region-specific or location-dependent instructions, messages to individual mobiles, conversation requests, channel assignments, TDM and selectable channel look-up tables, etc., into the TDM channel for each beam. The radio satellite network center 117 encodes and modulates each TDM channel and transmits the modulated TDM channels to mobiles through the MSAT satellite 105. The radio satellite network center 117 also receives transmissions from mobiles equipped with data transmitters and forwards received data to their appropriate destinations.

The radio satellite network center 117 also provides frequency control for the network, as described in "Design of an MSAT-X Transceiver and Related Ground Segment Technology Study Final Report, Volume II: MSAT-X Ground Segment Design", MSAT-X Report No. 131, Jet Propulsion Laboratory, Pasadena, Calif., 1986.

Base stations and gateways communicate with the radio satellite network center 117 through the satellite K_u - K_u

band link. The radio satellite network center 117 assigns operating frequencies and provides positive control over base station transmitters and gateway transmitters to ensure network integrity.

Broadcasters can operate their own broadcast base stations 115, transmitting a single digital audio or high rate data channel. Digital audio broadcast base stations digitize and compress audio signals, then encode and modulate these signals and transmit them at Ku-band to the satellite 105. The satellite 105 transponds the signals which the satellite receives from the broadcast base stations 115 to the mobile communications frequency and broadcasts them directly to mobile users.

Voice gateways 111 interconnect two-way telephone communications with the telephone network. Operators of voice gateways 111 operate their own facilities under the positive control of the radio satellite network center 117.

Dispatch base stations 113 not interconnected with the telephone network can be used by individual organizations for dispatch communications with fleets of vehicles. Dispatch base stations 113 are also controlled by the radio satellite network center 117. Voice pages can be sent through dispatch base stations 113 operated by paging companies.

The communications microchip is an important element of the present system. The radio satellite system takes advantage of the dramatic increases in processing capabilities of new semiconductor devices to consolidate most of the processing required by its highly sophisticated radios, preferably onto a single chip. This chip can be mass produced for very low cost.

The present invention overcomes the various problems relating to broadcasting of audio programming over the new mobile satellites. This invention, therefore, is expected to have a dramatic impact on the mobile satellite industry.

In use, the mobile station, using the present invention, receives two channels. A primary message/control channel and an arbitrary number of secondary selectable channels are broadcast through the satellite in each beam. The message/control channel is continuous, broadcast 24 hours a day; a given selectable channel may or may not be continuous, depending on how the selectable channel is being used. Each mobile station receives the message/control channel at all times that the receiver is turned on, and can be tuned by its user to simultaneously receive any one of the selectable channels. The message/control channel, from the viewpoint of the user, operates in the background; the message/control channel delivers data information to the mobile station, such as the spectrum location and bandwidth of available selectable channels and other control information relating to operation of the mobile station; differential corrections to improve GPS location computation; electronic device location information; region-specific or location-dependent instruction; messages such as alphanumeric and voice pages; emergency advisories; data bases for such things as traffic accidents, sports scores or stock quotes; and reprogramming information regarding new or modified services. Information in the message/control channel is coded for attention by particular receivers, groups of receivers, or all receivers. Selectable channels could include such things as music, talk shows, or other radio entertainment programming; facsimile transmissions; emergency broadcasts; or the receive portion of a two-way voice communication.

The ability to receive many data services through the message/control channel while tuned to a selectable channel yields great functionality. For example, the mobile station

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7. The electronic device as set forth in claim 1 with the selectable channel signal associated with a specific location.

8. The electronic device as set forth in claim 7 with said electronic device executing, responsive to a match between the stored location and the specific location, instructions contained within the communications control channel signal associated with the specific location.

9. The electronic device as set forth in claim 7 with said electronic device executing, responsive to a distance between the stored location and the specific location less than a specified range, instructions contained within the communications control channel signal associated with the specific location.

10. The electronic device as set forth in claim 1 with the selectable channel signal associated with a specific geographic region.

11. The electronic device as set forth in claim 10 with said electronic device executing, responsive to the stored location being within the specific geographic region, instructions associated with the specific geographic region.

12. The electronic device as set forth in claim 1 further comprising:

means for determining a location of said electronic device.

13. The electronic device as set forth in claim 12 with said determining means including a position determination device.

14. The electronic device as set forth in claim 13 with said position determination device including a Global Positioning System receiver.

15. The electronic device as set forth in claim 12 with said determining means including a radio determination system.

16. A mobile communications network, comprising:
a plurality of mobile stations comprised of a plurality of electronic devices, respectively, each of said plurality of electronic devices including,

means for determining location information on a location of said electronic device;

means for storing the location of said electronic device as a stored location;

means for receiving a communications control channel signal through which said electronic device receives a list of operating information for a plurality of selectable channel signals;

means for receiving, simultaneously with receipt of said communications control channel signal, one of the plurality of selectable channel signals, which selectable channel signal said electronic device identifies using the list of operating information provided through the communications control channel signal; and

means for executing instructions contained within the selectable channel signal, responsive to the stored location;

a central station delivering a time-division-multiplexed communications control channel signal to said plurality of mobile stations; and

a plurality of intermediate stations delivering the plurality of selectable channel signals to said plurality of mobile stations.

17. A method for delivering diverse communications services, including location-dependent instructions, from a transmitter at a central station to a plurality of receiving units using a plurality of selectable channels and a common communications control channel, and for executing particular location-dependent instructions responsive to a respective location of each of said plurality of receiving units, comprising the steps of:

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transmitting to said plurality of receiving units a communications control channel signal and a variable number of selectable channel signals;

sending to said plurality of receiving units, through said communications control channel signal, data relating to the variable number of selectable channel signals, said data including a plurality of channel names, a plurality of data rates, and a plurality of frequencies, each of said plurality of channel names associated with a frequency and a data rate as a channel name association, with channel name associations modifiable through updating of the communications control channel signal;

receiving, at a receiving unit, the communications control channel signal;

selecting, by a user at said receiving unit, a selectable channel signal by selecting a name of said selectable channel signal as a selectable-channel-signal-name;

extracting, from the selectable channel signal, location information specific to the receiving unit;

storing, at the receiving unit, the extracted location information;

executing, at the receiving unit, particular location-dependent instructions within the selectable channel signal, responsive to the stored extracted location information;

identifying, by the receiving unit using the data relating to the variable number of selectable channel signals, a particular frequency and a particular data rate associated with the selectable-channel-signal name;

tuning, by the receiving unit, to the particular frequency and the particular data rate associated with said selectable-channel-signal name; and

receiving said selectable channel signal at the receiving unit.

18. A method for delivering a data channel signal including a plurality of location-dependent instructions, to at least one micro-electronic device with a radio satellite unit, and for executing particular location-dependent instructions within the plurality of location-dependent instructions, responsive to a respective stored location of said micro-electronic device, comprising the steps of:

initializing said micro-electronic device with location information and initial frequencies and data rates of received signals;

transmitting the data channel signal including the plurality of location-dependent instructions to said micro-electronic device as broadcast transmissions consisting of a time-division-multiplexed channel signal and at least one selectable channel signal;

tuning in on the time-division-multiplexed channel signal; demodulating the time-division-multiplexed channel signal;

decoding the demodulated time-division-multiplexed channel signal as a time-division-multiplexed data signal;

decommutating the time-division-multiplexed data signal to a control signal, paging signals, and message signals; extracting from the control signal at least one broadcast channel look-up table comprising channel identification, frequency of operation, and data rate of a plurality of broadcast channels;

receiving selectable channel signals from broadcast transmissions;

comparing, at said micro-electronic device, the respective stored location with the plurality of location-dependent instructions to identify location-relevant instructions;

United States Patent [19]

Bird

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[54] LOCATION OF MISSING VEHICLES

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[73] Assignee: Trimble Navigation, Ltd., Sunnyvale, Calif.

[21] Appl. No.: 978,272

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[51] Int. Cl.⁶ H04B 7/185; G01S 5/02

[52] U.S. Cl. 342/357; 342/457

[58] Field of Search 342/357, 457

[56] References Cited

U.S. PATENT DOCUMENTS

4,908,629	3/1990	Apsell et al.	342/457
4,924,402	5/1990	Ando et al.	364/449
4,947,151	8/1990	Rosenberger	342/457
5,003,317	3/1991	Gray et al.	342/457
5,021,794	6/1991	Lawrence	342/457
5,043,736	8/1991	Darnell et al.	342/357
5,055,851	10/1991	Sheffer	342/457
5,177,685	1/1993	Davis et al.	364/443
5,208,756	5/1993	Song	364/449

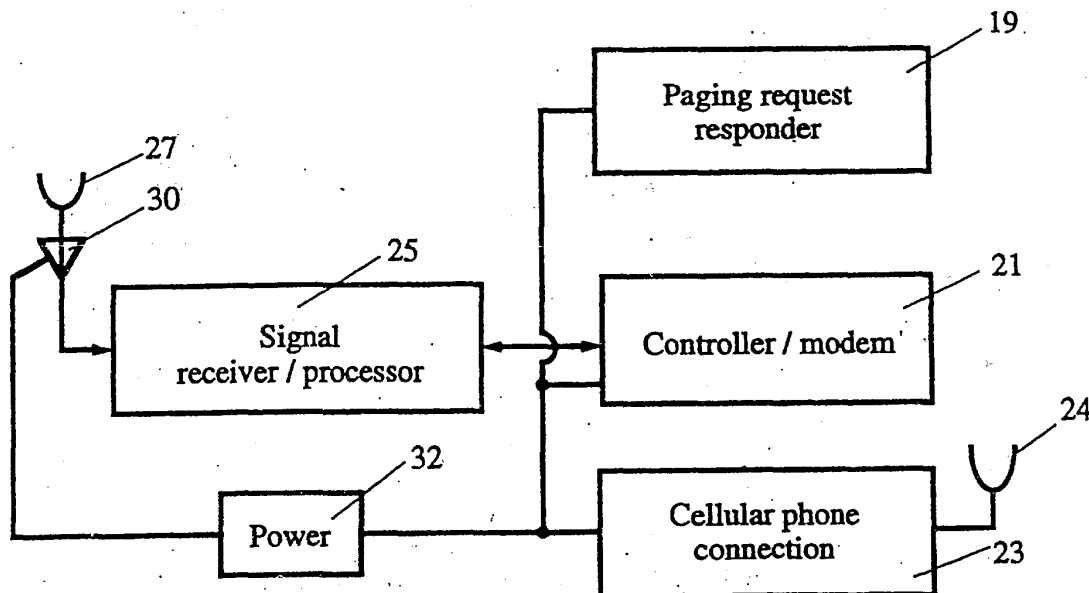
Primary Examiner—Theodore M. Blum
Attorney, Agent, or Firm—John Schipper

[57] ABSTRACT

Method and apparatus for determining the present location of a missing vehicle, such as an automobile or marine vessel, using a Global Positioning System that receives GPS signals from two or more GPS satellites. A GPS antenna, GPS signal receiver/processor, a paging responder, a cellular telephone and associated antenna, and a controller/modem are installed in a vehicle and electrically connected together. When the vehicle is

determined to be missing, because the vehicle has been misplaced, lost or stolen, the vehicle owner or operator contacts a vehicle location service center, which broadcasts a paging request that is received by the paging responder on the vehicle. The paging responder causes the controller/modem to interrogate the GPS receiver/processor to determine the present location of the vehicle. The receiver/processor determines the present vehicle location and notifies the controller/modem of such location. The controller/modem then causes the cellular telephone to notify the vehicle location service center of the present location of the missing vehicle so that the vehicle can be recovered. The GPS signal receiver/processor and GPS antenna can be replaced by a receiver/processor and associated antenna that works with a LORAN system, or with a group of gyroscopes or local magnetic field sensors mounted on the vehicle. Optionally, the signal receiver/processor is kept in a "sleep" mode to conserve power, until the controller/modem receives a paging request for its present location. Optionally, the receiver/processor is periodically activated to determine, and thus update, its present location. Optionally, the presence of the GPS antenna and/or the cellular telephone antenna on the vehicle is concealed. In another embodiment, a sensor is positioned on the vehicle, and the cellular telephone is caused to transmit to the vehicle location center a message containing information on the present location of the vehicle when the sensor senses occurrence of a selected trigger event, such as unauthorized movement of, or breaking into, the vehicle.

27 Claims, 4 Drawing Sheets



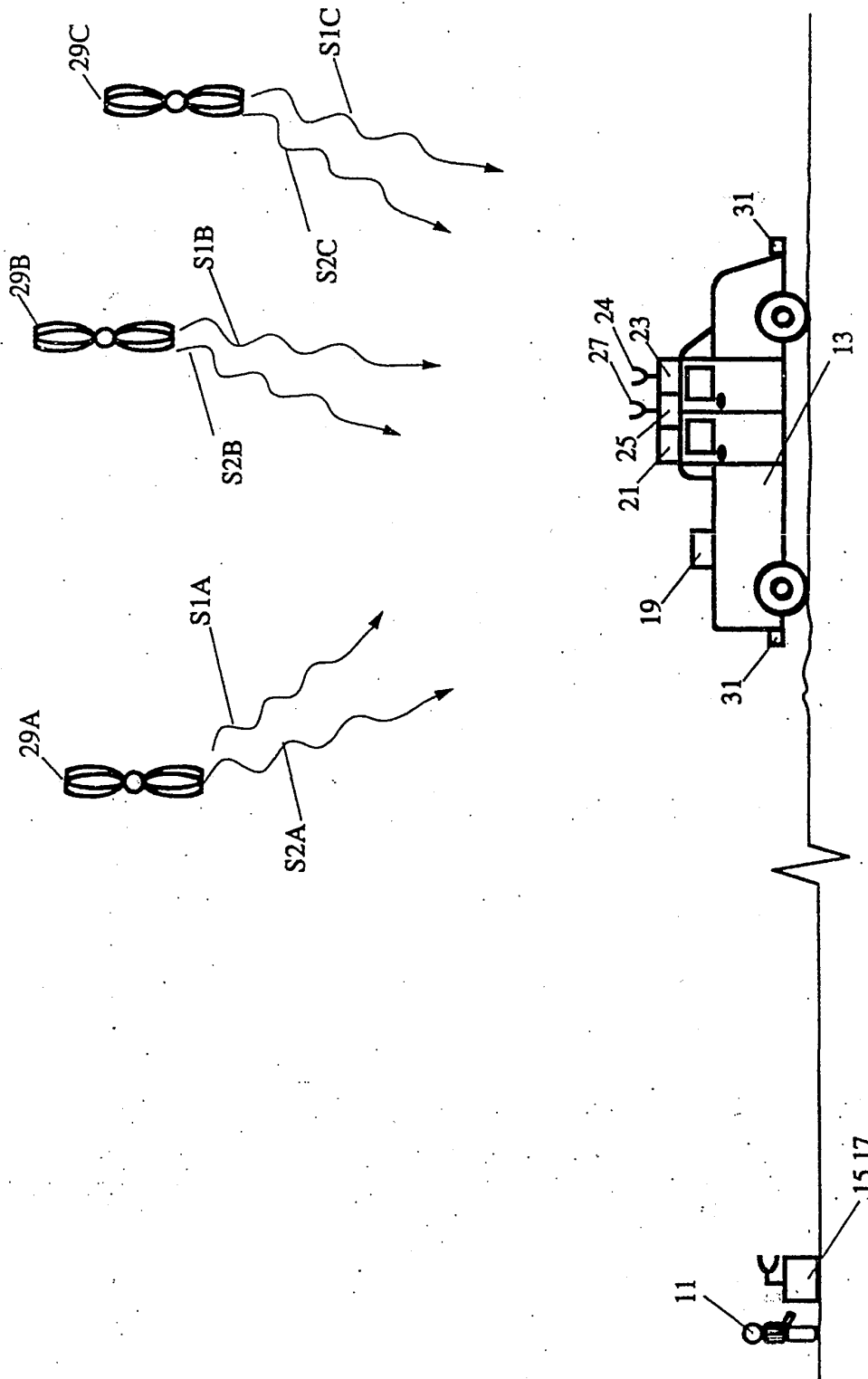
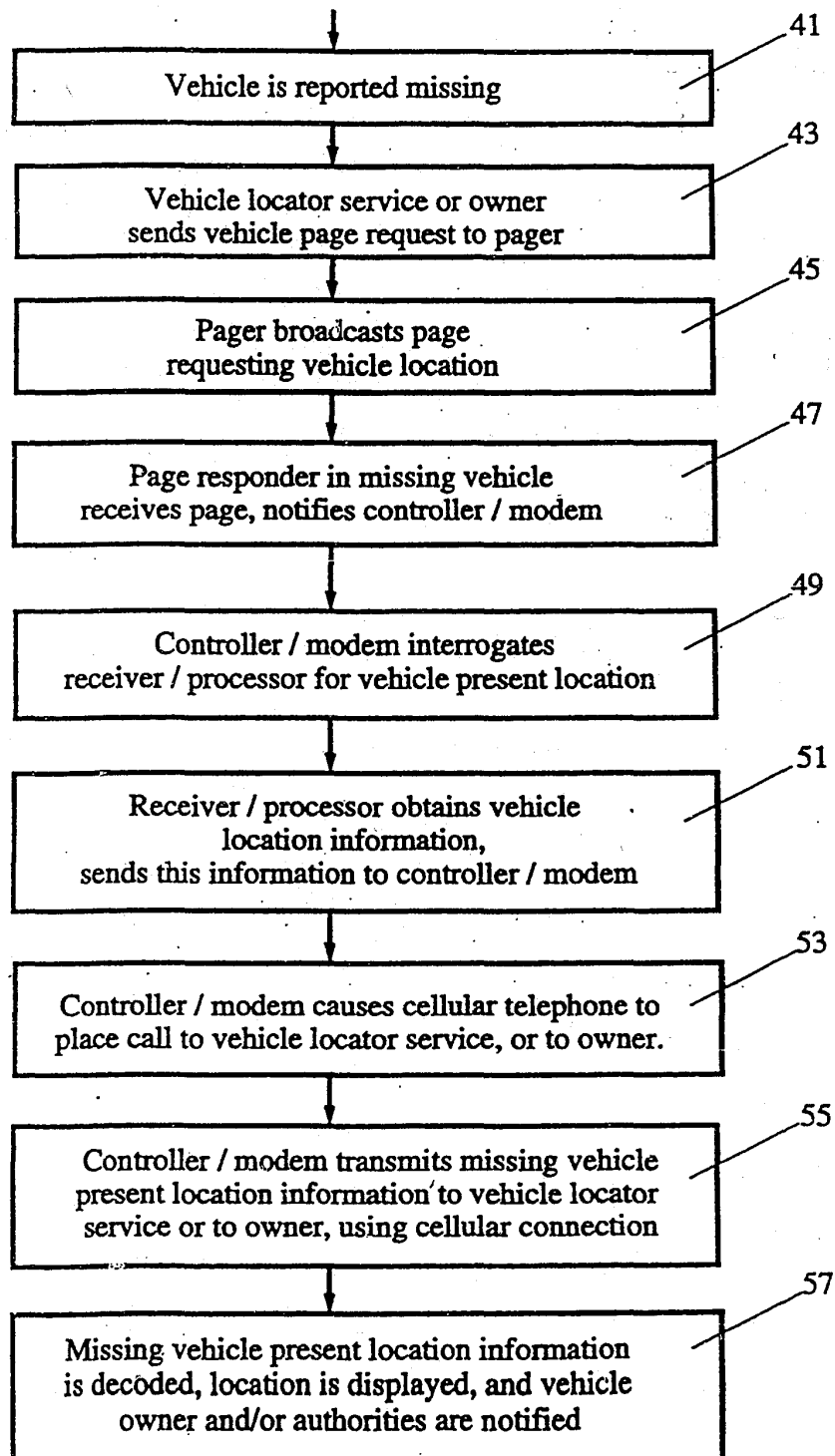


FIG. 1

**FIG. 2**

recovery of the vehicle or a related purpose. The page request may be coded to solicit one or more of several predetermined responses by the vehicle, such as contacting different telephone numbers. The GPS receiver/processor can be replaced by a receiver/processor that works with a LORAN system, or with a group of gyroscopes or local magnetic field sensors mounted on the vehicle.

The method and apparatus of the invention provide a missing vehicle locator system that allows a missing vehicle to be located anywhere on the Earth's surface that can be reached by a vehicle location paging request and GPS signals. The portion of the apparatus contained in the vehicle is preferably hidden and not in plain view of any person within or adjacent to the vehicle. Communications between the page broadcaster, the vehicle location center and the missing vehicle do not call attention to themselves so that no one in or adjacent to the missing vehicle is aware that such communications are being transmitted.

Because vehicle location is only reported after occurrence of a trigger event, such as determination that the vehicle is missing, the vehicle location service center tracks only a relatively small number of vehicles at one time, namely missing vehicles.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 is a schematic view of apparatus for practice of the invention.

FIGS. 2 and 3 are flow charts for practice according to two embodiments of the invention.

FIGS. 4 and 5 are schematic views of apparatus according to the two embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates apparatus used to locate a missing vehicle according to the invention. A vehicle owner or operator 11 realizes that his/her vehicle 13 is missing and initiates a GPS-assisted search for the vehicle by notifying a vehicle location center 15. The vehicle locator center 15 sends a vehicle pager request to a pager network 17, or initiates a vehicle pager request itself. A vehicle page is broadcast, specifying the missing vehicle 13 by means of a unique identifying code address or by other appropriate vehicle identification means. The vehicle 13 carries a paging responder 19, a controller/modem and interface 21, a cellular telephone 23 and associated antenna 24, and a GPS signal receiver/processor 25 that are electronically connected together. Preferably, each of these devices is concealed on or within the vehicle 13. For example, the receiver/processor 25 has one or more GPS antennas 27 (also hidden) to receive GPS position signals S1j and S2j(j=A, B, C) at the two frequencies used by each of the one or more GPS satellites 29A, 29B and 29C that transmit such signals. This antenna (or antennas) 27 can be mounted on or within one or more bumpers 31 or other projections of the vehicle 13, on a rear or side window of the vehicle, within a roof or top panel 33 of the vehicle 13, or elsewhere. Preferably, the antennas 24 and 27 are mounted on the vehicle so that the presence of these antennas is hard to detect.

A "page", as used herein, is a radiowave or other electronic communication, broadcast in a selected frequency band, that is intended only for and is sensed only by a particular receiver, referred to herein as a paging responder. A person or electronic device that carries or

is attached to the paging responder then responds by placing a telephone call or by performing some other task to respond affirmatively to the page. Operation of a paging system is discussed by Ward in U.S. Pat. No. 3,439,320 and by Bunting in U.S. Pat. No. 3,599,200, both incorporated herein by reference.

The GPS signal receiver/processor 25 can operate only in response to receipt of an interrogation signal from the controller/modem 21, if desired, in order to reduce the electrical current draw from a power supply for the controller/modem. In this embodiment, the receiver/processor 25 is normally in a "sleep" mode and is awakened only when needed. This approach conserves electrical power used to operate the receiver/processor 25 and also makes detection of the presence of the apparatus more difficult. Alternatively, the receiver/processor 25 may be awakened periodically (e.g., once every 15 minutes) to obtain a new fix on the GPS satellite(s) that provides the signals needed to calculate the present vehicle location. This apparatus serves as a missing vehicle locator system according to the following procedure.

FIG. 2 illustrates, in flow chart form, a procedure that can be followed to locate a missing vehicle. In step 41, a vehicle owner or operator notices that his/her vehicle 13 is missing and notifies a vehicle location service center (the "Center") 15. In step 43, the Center (or the vehicle owner) sends a page request to a pager network or broadcasts a paging request itself. A paging request is broadcast, requesting a response indicating the present location of the missing vehicle 13, in step 45. In step 47, the page responder 19 in the missing vehicle 13 receives the paging request and notifies the controller/modem 21 that a vehicle location request was received. In step 49, the controller/modem 21 interrogates the GPS signal receiver/processor 25, also located in the vehicle, as to the present, or last known, vehicle position. In step 51, the receiver/processor 25 obtains the present location information for the vehicle 13 from the GPS satellite signals and sends this position fix to the controller/modem 21. The receiver/processor 25 may have received this information continuously in the recent past, or the GPS receiver may have been "awakened" and caused to determine the present vehicle position by a missing vehicle notification received from the controller/modem 21.

In step 53, the controller/modem 21 causes the cellular telephone or similar communication means 23, also located in the missing vehicle 13, to place a call to the Center or to the owner. The handset for the cellular telephone 23 may be disabled by the controller/modem 21 to make the cellular phone appear to be non-operational, if the cellular phone is not hidden from view. When the Center answers the call from the cellular telephone 23, the controller/modem 21 transmits the vehicle present location information to the Center in a short burst of data, in step 55. The vehicle present location information can be updated continuously or intermittently, or the cellular telephone 23 may respond only once, as desired. In step 57, the Center decodes the vehicle position information (if this information is not already decoded), displays the vehicle present location on a map (optional), and notifies the vehicle owner and/or police of the vehicle's present location. The vehicle owner and/or police can then recover the missing vehicle. When the telephone call is terminated by the Center, the controller/modem discontinues sending location fixes.

Alternatively, the trigger event that causes the vehicle location center 15 in FIG. 1 to be notified may be unauthorized movement of the vehicle or some other unauthorized action sensed by a sensor positioned on or adjacent to the vehicle 13. If this trigger event occurs, the vehicle 13 itself may notify the vehicle location center 15 of the unauthorized action and of the present location of the vehicle, without requiring receipt of a page. This procedure is illustrated in flow chart form in FIG. 3. In step 67, unauthorized action involving a vehicle, such as movement of the vehicle, is sensed by a trigger event sensor 79 (FIG. 5) that is attached to or adjacent to the vehicle 13. The event sensor 79 causes the controller/modem 21 to interrogate the receiver/processor 25 for present location information on the (missing) vehicle, in step 69. The steps 71, 73, 75 and 77 in FIG. 3 are the same as the respective steps 51, 53, 55 and 57 in FIG. 2.

FIG. 4 illustrates electronic apparatus 61 to be carried on the vehicle according to the first embodiment of the invention. This apparatus includes: the antenna 27 to receive the GPS signals; an optional preamplifier 30 to enhance the GPS signals received by the antenna 27; the signal receiver/processor 25 to receive and process the GPS signals received from the antenna 27; the controller/modem 21 to receive a paging request, to interrogate the receiver/processor 25 when such paging request is received, and to transmit the vehicle location information, using a cellular connection; and the cellular telephone 23 to contact the vehicle location service center to assist the controller/modem 21 in transmitting the present location of the vehicle 13. The vehicle battery (not shown) or a separate power supply 32 may supply power to operate the paging responder 19, the controller/modem 21, the cellular transmitter 23, the GPS signal receiver/processor 25, the antenna 27 and/or the preamplifier 30. Preferably, a back-up power supply, such as 32, provisionally provides power for operation of the other apparatus components when power from the primary power source is not available.

FIG. 5 illustrates electronic apparatus to be carried on or provided adjacent to the vehicle according to the second embodiment of the invention. The paging request responder 19 shown in FIG. 4 is replaced by a trigger event sensor 79 that functions as discussed in connection with FIG. 3, with all other components being as in FIG. 4.

The Global Positioning System (GPS) is part of a satellite-based navigation system developed by the United States Defense Department under its Navstar program. A fully operational GPS includes up to 24 satellites approximately uniformly dispersed around six circular orbits with four satellites each, the orbits being inclined at an angle of 55° relative to the equator and being separated from each other by multiples of 60° longitude. The orbits have radii of approximately 26,560 kilometers and are approximately circular. The orbits are non-geosynchronous, with 0.5 sidereal day (11.967 hours) orbital time intervals, so that the satellites move with time relative to the Earth below. Theoretically, three or more GPS satellites will be visible from most points on the Earth's surface, and visual access to one or more such satellites can be used to determine an observer's position anywhere on the Earth's surface, 24 hours per day. In the present GPS procedure, GPS signals from three or more satellites are used to determine position. However, by using other signal coding techniques, it may be possible to use GPS signals re-

ceived from only two, or even one, GPS satellite for position determination. Each satellite carries a cesium or rubidium atomic clock to provide timing information for the signals transmitted by the satellites. Internal clock correction is provided for each satellite clock.

Each GPS satellite transmits two L-band carrier signals: an L1 signal having a frequency $f_1 = 1575.42$ MHz and an L2 signal having a frequency $f_2 = 1227.6$ MHz. These two frequencies are integral multiples $f_1 = 1500 f_0$ and $f_2 = 1200 f_0$ of a base frequency $f_0 = 1.023$ MHz. The L1 and L2 signals from each satellite are binary phase shift key (BPSK) modulated by predetermined pseudo random noise (PRN) codes that are different for each of the GPS satellites deployed. One motivation for use of two carrier signals L1 and L2 is to allow partial compensation for propagation delay of such a signal through the ionosphere, which delay varies approximately as the inverse square of signal frequency f (delay $\propto f^{-2}$). This phenomenon is discussed by MacDoran in U.S. Pat. No. 4,463,357, which discussion is incorporated by reference herein. When transit time delay through the ionosphere is determined, a phase delay associated with a given carrier signal can be determined.

Use of the PRN codes allows use of a plurality of GPS satellite signals for determining an observer's position and for providing navigation information. A signal transmitted by a particular GPS signal is selected by generating and matching, or correlating, the PRN code for that particular satellite. All PRN codes are known and are stored in GPS satellite signal receivers carried by ground observers. A first PRN code for each GPS satellite, sometimes referred to as a precision code or P-code, is a relatively long, fine-grained code having an associated clock rate of $10 f_0 = 10.23$ MHz. A second PRN code for each GPS satellite, sometimes referred to as a clear/acquisition code or C/A code, is intended to facilitate rapid satellite signal acquisition and is a relatively short, coarser-grained code having a clock rate of $f_0 = 1.023$ MHz. The C/A code for any GPS satellite has a length of 1023 chips or time increments before this code repeats. The P-code for any GPS satellite has a length of precisely one week (7,000 days) before this code repeats. The GPS satellite bit stream includes information on the ephemeris of each GPS satellite, parameters identifying the particular GPS satellite, and corrections for ionospheric signal propagation delays. A useful discussion of the GPS and techniques for obtaining position information from the satellite signals is found in Guide To GPS Positioning, edited by David Wells, Canadian GPS Associates, 1986.

A second configuration for global positioning is the GLONASS system, placed in orbit by the former Soviet Union. GLONASS also uses 24 satellites, distributed approximately uniformly in three orbital planes of eight satellites each. Each orbital plane has a nominal inclination of 64.8° relative to the equator, and the three orbital planes are separated from each other by multiples of 120° longitude. The GLONASS circular orbits have smaller radii, about 25,510 kilometers, and a satellite period of revolution of 8/17 of a sidereal day (11.26 hours). A GLONASS satellite and a GPS satellite will thus complete 17 and 16 revolutions, respectively, around the Earth every 8 days. The GLONASS system uses two carrier signals L1 and L2 with frequencies of $f_1 = (1.602 + 9k/16)$ MHz and $f_2 = (1.246 + 7k/16)$ MHz, where $k (= 0, 1, 2, \dots, 23)$ is the channel or satellite number. Because the channel frequencies are distinguishable from each other, the P-code, and also the

C/A code, is the same for each satellite. Reference to a Global Positioning System or GPS herein refers to a GPS satellite configuration and to a GLONASS satellite configuration.

Although implementation of the invention herein uses a GPS or GLONASS satellite system to provide "location fix" signals from which the location of the signal receiver processor can be determined, other methods may also be used to provide a location fix. For example, the LORAN system, which provides a plurality of three or more tall structures, each having a transmitter that broadcasts a time-coded message sequence, can be used to determine present vehicle location by triangulation. The LORAN system is described in U.S. Pat. No. 3,665,086, issued to Magee et al, which is incorporated herein by reference. If a time-coded message sequence is received from each of three LORAN transmitters, the relative time delays between these three messages can be used to determine the location of the signal receiver/processor with an estimated inaccuracy of several meters. One disadvantage of use of a LORAN system, vis-a-vis a GPS or GLONASS positioning system, is that a large number of tall structures, with transmitters mounted thereon, must be used to cover a given area with a LORAN system; whereas a relatively small number of GPS or GLONASS satellites suffice for location determination using a GPS or GLONASS configuration. Using a LORAN location determination system, a LORAN signal receiver/processor would replace the GPS (or GLONASS) signal receiver/processor in FIGS. 1 and 2, with all other features remaining as before.

A third method of providing a location fix for a missing vehicle is through "dead reckoning", using a plurality of gyroscopes whose angular orientations relative to an initial, fixed coordinate system are accumulated, read out and transmitted to the vehicle location service center, upon receipt of a command from a controller/modem carried by the vehicle. This approach to providing a location fix requires that the vehicle velocity $v(t)$ and gyroscopically-determined angle cosines $\alpha(t)$, $\beta(t)$ and $\chi(t)$ for vehicle orientation be monitored during all times the vehicle is in motion, in order to provide the cumulative location coordinate changes

$$\Delta x(t) = \int v(t') \cos \alpha(t') dt',$$

$$\Delta y(t) = \int v(t') \cos \beta(t') dt',$$

$$\Delta z(t) = \int v(t') \cos \chi(t') dt',$$

of the vehicle at any particular time t from a known initial location. Use of gyroscopes as a navigation instrument for determination of the present angle cosines of an object is described in U.S. Pat. No. 4,370,815, issued to Younkin. Use of a gyroscope for land vehicle navigation is disclosed by Romacker in U.S. Pat. No. 4,416,066. Use of a gyroscope and an induced magnetic field during rotation of a body to obtain an angle cosine and its time derivative is disclosed by Moore in U.S. Pat. No. 4,197,655. Use of a gyroscope and an acoustic surface wave sensor to obtain an angle cosine and its time derivative is disclosed in U.S. Pat. No. 4,384,409, issued to Lao. These patents, which are incorporated by reference herein, teach methods for use of one or more

gyroscopes for determining an angle cosine and its time derivative and for simple navigation.

A fourth method of providing a location fix for a missing vehicle is through dead reckoning, using a plurality of local magnetic field direction sensors whose angular orientations relative to an initial, fixed coordinate system are accumulated, read out and transmitted to the vehicle location service center, upon receipt of a command from a controller/modem carried by the vehicle. This approach to providing a location fix requires that the vehicle velocity $v(t)$ and the angle cosines $\alpha(t)$, $\beta(t)$ and $\chi(t)$ describing vehicle orientation, determined by the local magnetic field direction, also be monitored during all times the vehicle is in motion, in order to provide the cumulative location coordinate changes

$$\Delta x(t) = \int v(t') \cos \alpha(t') dt',$$

$$\Delta y(t) = \int v(t') \cos \beta(t') dt',$$

$$\Delta z(t) = \int v(t') \cos \chi(t') dt',$$

of the vehicle at any particular time t from a known initial location. Use of local magnetic field direction sensors to help determine the present direction of a moving object is described by Takai in U.S. Pat. No. 4,743,913. The Earth's magnetic field varies in intensity from about -0.7 Gauss near the South Pole to approximately 0 Gauss at the equator to around $+0.6$ Gauss at 60° North latitude, which passes near the magnetic north pole in the Hudson Bay region of North America, according to D. S. Parasnis, *Magnetism*, Harper & Brothers, New York, 1961, pp. 91-121. The direction of the local magnetic field varies in an irregular manner with the latitude and longitude coordinates on the Earth's surface. Thus, if a map of the amplitude and direction of the local magnetic field is prepared and stored in a computer memory, which can be carried on the vehicle or kept at a base station of the missing vehicle location system, use of the map plus the output signals from the local magnetic field sensors will allow the present location of the vehicle, whether in motion or not, to be determined with acceptable accuracy.

I claim:

1. Apparatus for determining the present location of a missing vehicle, the apparatus comprising:

a GPS signal antenna and receiver/processor, connected to the antenna, attached to a vehicle, to receive and process GPS signals to determine the present location of the vehicle to which the antenna and receiver/processor are attached;

an event sensor that determines when a selected trigger event involving the vehicle has occurred and issuing a sensor output signal when that event occurs;

controller means, connected to the GPS receiver/processor and to the event sensor, for receiving the event sensor output signal and, in response thereto, for issuing a first output signal that is received by the GPS receiver/processor that commands the receiver/processor to determine and issue as an output signal the present location of the receiver/processor, and for receiving the receiver/processor output signal representing present location of the receiver/processor and issuing this present location information as a second output signal;



United States Patent [19]

Buss et al.

[11] Patent Number: 5,539,395

[45] Date of Patent: Jul. 23, 1996

[54] LOCATION DEPENDENT INFORMATION RECEIVING DEVICE AND METHOD

[75] Inventors: Thomas E. Buss, Wellington; Michael J. DeLuca, Boca Raton, both of Fla.

[73] Assignee: Motorola, Inc., Schaumburg, Ill.

[21] Appl. No.: 496,865

[22] Filed: Jun. 30, 1995

Related U.S. Application Data

[63] Continuation of Ser. No. 143,966, Nov. 1, 1993, abandoned.

[51] Int. Cl.⁶ H04B 3/38; H04Q 7/00

[52] U.S. Cl. 340/827; 340/825.440; 340/825.470; 455/38.100

[58] Field of Search 340/827, 825.26, 340/825.27, 825.44, 825.47, 311.1, 905, 825.36, 825.49; 370/94.1; 379/57; 455/38.1, 18, 66; 369/7; 381/2

[56] References Cited

U.S. PATENT DOCUMENTS

3,984,807 10/1976 Haemming 340/825.49
4,644,351 2/1987 Zabarsky et al. 340/825.44

4,725,886 2/1988 Galumbeck et al. 340/825.47
4,812,843 3/1989 Champion III et al. 340/905
4,845,491 7/1989 Fascenda et al. 340/825.27
4,916,539 4/1990 Galumbeck 340/825.47
4,973,952 11/1990 Malec et al. 340/825.49
5,133,081 7/1992 Mayo
5,196,842 3/1993 Gomez et al. 340/311.1
5,254,986 10/1993 DeLuca 340/825.44
5,274,845 12/1993 Wang 340/825.49
5,317,311 5/1994 Martell et al. 340/905
5,406,271 4/1995 Sonnendorfer et al. 340/825.36

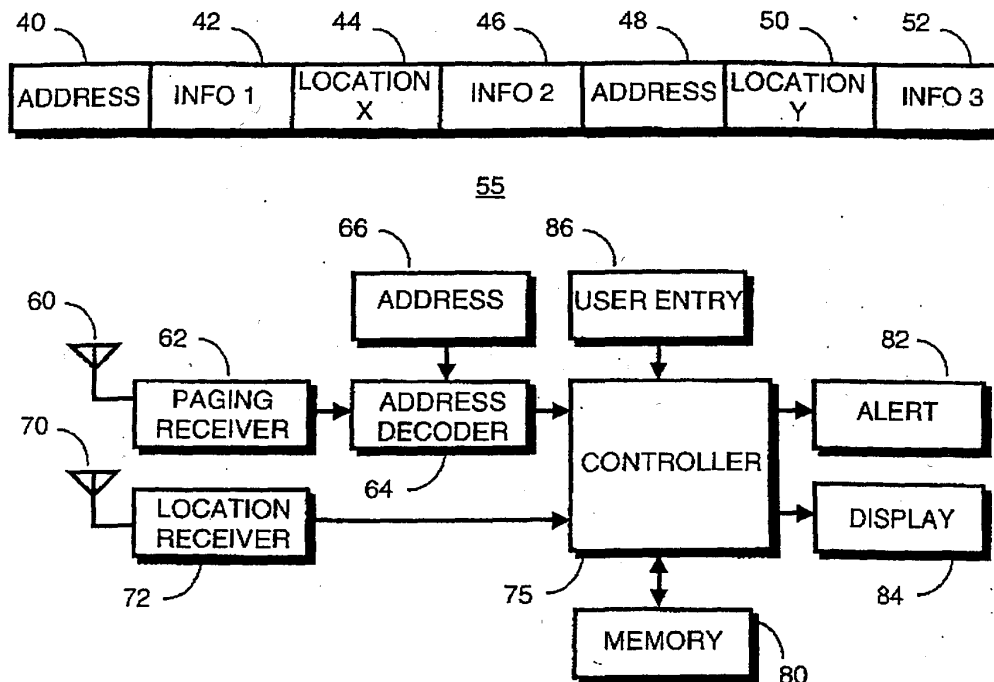
Primary Examiner—Michael Horabik

Assistant Examiner—Edward Merz

[57] ABSTRACT

A portable device (55) has a first receiver (62) for receiving a paging signal (40–52) from a paging system (10). A second receiver (72) receives area identification signals (20–26) from a second system. The received paging signals may be stored in a memory (80) for later retrieval. A controller (75) examines the paging signals (40–52) and selects messages having a location signal (44, 50) matching a location of the device (55). The address of the device (66) may also be used to select the messages. Upon selection, an alert is generated by an alert means (82) and the message is annunciated on a display (84).

19 Claims, 4 Drawing Sheets



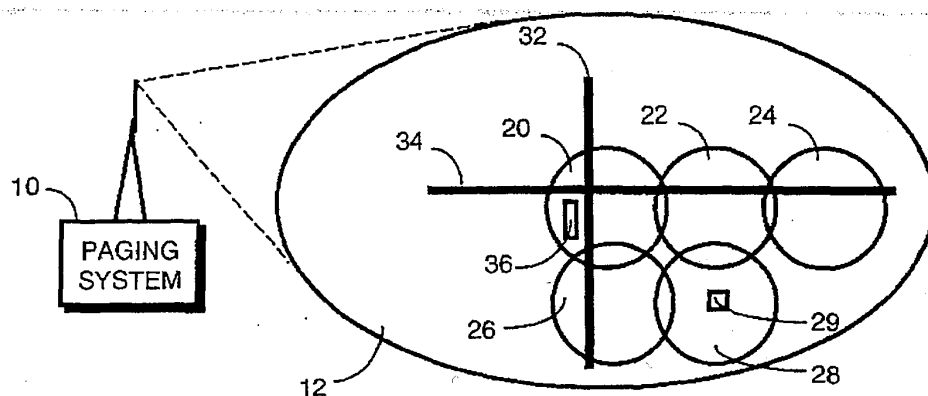


FIG. 1

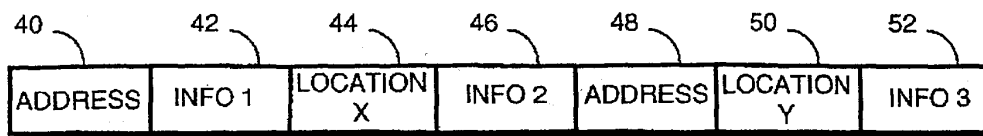


FIG. 2

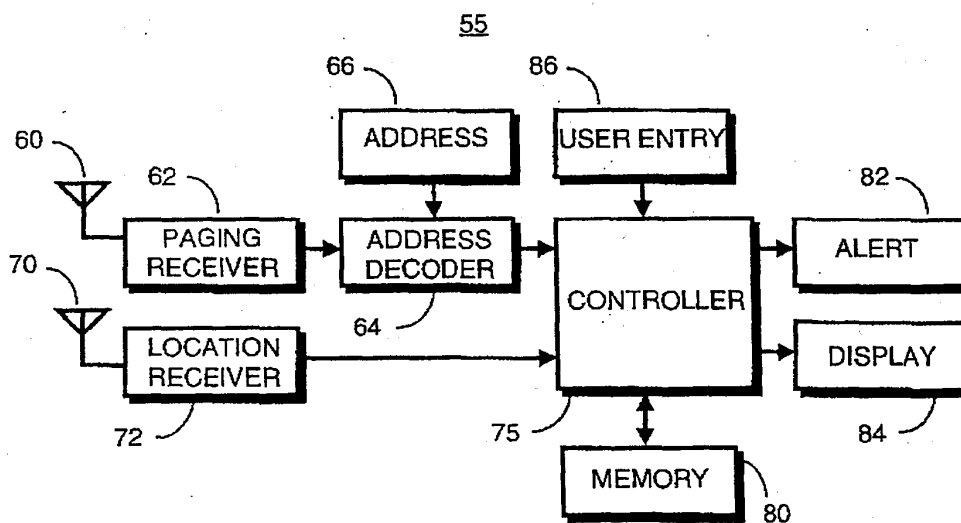
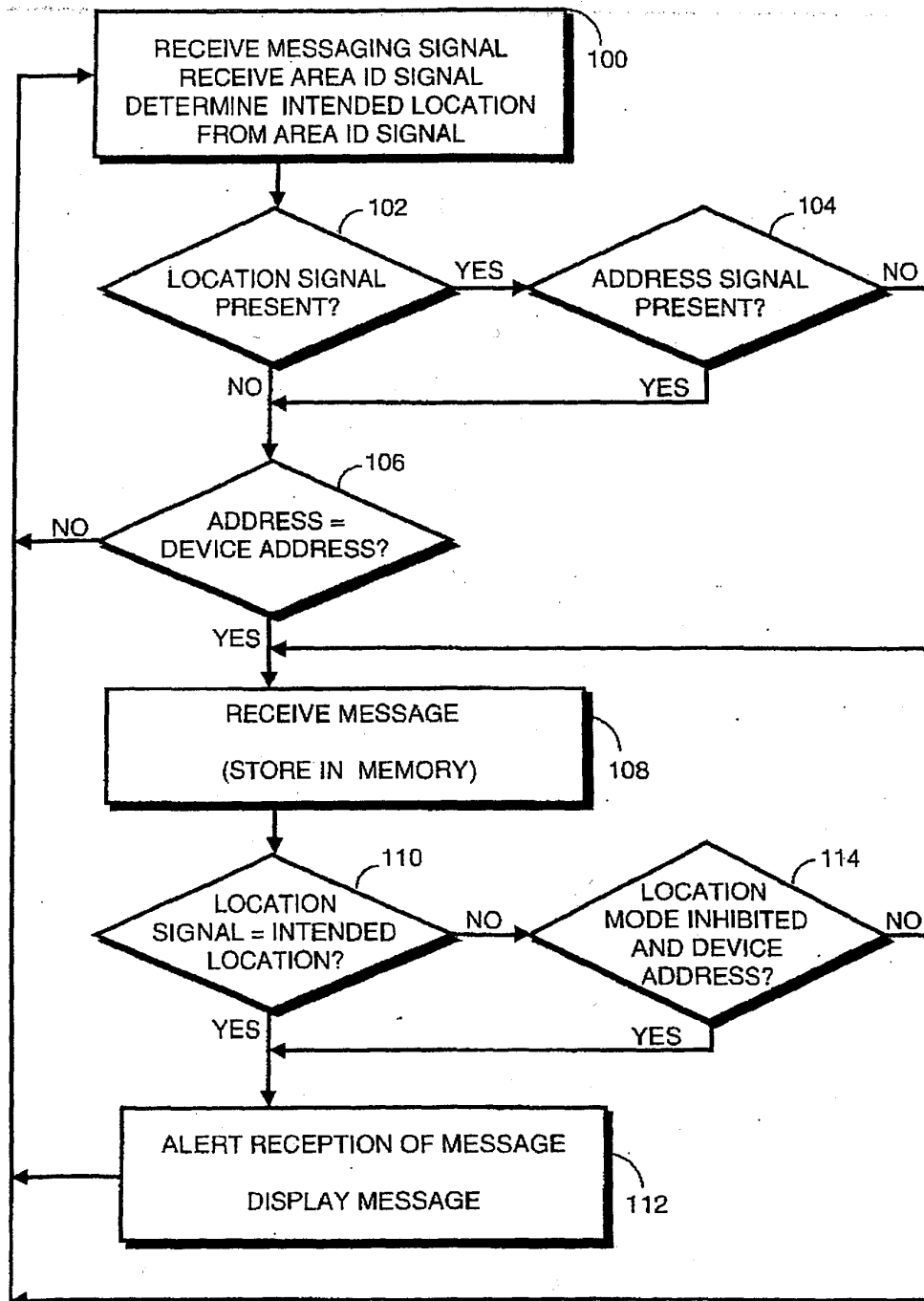
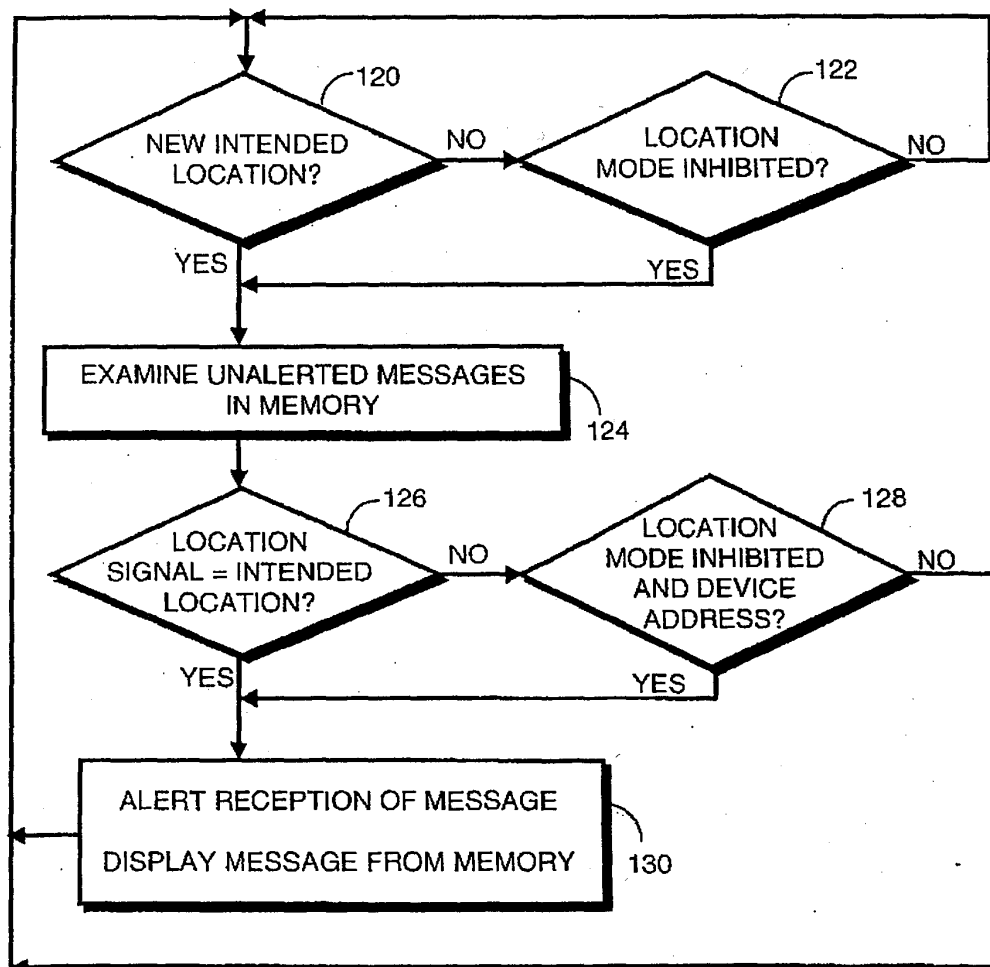
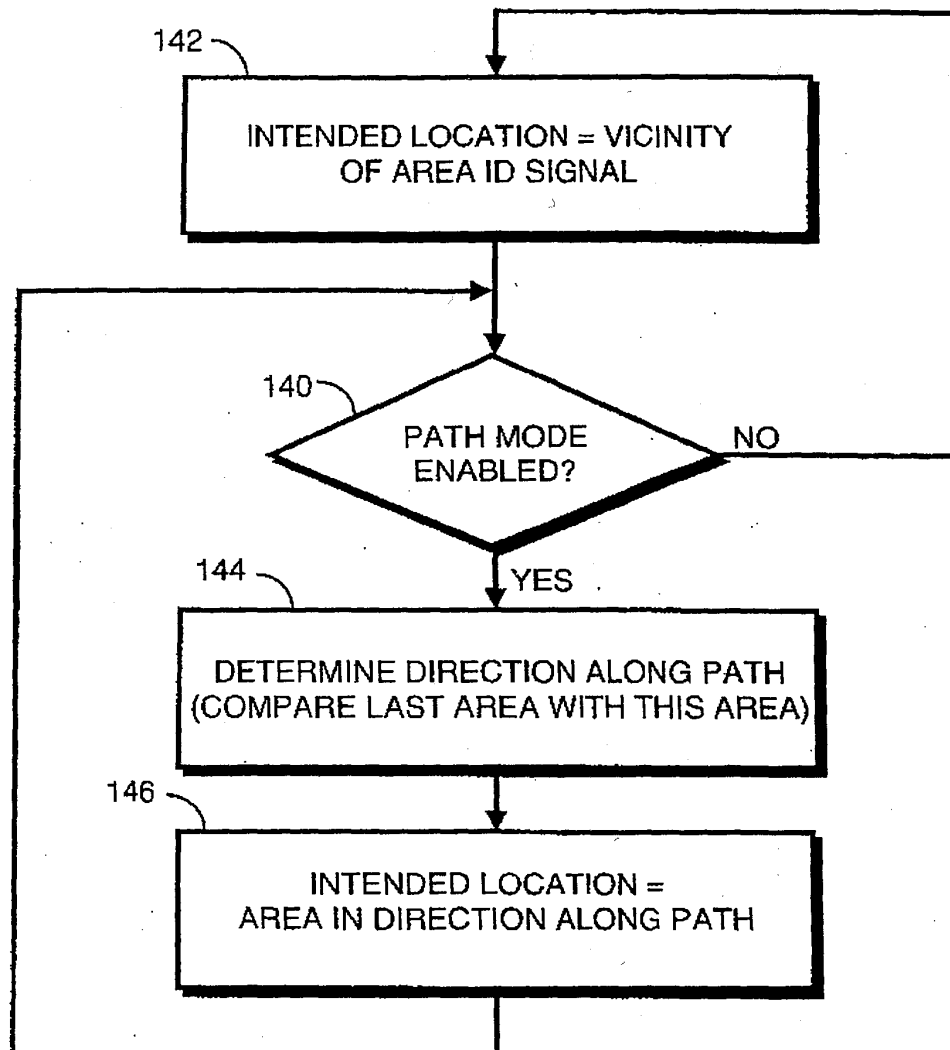


FIG. 3

**FIG. 4**

**FIG. 5**

**FIG. 6**

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LOCATION DEPENDENT INFORMATION RECEIVING DEVICE AND METHOD

This is a continuation of application Ser. No. 08/143,966 filed Nov. 1, 1993, now abandoned.

FIELD OF THE INVENTION

This invention relates generally to the field of information receiving portable devices which use a determined location for presentation of information.

BACKGROUND OF THE INVENTION

With the advent of information services for portable receiving devices such as pagers, a user may carry an information device capable of receiving and accessing a large volume of data. Additionally, with improved memory capability of pagers, a large volume of messages may be stored in the pager. Sorting through such a large volume of messages to find information relevant to the user may pose a tedious task for the pager user.

Additionally, the recent introduction of information services provides a new method of communicating a large amount of information to a large number of people at a relatively low cost. However, information may be relevant only to a user who either has entered or is about to enter a certain location, and not relevant when the user is located elsewhere.

Thus, what is needed is a device and method for selecting relevant information from the large amount of communicated information on the basis of an intended location of the user.

SUMMARY OF THE INVENTION

A location dependent message presentation device comprises a first receiver for receiving a messaging signal transmitted by a first communication system to a multiplicity of areas. The messaging signal including a multiplicity of messages having a location signal associated therewith. The device further includes a location determining means for determining a location of the device and a control means coupled to the receiver and the location determining means for selecting a message from the multiplicity of messages, the message having a location signal corresponding to the location of the device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a paging system having an information service which transmits a messaging signal within a coverage area divided into a multiplicity of areas by a second system in accordance with the preferred embodiment of the present invention.

FIG. 2 shows an example of a messaging signal transmitted by the paging system of the preferred embodiment of the present invention.

FIG. 3 shows a block diagram of a location dependent message display device operating in accordance with the preferred embodiment of the present invention.

FIG. 4 shows a flowchart of the device while receiving the messaging signal and the area identification signal in accordance with the preferred embodiment of the present invention.

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FIG. 5 shows a flowchart for alerting messages stored in optional memory in response to a change in intended location in accordance with a second embodiment of the present invention.

FIG. 6 shows a flowchart for determining the intended location of the device in accordance with the preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a paging system having information service which transmits a messaging signal within a coverage area divided into a multiplicity of areas by a second system in accordance with the preferred embodiment of the present invention. A paging system, 10, comprises a number of transmitters for transmitting messages within a large coverage region or area 12. A typical paging system may have a coverage area 12 which exceeds one thousand square miles or two thousand square kilometers. Also transmitting within the coverage area is a second system capable of identifying a multiplicity of areas 20, 22, 24, 26 and 28 substantially smaller than the coverage area 12. The second system may be any of a number of systems capable of indicating location in a particular area. Such systems include the global positioning system (GPS) capable of identifying a location within thirty yards or meters, portable telephone systems providing area identification signals such as the cellular telephone system or the personal communication system (PCS), or other highway location systems such as a system described in U.S. Pat. No. 5,133,081. In a preferred highway location system, each area 28 has a local base station 29 for transmitting an area identification signal within the area. FIG. 1 also shows an intersection of two streets, Northsouth street 32 and Eastwest street 34. At the intersection of the two streets is a location of interest 36. The location may correspond to a retail outlet, service center or residence of the user of the device.

FIG. 2 shows an example of a messaging signal transmitted by the paging system of the preferred embodiment of the present invention. A first message signal consists of a typical selective call message having an address 40 followed by first message information 42. A second message signal consists of a location signal 44 followed by second message information 46. A third message signal consists of an address 48 followed by a location signal 50 and third message information 52. Note that the third message may have the location signal 50 and address 48 occur in reverse order. Furthermore, the address, 40 and 48, may consist of more than one portion, there by allowing sub-addressing of paging receivers in a manner known to those familiar with the art. Also, the location signals 44 and 50 may indicate a plurality of locations in which the message is to be received. In the preferred embodiment, the messaging signal is carried upon the POCSAG protocol, a well known paging protocol which provides for both selective call messaging and information service messaging. Alternately, different paging protocols may be used, one such paging protocol providing for improved information services is the Motorola Flex™ paging protocol.

FIG. 3 shows a block diagram of a location dependent message display device 55 operating in accordance with the preferred embodiment of the present invention. The messaging signal of FIG. 2 is received at the device by an antenna 60, demodulated by receiver 62, and an address decoder 64 searches each message for a predetermined

way of communicating messages within a large area 12 for reception in individual smaller areas, such as predetermined area 20. In this case, the communication system determines at least one predetermined location for reception of the information portion, the location may be indicated by the sender to be predetermined area 20 near point of interest 36. The paging system then assigns a signal indicative of the predetermined location and transmits the message signal in area 12 which is substantially larger than the predetermined location 20.

FIG. 5 shows a flowchart for alerting messages stored in optional memory 80 in response to a change in intended location in accordance with a second embodiment of the present invention. The operation of FIG. 5 is an optional operation because substantially more memory may be required than is currently marketable in a conventional paging device, but anticipates its future practicality. Step 120 determines if a new intended location has been determined. Determination of intended location is described by FIG. 6. If the intended location remains unchanged, then step 122 determines if the location mode has been inhibited. If not inhibited, step 120 is returned to. If either a new intended location has been determined or the location mode inhibited, the memory 80 is examined for unalerted messages, that is messages that were received and stored in step 108 yet not alerted by step 112. In alternate embodiments, the unalerted requirement of step 124 may be modified or eliminated. Then, step 126 determines which unalerted messages have a location signal matching the intended location or, if the location mode is inhibited, step 128 determines which unalerted messages have an address signal matching the device address. If the result of either step 126 or 128 is true, then each identified message is alerted and displayed in step 130. Otherwise, step 130 is skipped and step 120 is returned to.

FIG. 5 shows alerting and displaying a message previously received by the device and stored in memory in response to the device having a new intended location. This aspect of the invention has the advantage of allowing for transmission of a message signal when the user is not in a desired vicinity and alerting and display of the message when the user enters the desired vicinity. For example, a user may pass through the vicinity of store 36 in a short time, two minutes for example. By first receiving and storing the message before the user enters the vicinity of the store and then alerting it when the user is in the vicinity, the message need not be transmitted during the two minutes while the user is physically in the vicinity of store 36. This aspect has the advantage of allowing the message signal to be transmitted at any time prior to the user's entry to the vicinity of the store. This allows the message to be transmitted during times when the paging system is lightly loaded, at night time for example, and should further reduce the cost of the transmission of the message signal. Furthermore, the user is assured that the information will be alerted while the user is in the vicinity of the store, even though the message signal was not transmitted then.

FIG. 5 also allows for inhibiting the location signal and detection, alerting and displaying messages having an address matching the device address independent of the location signal. As previously discussed, this allows the user to examine all messages directed at the user with different location signals.

FIG. 6 shows a flowchart for determining the intended location of the device in accordance with the preferred embodiment of the present invention. Beginning at step 140, if the path mode is not enabled, step 142 sets the intended

location to the vicinity of the area identification signal received by location receiver 72. This may be accomplished in a variety of ways. If the second location system is a global positioning system (GPS), then the latitude and longitude of the device can be ascertained from the GPS area identification signal and the intended location be a predetermined vicinity, such as any location within a quarter mile or a third of a kilometer of the device. In which case the location signals 44 and 50 could also contain latitude and longitude coordinates for analysis by controller 75. If the cellular or PCS telephone or the highway location system were used, then the intended location could correspond to cell in which the area identification signal was received, or expanded to include a predetermined number of cells in the surrounding vicinity. In this case, the location signal of FIG. 2 could correspond to an address signal identifying a cell of the system.

If the path mode is enabled, step 140 proceeds to step 144 to determine the direction along the path. The path mode may be enabled or disabled by a user selection via switches 86. As an example, if the user's normal path from employment at a location within area 24 along Eastwest street 34 to a residence located in area 26 off of Northsouth street 32, then the intended path begins at area 24 and goes along Eastwest street 34 through areas 22 and 20, to the intersection of Eastwest street 34 and Northsouth street 32, and along Northsouth street to the residence in area 26. The user may enter the above described path into the device using user entry switches 86, or by down-loading data from a personal computer to the device through a data interface (not shown) to the controller. Step 144 determines the direction along the path by determining a change from area 24 to area 22. Alternately, if the path mode was entered with the device at a path's end point, such as area 24, then the direction may be automatically determined to be in the only possible direction along the path, areas 24, 22, 20 then 26. After determining the direction, then step 146 determines the intended location to be the area in the determined direction along the path. In the above example, the direction was determined in area 22 and the direction of the path would include areas 22, 20, and 26, thus the intended location would correspond to areas 22, 20 and 26. If the path were long, the intended location can be limited to number of areas along the path which the user is expected to encounter within a predetermined amount of time or distance. For example, the intended area could be limited to areas 22 and 20 while the device is located in area 22. Since location of interest 36 is within the area of interest, the message corresponding to location 36 would be alerted and displayed as described with respect to FIGS. 4 and 5 before the device and its user are in the vicinity of location of interest 36. This aspect of the invention allows the user to plan a response to the message signal regarding the area of interest 36 before arrival in its vicinity.

Furthermore, area 24, while on the path is not a member of the intended location because it does not lie along the direction of the path from area 22 to area 26. This has the advantage of sparing the user from sorting through messages intended for a location in area 24, or locations which the user has already passed. An advantageous example of information for use in path mode is traffic conditions. This mode allows the user to be alerted to unusual traffic conditions along the predetermined path in advance of arrival of the traffic condition. If the message signal indicated the occurrence of a traffic accident blocking the intersection of Eastwest street and Northsouth street, then the user could plan an alternate route of travel in advance of encountering

said location determining means having a second receiver for receiving an area identification signal transmitted by a second communication system for transmitting a multiplicity of area identification signals within the multiplicity of areas, each of the multiplicity of area identification signals being indicative of a predetermined one of the areas wherein the location corresponds to one of the area identification signals;

a memory means for storing the multiplicity of messages;

an address decoder for identifying a message from the multiplicity of messages if the address signal of the message matches a predetermined address;

a control means coupled to said first receiver, said address decoder, and said location determining means for selecting the message if the location signal of the message corresponds to the location of the device and the address signal of the message corresponds to the predetermined address;

an alerting means coupled to said control means for generating an alert in response to said control means selecting the message; and

an annunciating means coupled to said control means for annunciating the message.

18. In a selective call receiver, a method of selectively receiving a message transmitted within a first area by a first radio frequency communication system, the message having an address portion indicative of a predetermined area within the first area, the method comprising the steps of:

(a) receiving a signal from a second radio frequency communication system, the signal indicative of a second area within the first area;

(b) determining an address signal in response to the signal; the address signal being indicative of a location of the device;

(c) receiving the address portion; and

(d) producing a reception signal indicative of a reception of the message if the address portion matches the address signal and the predetermined location is within the intended area.

19. A selective call receiver for receiving messages within a coverage area, comprising:

a first receiver for receiving an area identification signal transmitted by a system for transmitting one of a multiplicity of area identification signals to each of a multiplicity of areas within the coverage region, each of the areas being relatively smaller than the coverage region;

a second receiver for receiving a messaging signal transmitted to the coverage region, the messaging signal carrying a multiplicity of messages, a location portion of at least one of the multiplicity of messages containing information associated with at least one of the multiplicity of areas; and

means coupled to the first receiver and to the second receiver for displaying at least one of the messages carried by the messaging signal in response to the location portion of the at least one of the messages and in response a received area identification signal.

* * * * *

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5,539,395

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.: 5,539,395

DATED : July 23, 1996

INVENTOR(S): Buss et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 7, Claim 5, Line 54, delete "intended".

Column 7, Claim 6, Line 63, delete "intended".

Column 7, Claim 6, Line 63, after location insert -- of the device--.

Column 7, Claim 5, Line 53, delete "of the device".

Signed and Sealed this

Twenty-fourth Day of December, 1996

Attest:



BRUCE LEHMAN

Attesting Officer

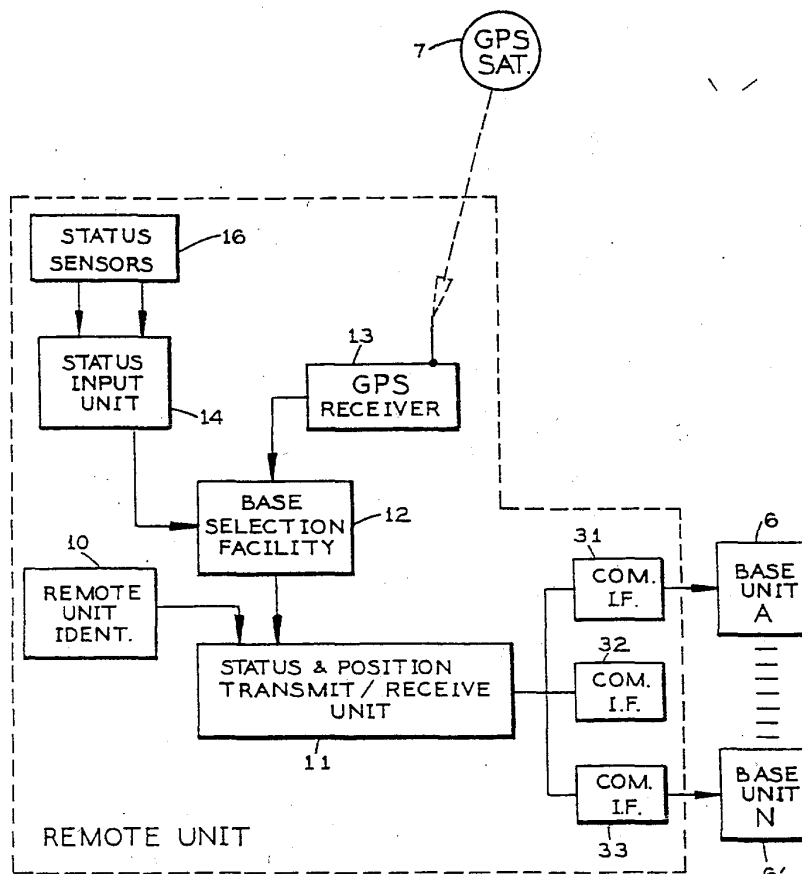
Commissioner of Patents and Trademarks

United States Patent [19][11] **Patent Number:** **5,504,491****Chapman**[45] **Date of Patent:** **Apr. 2, 1996**[54] **GLOBAL STATUS AND POSITION REPORTING SYSTEM**[76] **Inventor:** **Robert W. Chapman**, 2450 Hollywood Blvd., Suite 406, Hollywood, Fla. 33020[21] **Appl. No.:** **231,649**[22] **Filed:** **Apr. 25, 1994**[51] **Int. Cl.^o** **G01S 5/02**[52] **U.S. Cl.** **342/357; 342/457; 364/449**[58] **Field of Search** **342/457, 357; 364/449**[56] **References Cited****U.S. PATENT DOCUMENTS**

4,077,005	2/1978	Bishop	325/32
4,596,988	6/1986	Wanka	343/457
5,043,736	8/1991	Darnell et al.	342/357
5,119,102	6/1992	Barnard	342/357
5,223,844	6/1993	Mansell et al.	342/357
5,224,842	7/1993	Brown et al.	342/357

Primary Examiner—Thomas H. Tarcza*Assistant Examiner*—Dao L. Phan
Attorney, Agent, or Firm—Oltman and Flynn[57] **ABSTRACT**

A global status and position reporting system for a remote unit having a status and position transmit/receive unit with at least one status and/or event input connected to a respective status and/or event sensor for reporting at least one system status and/or event and position of the remote unit, and a status output connected to a communication interface; at least one base unit adapted for receiving a status and position report, disposed at a position spaced away from the remote unit; position independent communications means including communications interfaces respectively disposed in the remote unit and in the base unit for transmitting a status and position report from the remote unit to the base unit upon receipt of an activating prompt from the status sensor or a prompt initiated at the base unit. A global positioning satellite receiver is provided in the remote unit for receiving global positioning information from a system of global positioning satellites having a position output connected to the communications means for entering position information upon receiving the activating prompt.

26 Claims, 5 Drawing Sheets

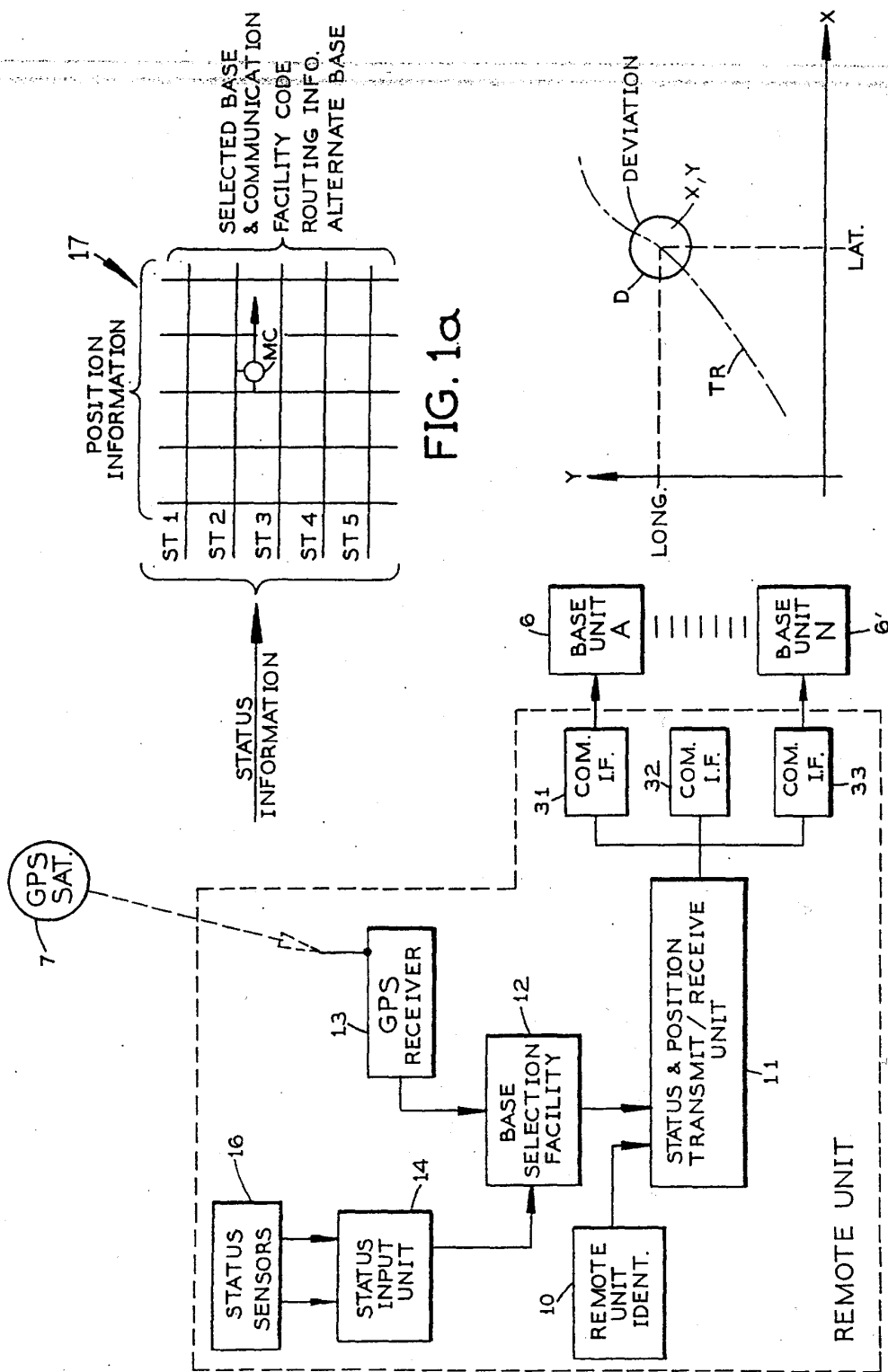


FIG. 1

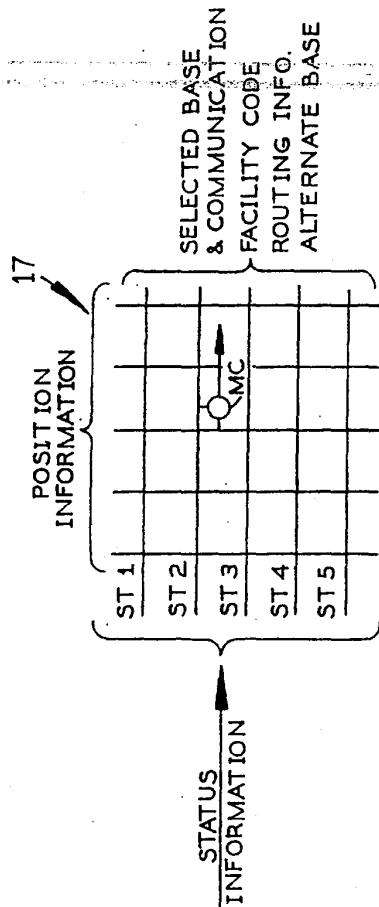


FIG. 1a

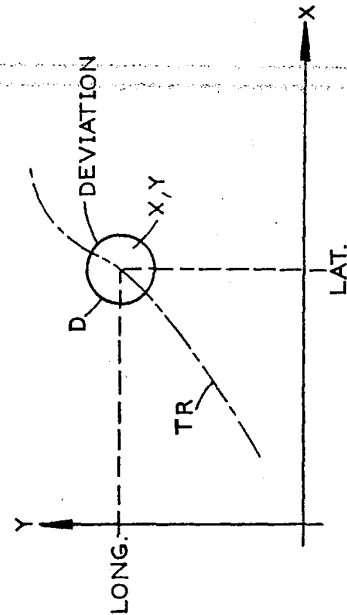


FIG. 6

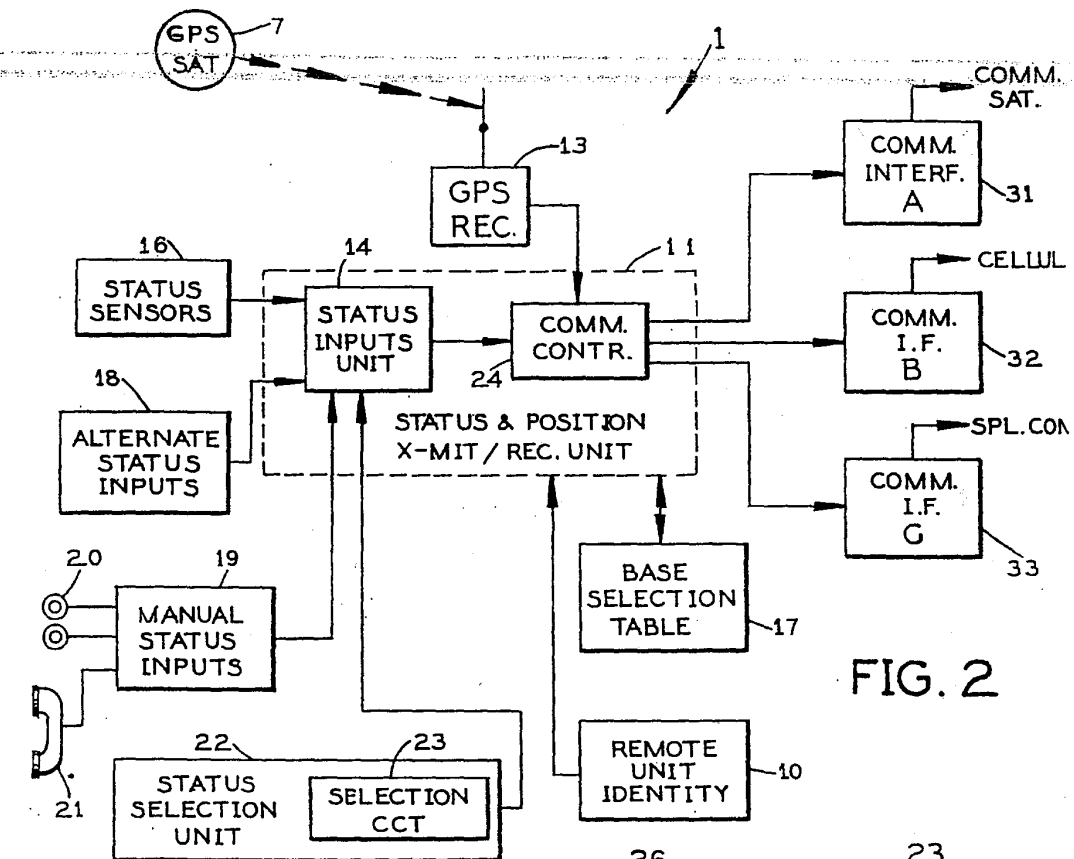


FIG. 2

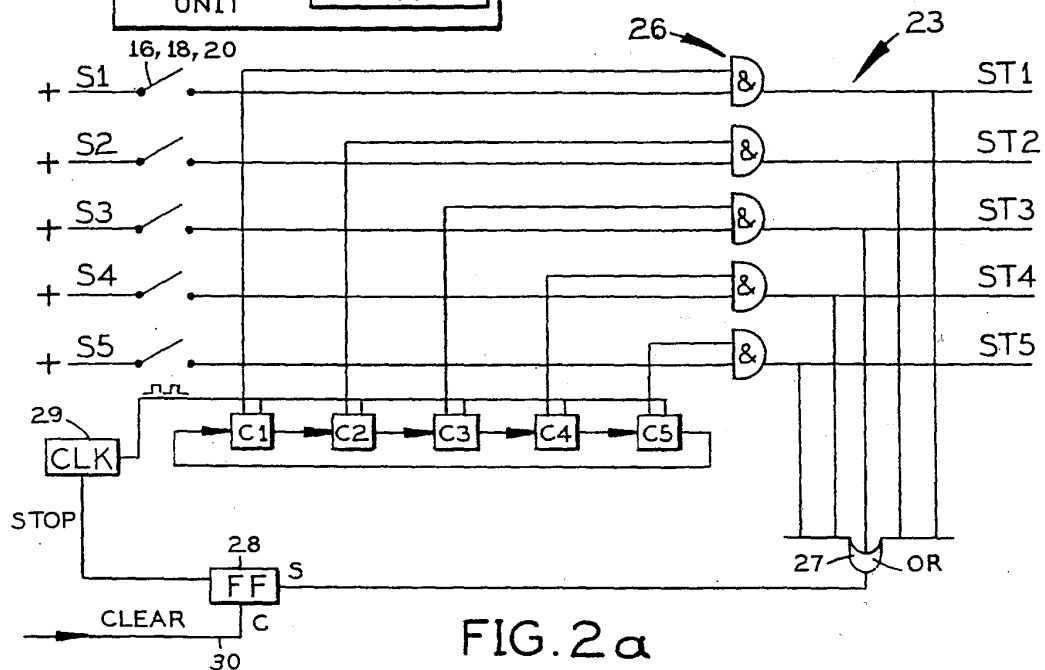


FIG. 2a

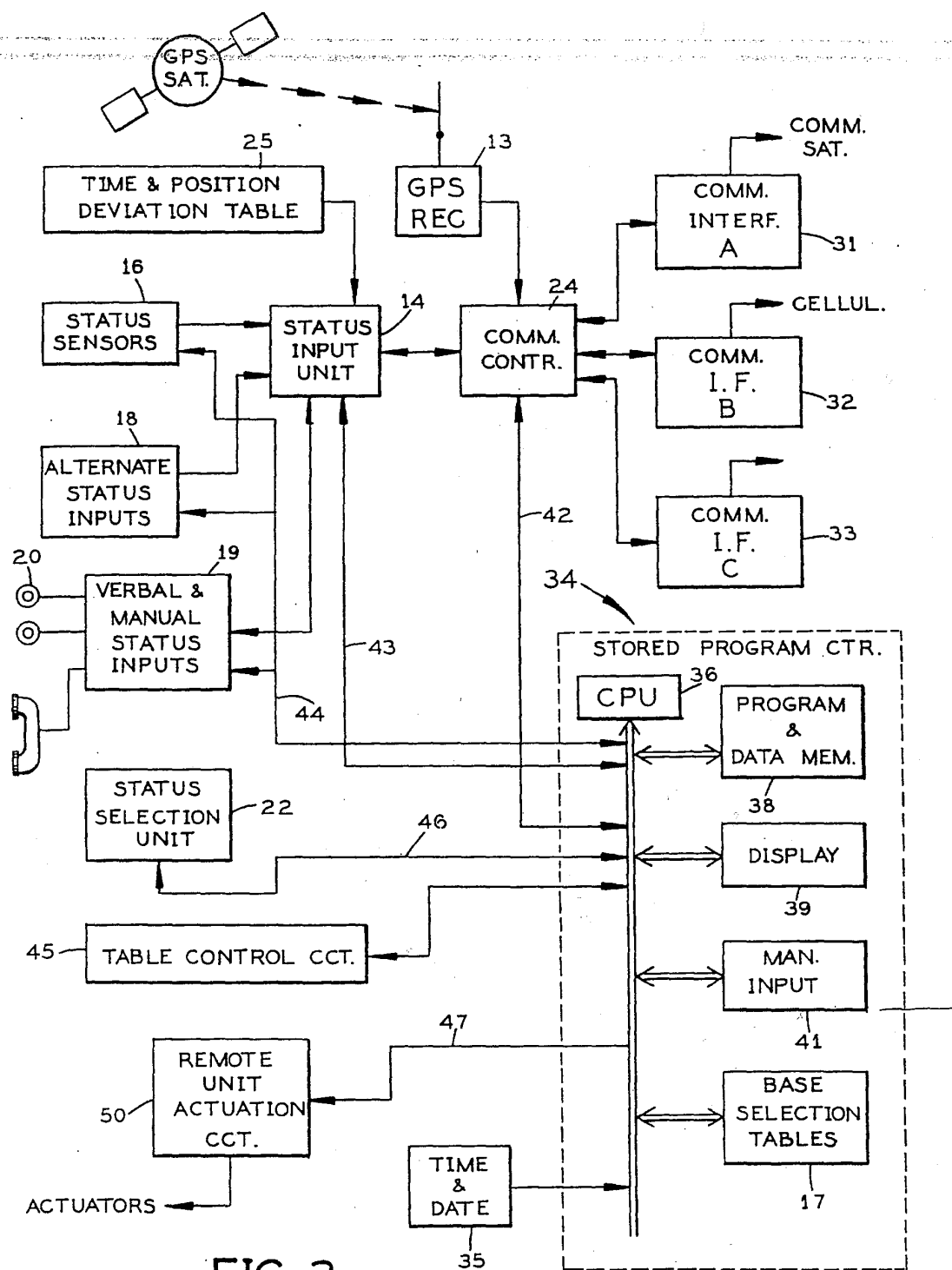


FIG. 3

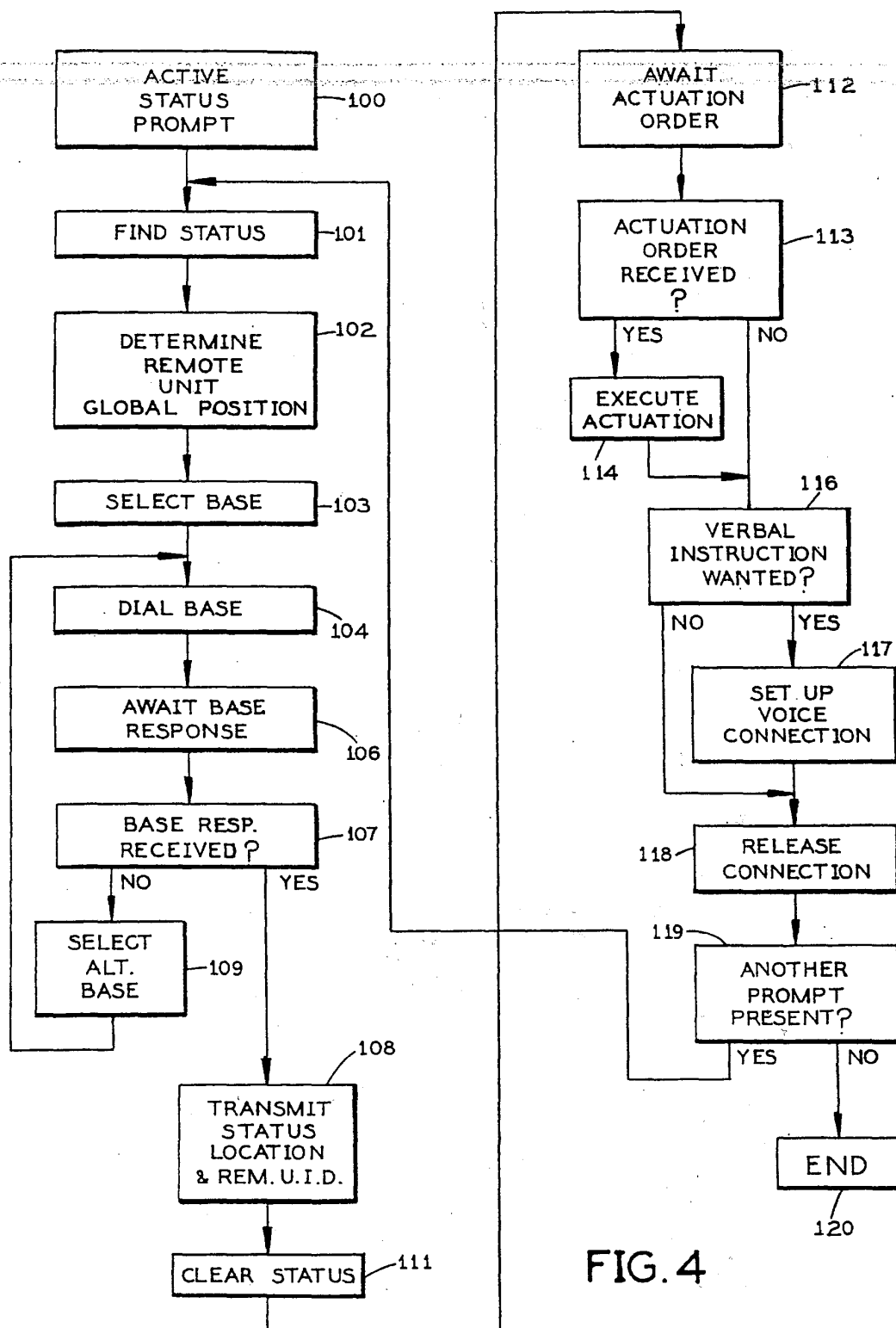


FIG. 4

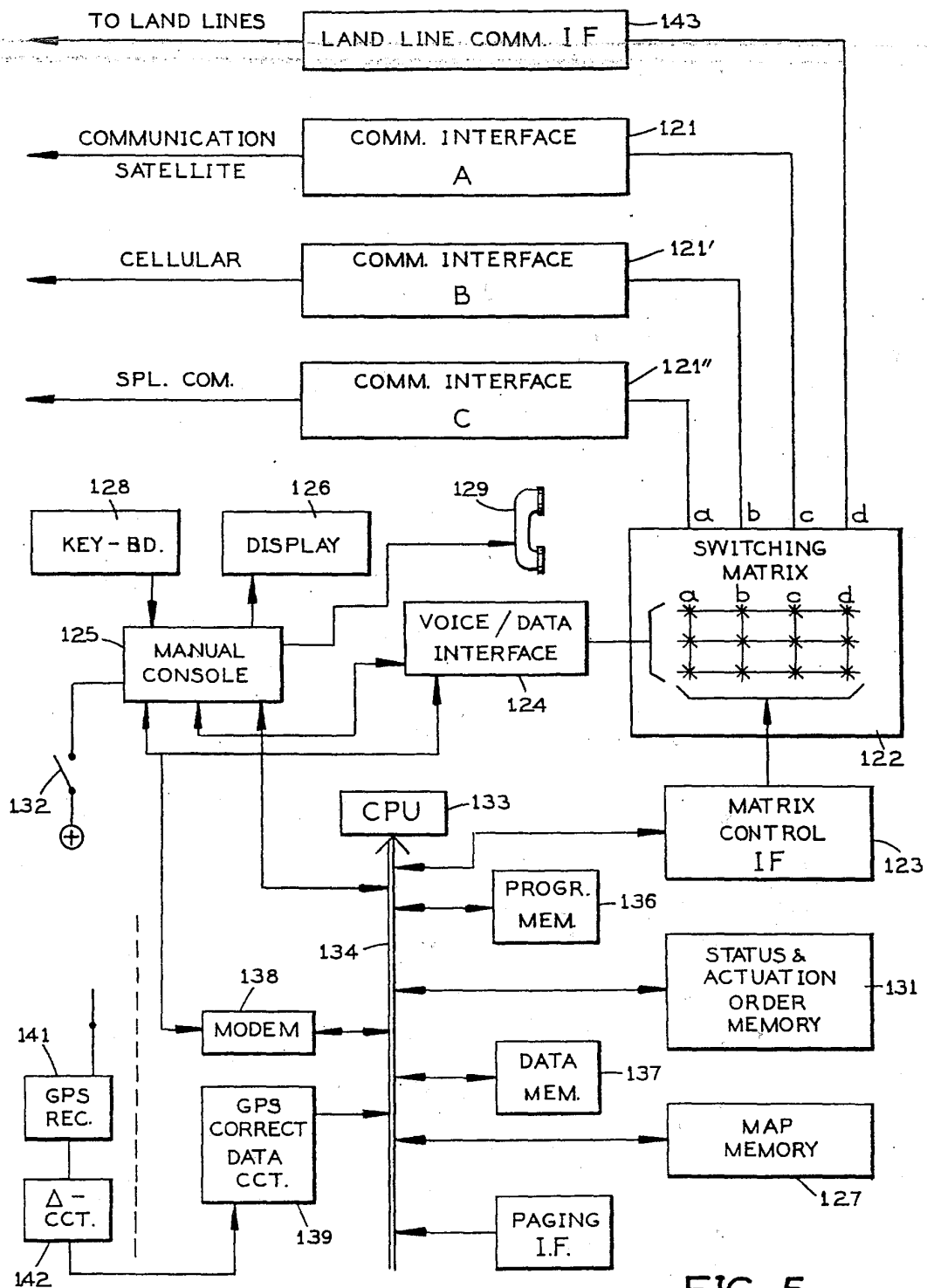


FIG. 5

GLOBAL STATUS AND POSITION REPORTING SYSTEM

The invention relates to a global status and position reporting system for enabling a roving or semi-stationary system, in the following called "remote unit", to report to a particular base station, in response to locally or globally generated prompts, its status and position in the form of a prearranged status and position code or in the form of a verbal status report.

BACKGROUND AND PRIOR ART

In numerous operations involving at least one remote unit, that are not bound to a single fixed position, there is often a need for means for reporting on a global basis the status of a remote unit, and its global location at the moment of reporting. The term "status" as here used may relate to any condition or event at the remote unit such as for example an emergency condition, lack of operability for any reason, or simply a non-problem status.

Various status and position reporting systems are known in the prior art. As an example, U.S. Pat. No. 5,223,844, Mansell et al., shows a vehicle tracking and security system wherein a fleet of vehicles maintain communication via commercial or police radio with a control center, and wherein each vehicle obtains position data from a direct link with global positioning satellites (GPS).

Such a system has the drawbacks that no prearranged provision is made for contacting a particular base that is best suited to handle an emergency, considering the type of emergency and the global position. U.S. Pat. No. 5,225,842, Brown et al., shows a vehicle tracking system for reporting very precise vehicle positions using a position correction system, with its corrections received via a communication link. This system has the further drawback that no reporting facility is provided for reporting combined status and position information. U.S. Pat. No. 5,043,736, Darnell et al., shows a cellular position locating system, wherein a remote unit maintains a record of its global position by means of a GPS receiver in the remote unit. The remote unit also maintains communication with a base unit via a cellular radio link and a modem in the remote unit.

Although the prior art shows various versions of status and position reporting systems, none of the prior art is arranged to automatically select a particular base station based on combined status and position information, so that any type of event, emergency or particular status that may occur at the remote unit can be automatically reported to a particular base equipped to respond to the event, status or emergency.

SUMMARY OF THE INVENTION

It is accordingly an object of the invention to provide a global status and position reporting system that overcomes the drawbacks of the known systems of this general type, and provides further capabilities not known in the prior art.

The invention provides, briefly stated, a capability for a remote unit to report at any time any status of the remote unit, such as an emergency, mechanical breakdown, criminal attack, as well as less urgent states or events, to one or a selected one of several base units, and it has in particular the capability of selecting a base station best equipped and best located to provide assistance based on combined status and location information. A status to be reported may for example also be a no change in status, or a change in

position beyond a certain limit, or no change in position. The remote unit may for example be an attachment to be worn by a person in cases wherein it is important to know if the person has moved beyond the limits of a certain area or track, or if the person has not moved beyond a certain limit. Such reporting would have significance for example in cases wherein a person is travelling or located in a wilderness and inadvertently strays from the predetermined path. The invention further provides the capability of selecting a communication facility such as satellite communication, cellular communication, special mobile radio communication or combination thereof, as may be available in different localities, on the basis of the location information obtained from "the GPS system."

The system provides further features and capabilities, including exchange of verbal information, as described in more detail in the following part of the summary.

The invention provides a global status and position reporting system for a remote unit having a status and position transmit/receive unit with at least one status and/or event input connected to a respective status and/or event sensor for reporting at least one system status and/or event and position of the remote unit, and a status output connected to a communication interface; at least one base unit adapted for receiving a status and position report, disposed at a position spaced away from the remote unit; position independent communications means including communications interfaces respectively disposed in the remote unit and in the base unit for transmitting a status and position report from the remote unit to the base unit upon receipt of an activating prompt from the status sensor or a prompt initiated at the base unit. A global positioning satellite receiver is provided in the remote unit for receiving global positioning information from a system of global positioning satellites having a position output connected to the communications means for entering position information upon receiving the activating prompt.

According to a further feature of the invention, the communications means include a cellular communication interface for transmitting the status and position information via a cellular communications network, and/or a communication satellite interface for transmitting the status and position information via a communications satellite system.

In the global status and reporting system according to the invention, the communications means may further include a special communications interface for transmitting the status and position information via a special radio link.

According to still another feature of the invention, the status input unit may have a plurality of inputs connected to respective status sensors for receiving at least an equal plurality of states and/or events at the remote unit, and a status interpretation unit for interpreting the relative degree of urgency caused by each of the states and/or events.

The remote unit may additionally include a verbal status input of the status input unit for verbally entering a status and/or events.

The global status and position reporting system can additionally include a global position satellite position correction unit connected to the base unit or to the remote unit for receiving a position correction from a position correction facility.

The global position reporting system according to the invention advantageously further includes a communication controller having an input connected to the status and position unit and at least one output connected to at least one of the cellular communication interface, the communication

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necting the base units with the remote unit. This arrangement may have significant utility in case a remote unit is found to be roaming within a range served by different base units 6,6' having different transmission facilities according to communications interfaces 31,32,33, and/or wherein the base units have different capabilities for rendering assistance to the remote unit in accordance with the pending status. For example, the remote unit may be a motor vehicle, a truck, a sea-going vessel, or an aircraft that may operate within ranges served by, for example, a transmission facility in the form of cellular radio, or mobile radio as used by e.g. government entities, or single sideband radio as used by seagoing vessels. Depending on the location and/or the type of status, the base selection tables insure that a status report is transmitted only to base stations that are operative at the time and possess the capability to render the required assistance, and/or have an interest in receiving the particular status report.

The status sensors could accordingly be e.g. switches that automatically report various types of inoperability or danger to the mission of the remote unit. The switches could also be manually operated switches. The status input unit 14 may uniquely encode each status being reported by a status sensor 16 into a status code that is presented to the status tables 17 together with position information from the GPS receiver 13. The status tables provide a first choice for a base station selection, or, if applicable, one of several alternate bases if a first selected base is incapable of rendering assistance or is inoperative. It follows that a remote unit identification code may simultaneously be transmitted, and also that time and date information at the base may be included in the base selection criteria.

FIG. 1a shows a layout of a base selection table, wherein status information and position information are entered as address coordinates, and the base selection is information stored in the selected addresses MC of the tables. Alternate base addresses may be provided if a selected base is not responding when addressed by the remote unit. As an example, five status signals ST1-ST5 are shown as ordinates to the table, and position information is entered as abscissas. The output from the tables stored at the selected coordinate address MC may include a selected base, communication facility, routing information, alternate base and so forth.

FIG. 2 shows a remote unit 1 having additional capabilities to those shown in FIG. 1. An alternate status input circuit 18 provides additional statuses if more than one status may obtain. A manual status input unit 19 may provide statuses from one or more manually operated pushbuttons or keys 20 that are labeled according to a pre-determined status. Verbal status information can be transmitted, once a communication path has been established, by means of a voice transmit-receive handset 21. In case multiple status indications are present, status selection is performed by a status selection unit 22 containing a selection circuit 23 which selects a first arriving or first priority status by means of a priority or first come selection circuit such as, for example, a transfer contact chain or a counting circuit in well-known manner.

FIG. 2a shows an example of a status selection circuit 23 having a counting chain with counting stages C1-C5 driven by a clock CLK 29. Each counting stage C1-C5 operates to select a respective AND-gate 26, each having one input connected to a status switch 16, 18, 20, and another input connected to a respective counting stage. If one status switch 16,18,20 is operated, indicating an active status, the counting chain will stop at the active status due to a stop signal from OR-gate 27 which has an input connected to each AND-gate output and sets a stop-flip-flop 28 which in turn

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stops the clock 29 at the respective AND-gate connected to an active status until the status information has been transmitted to a selected base and responded to, which causes the stop-flip-flop 28 to be cleared via a clear signal CLEAR on lead 30.

A communication control circuit 24 receives position information for the remote unit from GPS receiver 13 and the selected status from status input unit 14. Base selection is performed by the status selection circuit 22 in response to the sequence of arrival, and in accordance with the priority status code S1,S2 . . . S5, and the position information as presented to the base selection table 17 as described above. The communication control 24 activates the selected base via the particular communication interface 31,32,33 as indicated by an output from the base selection table 17, and the status information is transmitted via the selected communication interface 31,32,33 to the selected base unit 6,6'.

Each communications interface 31,32,33 provides the particular transmission protocol required for each transmission facility. In case different routing information is required for reaching different bases on the same communication facility, this routing information is also provided by the base selection tables 17 as part of the information stored at the selected address MC in the table.

In FIG. 2 the respective communication interfaces 31,32,33 further include the radio transmitters and receivers required for communicating with the available communications facilities, e.g. a communications satellite, or a cellular network, or a special communications radio system as shown for the respective interfaces A,B and C. It follows that additional or fewer interfaces may be provided as may be available and/or necessary depending upon the particular mission of the remote unit 1.

FIG. 3 shows a remote unit wherein controls for the status reporting system are provided by means of a stored program control 34, which includes a central processing unit (CPU) 36, having a data bus 37 connected to a program and data memory 38, a display unit 39, a manual input 41 and the base selection table 17 stored in memory, e.g. as part of the program and data memory 38. The display 39 may in the simplest case be one or a few light indicators or, in more complex cases, a display panel with an alpha-numeric display for visually indicating status and operating conditions for the remote unit. The manual input 41 may include power on/off switch, the manual status switches 20 and any other manual input as required for operation of the system.

FIG. 3 further shows a time and position deviation table 25 which stores anticipated locations combined with respective times for the remote unit. The time and position deviation table 25 is advantageously arranged such that the anticipated position coordinates, e.g. longitude and latitudes of the remote unit, are entered into the table, and each coordinate point of the table contains stored in memory an anticipated time value within which the remote unit is anticipated to be located. Any deviation in real time from the stored time value will be reported as a reportable status. It follows that a given deviation tolerance is also to be applied to the time deviation before a deviation is reported. The allowable tolerances may be variable stored parameters, or it can be a fixed parameter. Also, any deviation in actual position from an anticipated position stored in the time and position deviation table can be a reportable status. The actual position is known from the GPS receiving unit 13, and actual time, including date, is obtained from a time and date circuit 35 connected to the CPU 36. Also, a given allowable deviation in position can be stored in the time and position deviation table 25.

data interface 124 and the data bus 134, while voice is transmitted between the voice/data interface 124 and the manual console 125 by means of conventional voice transmission circuits, such as hybrids, balance circuits, etc. (not shown).

A conventional remote unit position correction interface 139 can be provided which provides GPS position correction data from a GPS receiver 141 located at a precisely known position, which transmits position corrections via a difference circuit 142 to a GPS correction data circuit 139, which in turn provides the GPS-position correction data to the CPU via data bus 134 for presenting precise location data to the operator display 126.

The switching matrix 122 can advantageously be expanded to include a data and voice connection between the base units to provide access from any or all remote units to any other base unit even if a remote unit may be unable to reach a particular base unit via its available communications interfaces. Such access can be provided, e.g. by means of a landline communications interface 143 connected to a vertical d of switching matrix 122.

I claim:

1. A status and position reporting system comprising at least one movable remote unit, a plurality of bases disposed apart from said remote unit, status determining means and position determining means in said remote unit, status and position reporting means in said remote unit connected to said status determining means and said position determining means for reporting status information and position information pertaining to said remote unit, remote unit communication means in said remote unit connected to said status and position reporting means for communicating said status and position information from said remote unit to said base; and base selection means in said remote unit connected to said status and position reporting means operative for selecting one of said bases in response to data in said status and position information.

2. A status and position reporting system according to claim 1, wherein said position determining means in said remote unit is operative for determining global position data for said remote unit.

3. A status and position reporting system according to claim 2, wherein said base selection means include a base selection table having coordinates for respectively receiving said status information and said position information, said base selection table having storage means for storing addressing information connected to an input of said remote unit communications means for addressing a selected one of said plurality of bases.

4. A status and position reporting system according to claim 3, wherein said addressing information includes identification data for said remote unit.

5. A status and position reporting system according to claim 3, wherein said addressing information includes alternate base selection data for selecting an alternate one of said bases in case a first selected base is unavailable.

6. A status and position reporting system according to claim 2, wherein said position determining means include a global positioning satellite receiver connected to an input of said position determining means.

7. A status and position reporting system according to claim 1, wherein said remote unit communications means include at least one remote unit communications interface disposed in said remote unit, said remote unit communications interface being operative for communicating said status and position information to said base.

8. A status and position reporting system according to

claim 7, wherein said remote unit communications interface includes radio transmit/receive devices being adapted for communication with at least one of a satellite communications system, a cellular radio communications system, and a special radio communications system.

9. A status and position reporting system according to claim 1, wherein said status determining means include a plurality of status sensors, each adapted for reporting a respective remote unit status.

10. A status and position reporting system according to claim 1, wherein said status determining means includes at least one manual switch for manually reporting status information.

11. A status and position reporting system according to claim 1, wherein said status determining means include a voice transmitter/receiver for verbally reporting status information.

12. A status and position reporting system according to claim 1, wherein said status determining means is operative for reporting a plurality of statuses, and status selecting means connected to said status determining means for selecting one of said plurality of statuses.

13. A status and position reporting system according to claim 12, wherein said status selecting means include sequential status selecting means for sequentially selecting one of said statuses.

14. A status and position selecting system according to claim 13, wherein said sequential status selecting means include a counting chain having a plurality of counting stages, an equal plurality of AND-gates each having one input connected to a respective counting stage and another input connected to a respective status sensor, a clock generator for driving said counting chain, an OR-gate having an equal plurality of inputs each connected to a respective AND-gate output and an OR-gate output, a stop-flip-flop having a set input connected to said OR-gate output and a clear input connected to a response lead for clearing said stop-flip-flop upon receiving a response signal from said base.

15. A status and position reporting system according to claim 1, wherein said remote unit includes a stored program control for controlling said status determining means, and said position determining means, said stored program control composed of a central processing unit, a program and data memory connected to said central processing unit, and base selection tables included in said program and data memory.

16. A status and position reporting system according to claim 1, wherein said base includes at least one base communication interface operative for wirelessly communicating with said remote unit communications means, a manual console having an input connected to said base communications interface, and an information display connected to said manual console for visually displaying status information received from said remote unit.

17. A status and position reporting system according to claim 16, wherein said information display is adapted for displaying status and position information from said remote unit.

18. A status and position reporting system according to claim 16, wherein said information display is adapted for displaying remote unit identity information from said remote unit.

19. A status and position reporting system according to claim 16, including a plurality of remote units, further including a switching matrix in said base having a first plurality of matrix inputs, and a second plurality of matrix



United States Patent [19]

Fomukong et al.

[11] Patent Number: 5,918,159

[45] **Date of Patent:** Jun. 29, 1999

- [54] LOCATION REPORTING SATELLITE
PAGING SYSTEM WITH OPTIONAL
BLOCKING OF LOCATION REPORTING

- | | | | |
|-----------|---------|-------------------|------------|
| 5,422,813 | 6/1995 | Schuchman | 455/440 X |
| 5,506,886 | 4/1996 | Maine et al. | 455/12.1 X |
| 5,539,395 | 7/1996 | Buss et al. | 455/38.1 X |
| 5,568,153 | 10/1996 | Beliveau | 342/357 |

- [76] Inventors: **Mundi Fomukong**, 10853 Rose Ave., #49, West Los Angeles, Calif. 90034; **Denzil Chesney**, 57 Ozone Ave., Los Angeles, Calif. 90291

Primary Examiner—Wellington Chin
Assistant Examiner—Philip J. Sobutka

- [21] Appl. No.: 08/905,674

- [22] Filed: Aug. 4, 1997

- [51] **Int. Cl.**⁶ **H04Q 7/12**

- [52] U.S. Cl. 455/38.1; 455/456; 455/12.1;
455/31.3; 340/825.44; 340/825.49; 340/825.54

- [58] **Field of Search** 455/427, 428,
455/432, 433, 434, 440, 456, 457.8, 414,
38.1, 38.2, 38.4, 5, 31.2, 3, 227, 12.1, 13.1,
458, 459, 100; 342/357; 701/213; 340/825.44,
825.49, 825.36, 825.54

- [56]
- References Cited**

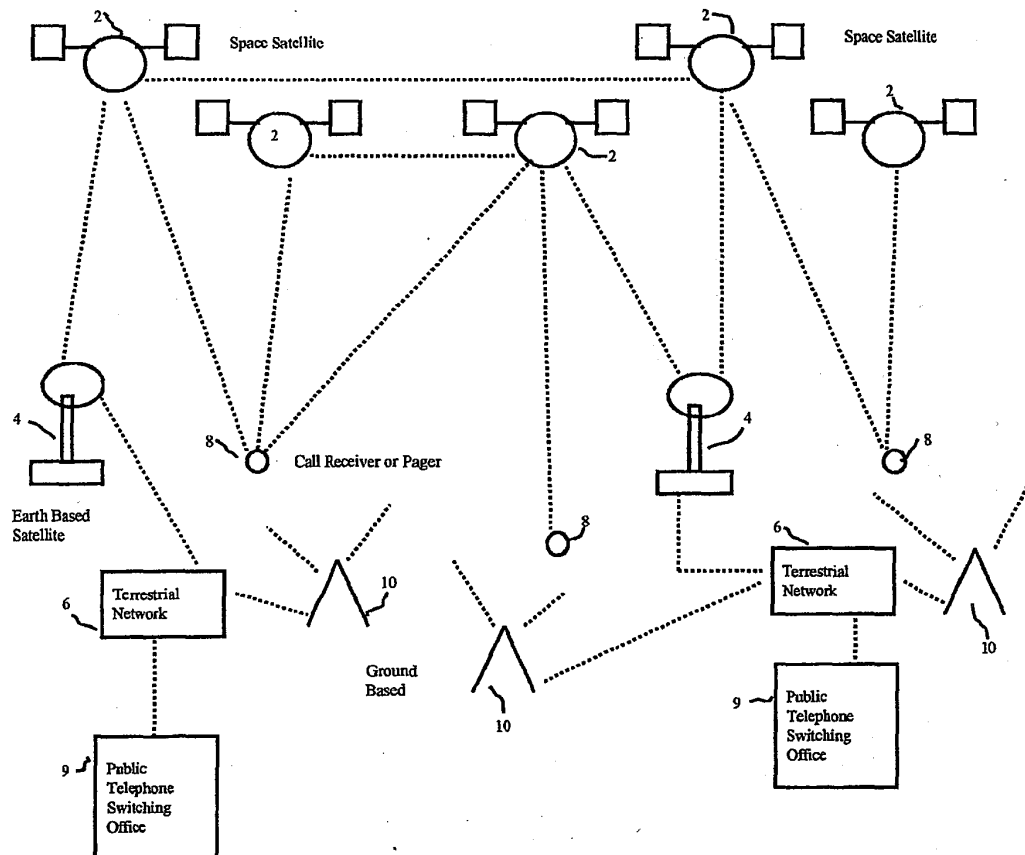
U.S. PATENT DOCUMENTS

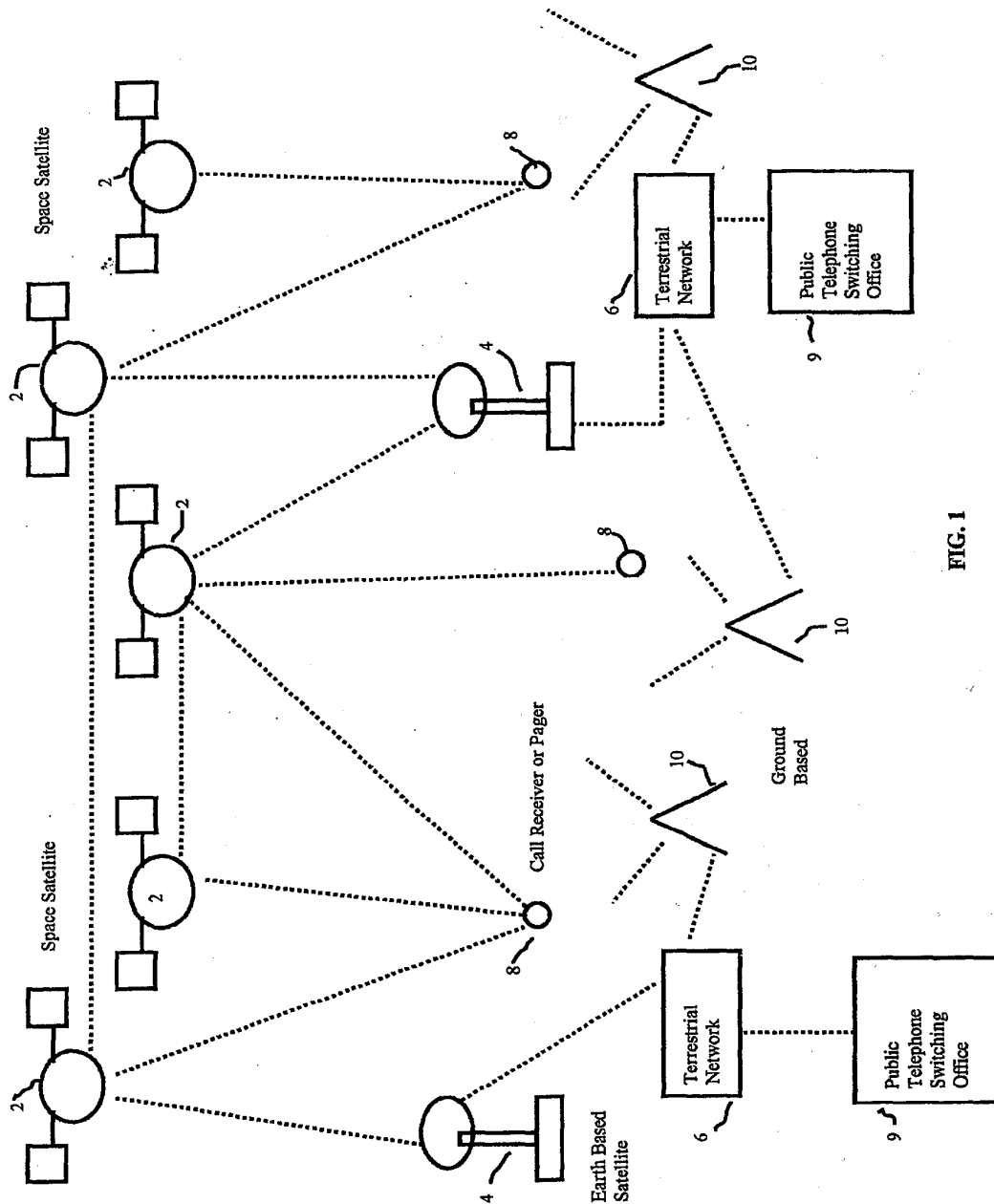
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|-----------|--------|--------------------|------------|
| 5,126,733 | 6/1992 | Sagers et al. | 455/38.1 X |
|-----------|--------|--------------------|------------|

ABSTRACT

A location reporting satellite paging communication system comprising space satellites, ground stations and a call receiver adapted to resolve a global position from signals transmitted from satellites and earth based communication means. The call receiver or callee in possession of the call receiver updates the paging network with a global position as requested by the paging network. A caller paging a subscriber or callee in possession of the call receiver may request the global location of the callee. The paging network could divulge or block such information from a caller depending on the requirements of the subscriber.

14 Claims, 4 Drawing Sheets





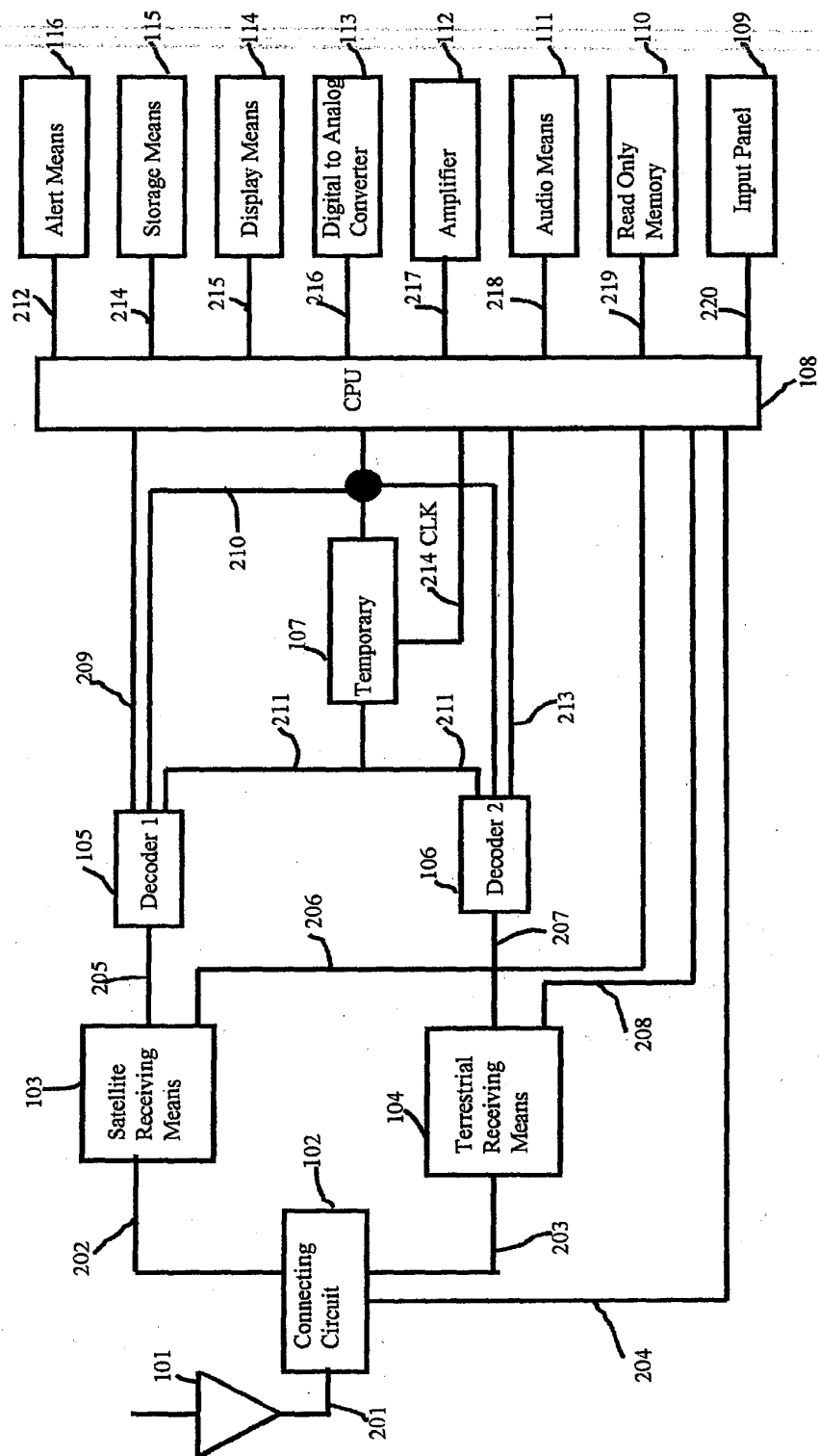


FIG. 2

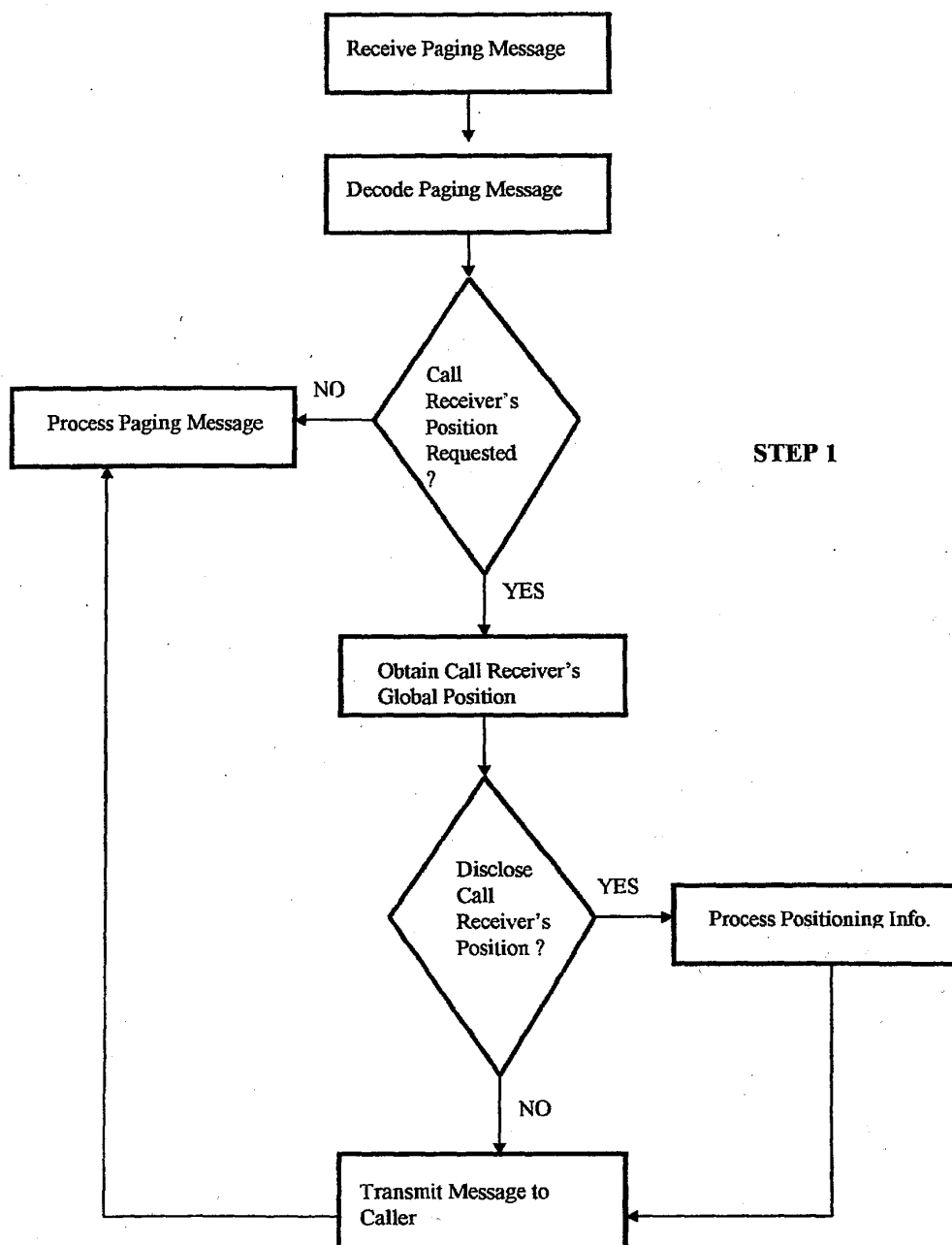


FIG. 3

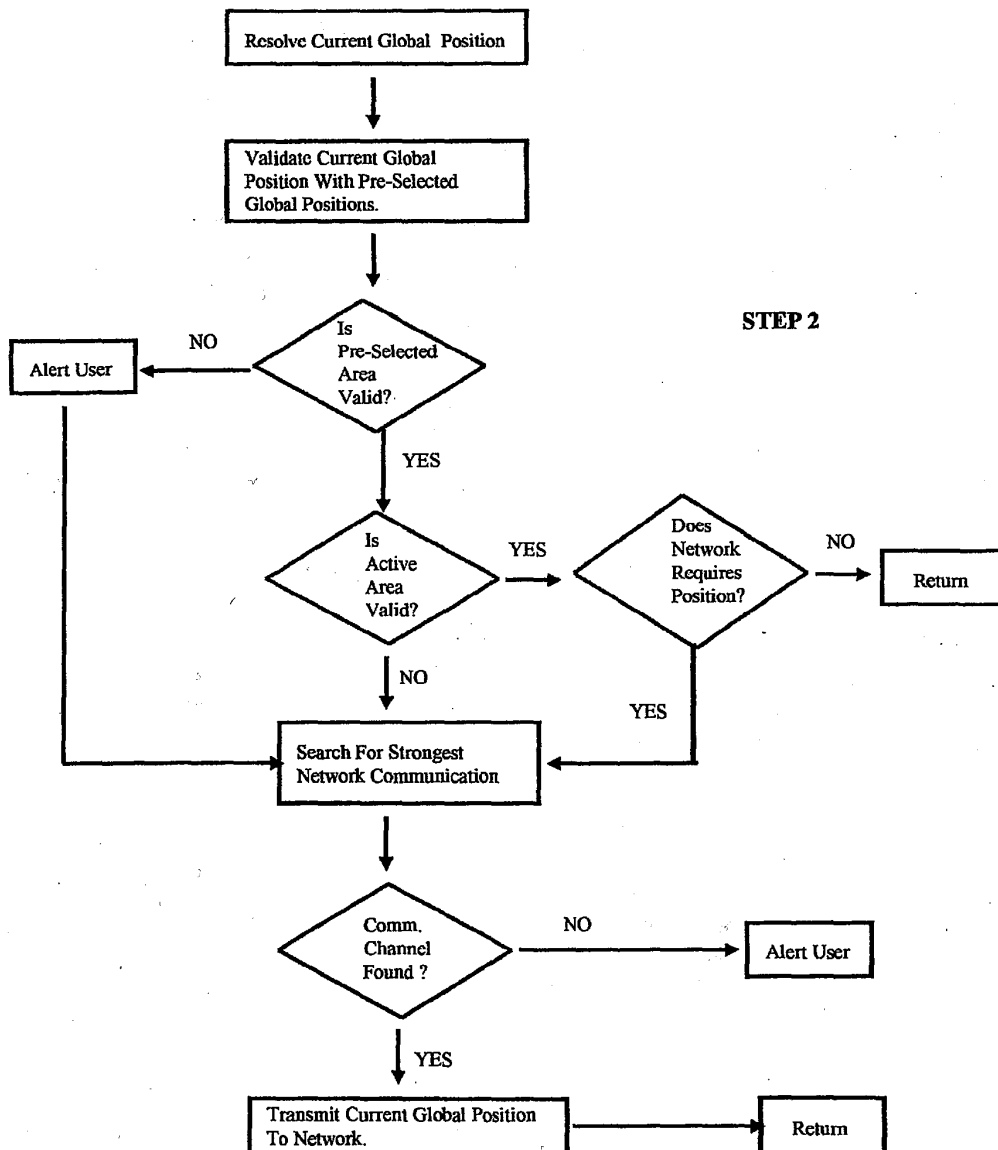


FIG. 4

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LOCATION REPORTING SATELLITE PAGING SYSTEM WITH OPTIONAL BLOCKING OF LOCATION REPORTING

TECHNICAL FIELD OF THE INVENTION

This invention relates to paging telecommunication services and systems, specifically to such services and systems that employ satellites.

BACKGROUND OF THE INVENTION

Today a subscriber to a paging network selects areas where they wish to receive their pages. Each time a subscriber's message is processed by the paging network, the message is transmitted to all the global areas pre-selected by the subscriber to receive pages. However if a subscriber elects to receive pages at any worldwide location, the cost of transmitting a page to the subscriber will be very expensive making this technique highly inefficient. For example, if a caller residing in the same geographical location or neighborhood as a subscriber pages the subscriber, the message will be transmitted globally even though the subscriber and the caller might be a couple of miles apart. Other paging systems have gone a little bit further by allowing a subscriber to periodically update the paging network with their current global position (active area) as the subscriber travels from one location to another. Each time a paging network processes a message for a subscriber, the current global position or active area of the call receiver is validated against the areas pre-selected by the subscriber to receive pages. If the active area is within the subscriber's pre-selected area to receive pages the message is transmitted to the subscriber. As the subscriber travels from city to city or continent to continent, there will clearly be a need to alert the subscriber when they are out of their pre-selected or active paging area. Therefore, the current global active area of the call receiver should be made available to a user or subscriber in possession of the call receiver such that the network could be updated with this information when the need arises. This can only be feasible if the call receiver or pager is equipped with adequate means to resolve its position at any worldwide location.

Today, unlike other mobile telecommunication devices such as cellular telephones, pagers are utilized by a greater cross section of the population since they are relatively inexpensive to acquire. To a family, friend or business, the benefits of such a paging system will be tremendous. Individuals sending paging messages will be able to request from the paging network the global location where the paging message was sent. This will enable a caller to know the worldwide location of a callee or subscriber in possession of the call receiver each time a paging message is sent. To the network provider, the cost of transmitting a message to a subscriber will be reduced as pages will be targeted to specific global areas rather than using the conventional blind paging technique. A subscriber in possession of the call receiver will have the ability to obtain continuing global positioning information whenever necessary. A subscriber may allow callers sending a message to obtain positioning information from the network that will reveal the global position or location of the call receiver in certain instances while blocking such information from being divulged to callers in other instances. In an emergency situation the paging network could provide information regarding the global location of a distressed subscriber in possession of the call receiver.

SUMMARY OF THE INVENTION

This invention will provide a call receiver or pager with means to receive, store, and replay voice and alphanumeric

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messages transmitted from satellites and earth based communication means.

This invention will provide a call receiver with means to resolve a global position (latitude, longitude) from signals transmitted from satellites and earth based communication means.

This invention will provide an effective means to allow a subscriber to prevent their global position from being divulged to a caller or callers at certain instances, while allowing such information to be divulged at other instances.

This invention will provide a means to alert a user in possession of the call receiver or pager each time they are out of their pre-selected or current active paging area.

This invention will provide an efficient means to update the paging network, the current global position of the call receiver.

This invention will provide an efficient means for a call receiver, to concurrently process positioning and paging messages transmitted from satellites and earth based communication means.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 shows the global satellite paging network in accordance with the present invention.

FIG. 2 shows a block diagram of the call receiver or pager in accordance with the present invention.

FIG. 3 shows a flow chart illustrating the operation of a paging network control station each time a caller request for the global position of a call receiver.

FIG. 4 is a flow chart illustrating the operation of a call receiver when a global position is resolved in an attempt to determine if the call receiver is out of their paging area.

THE PRESENT SYSTEM

The present system will consist of satellites in space [2], communicating with earth based stations [4] and the call receiver or pager [8]. Ground based transmitters [10] will be employed to transmit pages to the call receiver [8]. Terrestrial network control stations [6], will be employed to effectively control the activities of the entire global paging network. The system will be developed such that a call receiver or pager operating under an existing paging systems will work.

Upon subscribing to a paging network a subscriber selects global areas (pre-selected paging areas) where they wish to receive paging messages. The pre-selected areas, pager ID, paging protocol and other relevant information of the call receiver are stored in the data library of a paging control station [6] for all pagers utilizing the paging network. A call receiver [8], will periodically resolve a global position from signals transmitted from satellites and earth based communication means. The resolved global position will be periodically utilized to update the network each time a user is out of their paging area or each time the paging network requests a call receiver to disclose their global position. This will enable the paging network to know the exact global location of a call receiver whenever the need arises. Messages received for a call receiver are processed by the network and transmitted to the global or active area of the call receiver.

To initiate a page, a caller may use any regular communication device such as a telephone to access the paging network. The caller may add specific codes to a paging message to enable the paging network to disclose the call

receiver's global position after the message is transmitted. The caller's message is firstly processed by the local telephone-switching office [9] before transmission to the paging control station [6]. The paging control station [6] will be employed to control all the activities of the network. Upon receiving a paging message, a paging control station decodes the message for relevant information such as pager ID and determines if a caller requires the global position of the pager. Other relevant information such as the paging protocol of the call receiver, pre-selected or preferred worldwide areas to receive pages and the current active area of the call receiver are retrieved from the paging control station's data library. The paging control station [6] validates the current active area of the call receiver with the call receiver's pre-selected areas to receive pages. If the call receiver's current active area is valid and within a pre-defined time interval the message is transmitted to the call receiver. If the current active area is invalid (call receiver is out of pre-selected paging area) the message is not transmitted to the callee and the caller is notified. In instances where the current active area of the call receiver is valid but the call receiver has not updated the network with its current position over a pre-defined time period, the paging control station will encode the message such that a request will be placed for the call receiver to update its current active global position. As each subscriber of the paging network can only travel a limited distance by air, land or sea within a pre-defined time interval; the paging network, based upon when a call receiver last updated their global location will select appropriate earth based stations and space satellites to transmit the message to the call receiver at specified worldwide locations. The call receiver upon receiving this signal will disclose their global location.

As a user travels from city to city or country to country, the call receiver will periodically resolve a global position from signals transmitted from satellites and earth based communication means. This information will be utilized by the call receiver or user in possession of the call receiver to update the current active area held by the paging network for that call receiver. Also, the call receiver will store this information in its memory such that future resolved global positions could be validated against this information to ensure that the active area currently held and utilized by the paging network to transmit pages to the call receiver is not outdated.

Once a control station determines where a message will be sent, the control station determines the best possible way to transmit the message. With a knowledge of the geographical distribution of all earth based satellite transmitters [4], ground base transmitter stations [10] and space satellites [2], the paging control station [6] will encode a message such that the sequence of transmission of the message will be included. The ID of all the ground stations or space satellites that will be employed in the message transmission chain will be encoded in a chronological order and the message will be routed to the first ground station. This station could be an earth station that transmits directly to satellite [4], or a ground based transmitter [10]. For example, after a paging control station encodes a message and determines which stations (earth or satellite) should transmit the message, the message is routed to the first earth station. The first earth station could either transmit the message directly to satellite or beam the message to their coverage area. Subsequent stations that receive the message decode the message and determine if other stations are required to transmit the message. If other stations are required to transmit the message the current station re-encodes the message so as to

eliminate itself from the message transmission chain before retransmitting the message to the next station. By re-encoding the message an earth station or satellite station will prevent subsequent stations involved in the message transmission chain to retransmit the message back to that station. If an earth station or satellite determines it is required to broadcast a message, the message is beamed to the area covered by that station. The transmission chain continues until the last station broadcasts the message and acknowledges with a status signal which is sent back to the paging control station. Upon receiving this signal, the ground control station can alert the caller that the message was successfully sent. Therefore, with a knowledge of the geographical distribution of the paging network's earth and satellite transmitters, and a knowledge of the current active area of a call receiver, a ground control paging station could effectively encode a caller's message to include all satellite and earth based stations that will be employed in the message transmission chain. This will eventually minimize the risk of a satellite or earth based transmitter from being overloaded.

Once a paging control station [6] receives a message from a caller, the control station determines if the caller requested the global position of the call receiver. The control station then verifies from its data library if the positioning disclosure feature for that call receiver or pager has not been blocked by the subscriber. Each call receiver will have a special code whereby if identified in a caller's paging information, will allow the paging control station to disclose the call receiver's global position. If such a code is not detected in a caller's message and the caller requested the global location of a callee in possession of the call receiver, the caller will be immediately notified that their request was not authorized by the subscriber or callee. A subscriber may change their positioning disclosure code at anytime and reveal such information only to individuals who could acquire information regarding their global whereabouts from the paging network. The paging network will only override the users request and disclose a subscribers global position only in an emergency circumstance.

If the positioning disclosure feature is blocked for any call, a message is sent to the caller indicating that the subscriber does not wish their current global position disclosed. If the positioning disclosure feature is active, the control station retrieves the coordinates of the call receiver's global position and encodes that information before transmission to the caller. Such information may describe the latitude and longitude of the subscriber including a more simplified information such as the country, city or town where the message was sent. The steps carried out by the control station during this process are best illustrated in step 1, FIG. 3. In this illustration, the paging control station upon receiving a paging message decodes the message and checks if the message includes a request for the call receiver's global position. If such information is not required the message is processed normally. If the call receiver's global position is required and the positioning disclosure code is detected, the call receiver's positioning information is retrieved from the data bank of the paging control station. If the information retrieved from the paging control station's databank is unavailable or out of date, a request could be made that the call receiver's disclose its current position. If the control station establishes that the positioning disclosure feature is blocked for that message, the caller is immediately notified with the appropriate message. If the call receiver's positioning disclosure feature for the message in process is active, the positioning information of the call receiver is processed

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and transmitted to the caller and the caller's message is processed for dispatch to the call receiver as previously disclosed.

For global positioning, the call receiver will be pre-programmed to periodically resolve a position from signals transmitted from satellites and earth based communication means. Some of the satellites and earth based transmitters used to transmit paging information could be employed to transmit referenced positioning signals to the call receivers. Alternatively the Global Positioning System well known in the art as GPS could also be utilized by the call receiver to resolve a global position. However the call receiver should have a means to resolve a global position from L-band signals transmitted from at least one satellite, depending on the resolving technique employed. GPS is currently being used to provide worldwide positioning information to mobile users around the globe. Such positioning information has an accuracy of about one hundred meters and could further be improved to an accuracy of five meters if referenced signals from ground based transmitters are utilized in the resolving process. A fully operational Global Positioning System includes up to 24 satellites dispersed around six circular orbits. The dispersion and inclination of the satellites is such that at least three or more satellites are readily visible from most parts on the earth surface. In a typical example, for a call receiver to resolve a global position, the call receiver need to solve for two variables of position, latitude and longitude. The satellites, equipped with atomic clocks act as a beacon and transmit signals that tell the call receiver where it is and what time the signal was sent. From this information, a call receiver can determine how far it is from the satellite by comparing the time sent with the time received and multiplying by the speed of light (distance=velocity * time). Since there is a bias between the GPS time and the user's time, a third variable time will be required. Having three satellites in view at any point in time, a call receiver will be able to solve for latitude, longitude and time. For three dimensional positioning a fourth variable and satellite will be required. Upon resolving a global position the call receiver or pager could update the network with its present global location or the call receiver could alert a user when they are out of their active or preselected global areas to receive pages.

THE CALL RECEIVER OR PAGER

The call receiver (FIG. 2) will receive messages transmitted from satellites and terrestrial based transmitters through the transceiver [101]. The connecting circuitry [102] of the call receiver, controlled by the CPU [108], will route satellite based signals via 202 to the satellite receiving means [103] and terrestrial based signals via 203 to the terrestrial receiving means [104]. The connecting circuitry may include a filter arrangement and a switch that will allow L-band or satellite frequencies to pass via 202 and terrestrial or Ultra High Frequencies to pass via 203. This signals could either be paging message signals or global positioning signals. Therefore depending on the pre-loaded protocols and initialization data, the CPU will drive the connecting circuitry [102], satellite receiving means [103], terrestrial receiving means [104] to scan and process specific frequencies.

Satellite signals are processed by the satellite receiving means [103]. This unit will process global positioning satellite signals and satellite message signals. The satellite receiving unit will include satellite signal amplifiers, mixers and filters that will convert the L band global positioning and message signals received from the connecting circuit [102]

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to an appropriate level for efficient processing by the decoding circuit [105]. The satellite receiving means circuitry is well known by any one well skilled in the art. The operation of this unit is controlled by the microprocessor or CPU [108] via 206.

The CPU determines the appropriate intermediate frequencies and output signals that will be generated by the satellite receiving unit [103]. This is based on the initialization parameters pre-loaded in the ROM [110] of the call receiver. The CPU controls the satellite receiving unit via 206, and the output signals produced by the satellite receiving unit [103] are routed via 205 to the decoder [105] for intelligence extraction and error correction. Decoder [105] is controlled by the CPU [108] via 209. Transmission of data directly by Decoder [105] or Decoder [106] to the CPU input port via 210 is determined by the CPU. If the CPU determines satellite messages are of high priority Decoder [165] is signaled via 209 to transmit data directly to the CPU via 210 and Decoder [106] is signaled via 213 to temporary hold its data. Decoder [106] will store its data in the Temporary Store [107] via 211 for later retrieval by the CPU. If terrestrial based signals are of a higher priority Decoder [105] is signaled to temporary hold its data. Again each decoder could be equipped with a store eliminating the use of the Temporary Store [107]. If a decoder is not equipped with storage means, the decoder could download its data via 211 to the temporary data storage while the other decoder will transmit directly to the CPU via 210. If multiple decoders are required to decode multiple satellite and earth based signals (message and positioning signals), the CPU could again determine when each decoder should transmit its data to the CPU's input port, with each decoder equipped with the appropriate storage means to temporarily hold its data until such transmit instruction is received from the CPU.

Terrestrial based signals will be processed by the terrestrial receiving means [104]. This UHF or VHF signals will be routed by the connecting circuitry [102] via 203 to the terrestrial receiver [104]. Again, the terrestrial receiving unit will include Ultra High Frequency (UHF) or Very High Frequency (VHF) amplifiers, filters and down converting circuitry to process the signal from 203 to an appropriate level for efficient processing by decoder [106]. Direct transmission of data from decoder 2 [106] to the CPU via 210 will be controlled by the CPU. The operation of this part of the receiver will be similar to the satellite receiving end. Therefore, the CPU [108] will control the operation of the connecting circuitry, the satellite and terrestrial receiving means. The CPU [108] will have the ability to determine exactly when a satellite or terrestrial message or positioning signal is received and processed.

Once the CPU completes processing data from a decoder [106,107], the CPU retrieves data from the temporary data storage [107] for processing. As previously stated multiple decoders could be employed. In this situation each decoder will have the ability to store or hold its data temporarily or use the temporary storage [107] until signaled by the CPU to transmit data directly via 210. Relevant communication links will be added to interface the newly added decoders to the CPU [108], satellite receiving unit [103], and the terrestrial receiving unit [104]. With this technique all message and positioning signals transmitted from either satellite or earth based communication means will be eventually decoded and processed by the CPU, with rarely any message being lost or corrupted in this process.

To conserve receiver power, the CPU could be pre-programmed so as to control the connecting circuitry [102],

the satellite receiving module [103], and the terrestrial receiving module [104], to process positioning signals periodically. In this situation only paging messages (voice and alphanumeric) will be allowed to pass, while positioning information signals will be periodically blocked. If a paging message received requires the call receiver to disclose its current global location, the CPU [108] upon detecting this request will allow the call receiver to resolve a global position from satellite and earth based referenced signals before resuming operation normally.

If a decoded message received by the CPU via 210 is voice or alphanumeric, the CPU alerts the user either through the display [114], alert means [116] or audio means [111] as to the presence of a new message. Alphanumeric messages are displayed through the display, while voice messages are routed to the digital to analog (D/A) converter [113], so that they are converted to their analog format by the D/A converter. The analog signal is amplified by the amplifier [112], and the amplified signal is used to drive the audio means [111] (speaker or earphone). The memory means [115] is used to store messages for future replay by the user. These messages are first compressed by the CPU before storage in memory. Prior to replay or redisplay the messages are decompressed.

Once a user subscribes to the global paging network, the call receiver is initialized. Relevant data such as the paging protocols, frequencies, preferred paging locations and other relevant data are down loaded into the ROM [110] of the call receiver. As the user travels from one global location to another, this information will be used by the CPU to control the actions of all modules of the call receiver.

A call receiver will have the ability to resolve a global position from signals transmitted from satellites and earth based communication means. Periodically, the call receiver will resolve a global position from these signals and compare it to reference encoded global position coordinates pre-loaded in its ROM [110]. If the CPU [108] establishes that the current global position of the call receiver is not within the user's preferred location to receive pages, the user is immediately alerted that they are out of their paging area and no paging messages will be received. If the call receiver's current active area to receive pages is not within the previously stored active areas, the user is alerted to update the paging network with their current active area. The network may also request the call receiver for its current global position. If such a message is received the callee or user in possession of the call receiver is notified that an update of the network is required. The call receiver will scan for the strongest network communicating channel via transceiver [101]. If such a link is established, the call receiver will automatically update the network with its current global positioning coordinates. In circumstances where the call receiver does not find a suitable network channel for direct communication, the call receiver will alert the user that no RF communicating channel was found for automatic update of its current global position. In this situation a user could update the network by calling in and disclosing their current global coordinates resolved by the call receiver. If the user is required to update the network, the call receiver will periodically alert the user to update the network until an input is received from the user through input panel [109] via 220 indicating that the action has taken place. The CPU [108] will store in its memory the current resolved global position of the call receiver as the current active area of the call receiver held by the paging network. This will enable the CPU to determine when an active area update of the paging network is required without waiting for the network to

request for such information. The actions undertaken by the call receiver during this processes are best illustrated in Step 2; FIG. 4. In this illustration, the call receiver first resolves a global position. Such a request might have been initiated from the user through input panel [109], the paging network or from within the call receiver's CPU. Upon resolving a global position, the call receiver validates this position with the pre-selected areas to receive pages usually stored in the ROM. If the pre-selected areas are valid, the call receiver further checks if its current active area to receive pages is valid. If the call receiver's current active area to receive pages is valid, the CPU checks if the paging network requires the current global coordinates of the pager. If the network does not require the call receiver to update its position, the call receiver resumes operation normally. If the current active area of the call receiver is invalid or the pre-selected area to receive pages is invalid or the network had requested for the call receiver's global location, the call receiver searches for the strongest network communication channel to transmit its current global position. If such a channel is found the network is automatically updated. If no such channel is found the user is alerted to update the network with the current global coordinates resolved by the call receiver.

At any point in time a subscriber could use the call receiver or any relevant terrestrial communication device to activate or deactivate their positioning disclosure feature from the network. In the deactivated mode the network will not disclose a subscriber's global location to a caller requesting that information. A user may override the periodic global positioning resolving feature of the call receiver to obtain a current global position through the input panel [109] at any time. Once the CPU [108] resolves and makes this information available to the user, the terrestrial receiving means [104], satellite receiving means [103] and the connecting circuit [102] will be signaled to resume operation normally. With the aid of the input panel [109] and the display [114] relevant information such as current active paging area, pre-selected areas, and the call receiver's current global position will always be made available to a user such that an update of the paging network could be done by a user in possession of the call receiver at any point in time and at any global location without a request from the network.

We claim:

1. A satellite paging communication system with means to locate the global position of a of a call receiver unit comprising:

space satellites and terrestrial stations, some of which are adapted for the purpose of transmitting paging information and some of which, are adapted for the purpose of transmitting positioning information;

ground control stations for processing the said information and controlling the actions of the paging network;

the call receiver or pager having means to resolve a global position from satellites or earth based communication means;

the system divulging to certain or all callers the global location of a callee in possession of the said call receiver while blocking such information from being divulged to certain or all other callers.

2. the ground control station of claim 1 with means to determine upon receipt of a callers message that the caller requires the global location of a callee in possession of the call receiver according to claim 1 and the said ground control station having further means to establish that a callee requires their global location disclosed.

3. The message information provided by a caller to the ground control station according to claim 2 wherein the said message comprises specific information that the said ground control station could determine that the global position of a callee in possession of the said call receiver is required.

4. The message information transmitted to a caller by the ground control station according to claim 2 comprising specific information that will describe the global location of a callee or comprising specific information that may indicate to the caller that a callee does not require their global location disclosed.

5. The ground control station of claim 1 with means to determine and request a call receiver of the paging network to disclose a global location when such information is required by the paging network.

6. The message of the ground control station of claim 5 comprising specific information that will enable a call receiver of the paging system according to claim 1 initiate the disclosure of a global position upon receipt of the said message.

7. The technique employed by the paging system of claim 1 to transmit paging information to a callee in possession of the call receiver of claim 1 comprising:

employing ground control stations to arrange or prepare a call receiver's message to include all satellites and earth based stations that will be utilized to transmit the message to the said call receiver and routing the message to the first ground transmitter;

employing the said satellites and earth stations involved in the message transmission chain to either beam the message to their coverage area or re-encode the message to eliminate the said station from the message transmission chain before redirecting the message to a subsequent satellite or earth station involved in the message transmission chain.

8. The call receiver according to claim 1 comprising:

connecting means to connect satellite signals to the satellite receiving end and terrestrial signals to the terrestrial receiving end;

satellite receiving means for receiving and processing satellite positioning and message signals and terrestrial receiving means for receiving and processing terrestrial positioning and message signals;

temporary storage means to hold either data from the satellite or terrestrial receiving circuitry while the other is being processed;

relevant means to resolve a global position from data received from either the satellite or terrestrial receiving ends.

9. The technique employed by the call receiver according to claim 8 to concurrently process satellite and terrestrial based message and positioning signals wherein either the satellite or terrestrial processing end could temporarily store their data while the other is being processed, until an appropriate time when such an action is reversed.

10. The technique employed by the call receiver of claim 8 to either block the processing of satellite or terrestrial signals while allowing such information to be processed at a later time.

11. The call receiver according to claim 8 with means to activate or deactivate the positioning disclosure feature from the paging network by transmitting specific information to the paging network that will enable the blocking of none, certain or all users to the global location of the call receiver.

12. The call receiver according to claim 8 with means to alert a user or paging network each time the said call receiver is out of its preferred or active area to receive pages and comprising the steps of:

resolving a global position from referenced satellite and earth based signals;

validating the said resolved global position with pre-selected or active areas to receive pages stored within the memory means of the said call receiver;

alerting a user each time a pre selected or active area is invalid;

updating the paging network with the resolved global position of the call receiver.

13. The information transmitted to the paging network of claim 1 by either the call receiver of claim 1 or a callee in possession of the said call receiver which contains specific information that will enable the paging network to divulge or block the global location of the said call receiver from certain or all callers.

14. The technique employed by the said call receiver of claim 1 to enable a callee in possession of the said call receiver disclose a global position when a suitable communication channel is unavailable for the said call receiver to disclose such information wherein the said call receiver periodically alerts the said callee with distinct tones until relevant information or input is received from either the said callee or paging system that such an action was undertaken.

* * * * *



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
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09/753,178 12/30/00 FOMUKONG

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10853 ROSE AVE, #49
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WM01/1023

EXAMINER

TRIEU, V

ART UNIT

PAPER NUMBER

2632

DATE MAILED:

10/23/01

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

Office Action Summary	Application No.	Applicant(s)	
	09/753,178	FOMUKONG, MUNDI	
	Examiner	Art Unit	
	Van T Trieu	2632	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 30 December 2000.
- 2a) ☐ This action is FINAL. 2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1-19 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☒ Claim(s) 1-19 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
- 11) ☐ The proposed drawing correction filed on _____ is: a) ☐ approved b) ☐ disapproved by the Examiner.
If approved, corrected drawings are required in reply to this Office action.
- 12) ☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. §§ 119 and 120

- 13) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
* See the attached detailed Office action for a list of the certified copies not received.
- 14) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).
a) ☐ The translation of the foreign language provisional application has been received.
- 15) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Attachment(s)

- | | |
|--|---|
| 1) ☒ Notice of References Cited (PTO-892) | 4) ☐ Interview Summary (PTO-413) Paper No(s). _____ |
| 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | 5) ☐ Notice of Informal Patent Application (PTO-152) |
| 3) ☒ Information Disclosure Statement(s) (PTO-1449) Paper No(s) <u>2</u> . | 6) ☐ Other: |

DETAILED ACTION

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

1. Claims 1-15 and 17-19 are rejected under 35 U.S.C. 102(b) as being anticipated by **Schipper** [US 5,669,061].

Regarding claim 1, the claimed obtaining the location of the remote unit (the central mobile cellular telephone switching office/network MCTSO 30 obtains the geographic boundary of the mobile cellular 11 as SATPS receiver/processor 15 of that cellular 11 receives the present location of the mobile cellular 11 in a vehicle from the SATPS 21, 23, 25 and 27, see Fig. 1 and step 51 of Fig. 4, col. 6, lines 10-43, col. 7, lines 13-39, col. 9, lines 50-63 and col. 10, lines 49-56); and the obtaining at the network geographic boundary information within the location of the remote unit (the MCTSO 30 obtains the electronic map network of the region R including the geographic boundary of the mobile cellular 11 presently located at cellzone CZ1 and the nearby cellzones CZ2, CZ3, etc. in the region R directly or indirectly from the SATPS receive/processor 15 of the mobile cellular 11, see Fig. 1 and step 53 of Fig. 4, col. 6, lines 10-43, col. 7, lines 39-46, col. 50-63, col. 5-10 and col. 10, lines 52-60); and the determining whether the remote unit is within the geographic boundary (see steps 55-63 of Fig. 4, col. 11, lines

1-43); and the forwarding the location of the remote unit to the network upon determination that the remote unit is within the geographic boundary (if the mobile cellular 11 is still within the cellzone CZ1 then the MCTSO 30 sends a notification to the cellular caller or to notify the vehicle owner about the present location of the missing vehicle, see col. 6, lines 40-47 and col. 12, lines 54-60).

Regarding claim 2, all the claimed subject matter are cited in respect to claim 1 above, and the obtaining radii and calculating the angle of inclination (see Figs. 4 and 5, col. 14, lines 15-22 and col. 15, lines 32-65).

Regarding claim 3, all the claimed subject matter are cited in respect to claim 1 above.

Regarding claim 4, all the claimed subject matter are cited in respect to claim 1 above.

Regarding claim 5, all the claimed subject matters are cited in respect to claim 1 above, and the re-defining at least a geographic region in the prescribed geographic boundary (the MCTSO 30 re-defines of the first electronic map with a second electronic map, a new cellzone with the changing of boundary or a set of alternate boundary of the cellzone, see Figs. 2-4, col. 10, lines 61-65, col. 13, lines 35-67 and col. 14, lines 1-14.

Regarding claim 6, all the claimed subject matters are cited in respect to claim 1 above.

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Regarding claim 7, all the claimed subject matters are cited in respect to claim 1 above, and the at least a second communication unit able to request for the location of the first communication unit present within a geographic boundary prescribed by the at least second communication (the telephone caller or the vehicle owner requests for the location of the mobile cellular 11 or the subscriber, see col. 6, lines 40-48, col. 10, lines 5-26 and col. 12, lines 54-64).

Regarding claim 8, all the claimed subject matters are cited in respect to claim 7 above.

Regarding claim 9, all the claimed subject matters are cited in respect to claims 1 and 7 above.

Regarding claim 10, all the claimed subject matters are cited in respect to claim 9 above, such as the distances and time intervals, see Figs. 2-6.

Regarding claim 11, all the claimed subject matters are cited in respect to claims 9 and 10 above.

Regarding claim 12, all the claimed subject matters are cited in respect to claims 1 and 7 above.

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Regarding claim 13, all the claimed subject matters are cited in respect to claim 12 above, such as tracking of unauthorized moving vehicle.

Regarding claim 14, all the claimed subject matters are cited in respect to claim 1 above, the global position (GPS 21, 23, 25 and 27, see Fig. 1).

Regarding claim 15, all the claimed subject matters are cited in respect to claim 14 above, such as the theft vehicle is prohibited at the undesired geographic location.

Regarding claim 17, all the claimed subject matters are cited in respect to claims 1 and 7 above.

Regarding claim 18, all the claimed subject matters are cited in respect to claim 17 above.

Regarding claim 19, all the claimed subject matters are cited in respect to claim 17 above.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the

invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

2. Claim 16 is rejected under 35 U.S.C. 103(a) as being unpatentable over **Schipper** [US 5,669,061] in view of **Rubin et al** [US 6,108,365].

Regarding claim 16, **Schipper** fails to disclose the means to provide its velocity to the network and having means to further determine its velocity within the network's prescribed velocity before divulging its location to the network. However, **Schipper** teaches that the GPS transmits information from which an observer's present location and/or the time of observation can be determined to the mobile cellular GPS receiver/processor 11 and/or the central MCTSO 30. The signal from the satellite is binary phase shift key (BPSK) modulated by two pseudo-random noise PRN codes designated as P-codes and C/A codes, see Fig. 1, col. 14, lines 15-67 and col. 15, lines 1-65. **Rubin et al** discloses the transmitters of the GPS satellites send 50 bit per second data superimposed on their output signals which are called Gold codes. The data is decoded at the central access control 10 or GPS receiver/processor 16 to using known techniques to determine the precise position and velocity (vector) information and then transmits the position information to the user/subscriber via transmission medium. The correction data for the expected velocity of propagation is also decoded in known fashion, see 1, 14, 15 and 17, col. 8, lines 38-67 and col. 9, lines 1-43. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to implement the techniques to determine the position and velocity information of **Rubin et al** to the GPS receive/processor of **Schipper** in order to provide

a higher accuracy of the location of monitored object or individual since that techniques is very well known in the art.

Conclusion

3. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

King et al discloses a method and apparatus for location determination of a mobile station in a fixed communication system having at least one base station reduces the computational load on the mobile station. The satellite position data are conveyed to the mobile station. [US 6,211,819]

Eschenbach et al discloses a method and apparatus for monitoring the present location of a person to be confined to a designed site. The present location or change location of the person is determined and compared with the permitted site location coordinates at a sequence of selected times. [US 6,181,253]

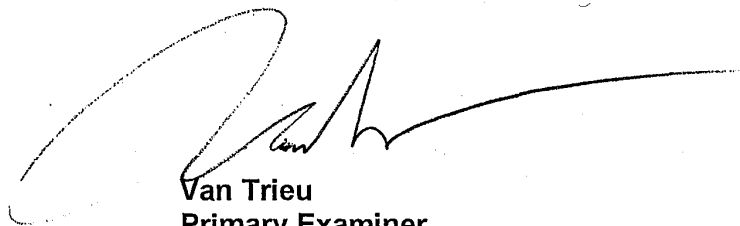
Linguist et al discloses an adaptive cellular paging system operable to receive separate message that is distinct from other cells/regions. [US 5,517,690]

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to primary examiner **Van Trieu** whose telephone number is (703) 308-5220. The examiner can normally be reached on Mon-Fri from 7:00 AM to 4:00 PM.

Art Unit: 2632

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Mr. **Jeffery Hofsass** can be reached on (703) 305-4717.

The office facsimile number is (703) 872-9314.

A handwritten signature in black ink, appearing to read 'Van Trieu', with a large, sweeping flourish extending to the right.

Van Trieu
Primary Examiner
Date: 10/19/01

Notice of Reference Cited

Application/Control No.

09/753,178

Applicant(s)/Patent Under
Reexamination
FOMUKONG, MUNDI

Examiner

Van T Trieu

Art Unit

2632

Page 1 of 1

U.S. PATENT DOCUMENTS

*	Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification	
A	US-5,669,061	09-1997	J. F. Schipper	455	429
B	US-6,108,365	08-2000	P. A. Rubin, et al	340	5.2
C	US-6,211,819	04-2001	T. M. King, et al	342	357.09
D	US-6,181,253	01-2001	R. F. Eschenbach, et al	340	573.1
E	US-5,517,690	05-1996	R. D. Linquist, et al	340	7.27
F	US-				
G	US-				
H	US-				
I	US-				
J	US-				
K	US-				
L	US-				
M	US-				

FOREIGN PATENT DOCUMENTS

*	Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification	
N						
O						
P						
Q						
R						
S						
T						

NON-PATENT DOCUMENTS

*	Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)				
U					
V					
W					
X					

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.



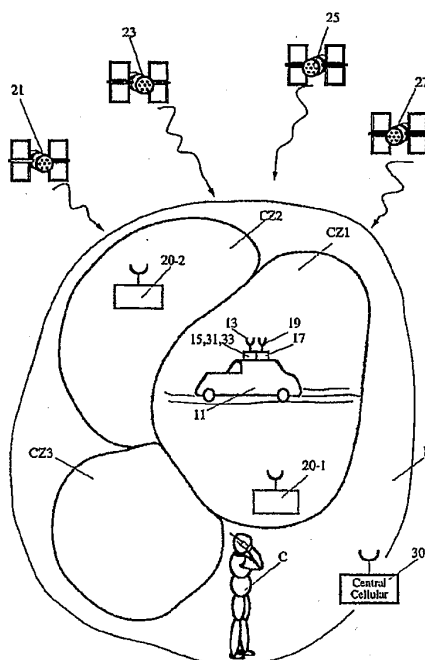
US005669061A

United States Patent [19]
Schipper[11] **Patent Number:** **5,669,061**
[45] **Date of Patent:** **Sep. 16, 1997**[54] **AUTOMATIC CELLULAR PHONE TRACKING**[75] **Inventor:** John F. Schipper, Palo Alto, Calif.[73] **Assignee:** Trimble Navigation Limited,
Sunnyvale, Calif.[21] **Appl. No.:** 292,856[22] **Filed:** Aug. 19, 1994[51] **Int. Cl.⁶** H04Q 7/22[52] **U.S. Cl.** 455/429; 455/440; 342/357[58] **Field of Search** 455/33.1, 33.2,
455/33.3, 33.4, 53.1, 54.1, 54.2, 56.1, 70;
379/59, 60; 342/457, 357[56] **References Cited****U.S. PATENT DOCUMENTS**

5,055,851	10/1991	Sheffer	455/54.1 X
5,208,756	5/1993	Song	455/54.1 X
5,214,789	5/1993	George	455/33.2
5,235,633	8/1993	Dennison et al.	455/33.2 X
5,390,339	2/1995	Bruckert et al.	455/33.2
5,396,540	3/1995	Gooch	379/59
5,396,647	3/1995	Thompson et al.	455/33.2
5,418,537	5/1995	Bird	342/357
5,483,664	1/1996	Moritz et al.	455/33.2 X
5,546,445	8/1996	Dennison et al.	379/60

Primary Examiner—Reinhard J. Hisenzopf*Assistant Examiner*—Philip J. Sobutka*Attorney, Agent, or Firm*—John Schipper[57] **ABSTRACT**

A system for tracking the location of, and for providing cellular telephone handoff for, a mobile cellphone user as the cellphone user moves from one cellzone to another. A boundary curve B12 between a first cellzone and an adjacent second cellzone is defined in an electronic map by an equation $h_{B12}(x,y,z)-K12=0$ for points with spatial location coordinates (x,y,z) lying on the curve B12, where K12 is a selected constant. First and second quasi-boundary curves QB1 and QB2, lying within the first and second cellzones, respectively, are defined, where each point on the curve QB_i ($i=1,2$) lies at a selected distance d_i from the boundary curve B12. A region CR12 of points lying between the quasi-boundary curves QB1 and QB2 and including the boundary curve B12 is defined. The present location of the cellphone user is determined using a Satellite Positioning System (SATPS) such as GPS or GLONASS. Cellular telephone service for the cellphone user is provided (1) by a first cellular service provider or (2) by a second cellular service provider, when the cellphone user is located (1) within the first cellzone, not including the overlap region CR12, or (2) within the second cellzone, not including the overlap region CR12. When the cellphone user enters the region CR12 from within the first cellzone and proceeds toward the boundary curve B12, the system carried by the cellphone user notifies at least one of the first and second cellular service providers that the cellphone user is about to leave the first cellzone and about to enter the second cellzone. The system may be extended (1) to determine the approximate location of a missing vehicle and (2) to dynamically change the boundary curves of at least one cellzone to relieve cellular service overloading that occurs within that cellzone.

22 Claims, 6 Drawing Sheets

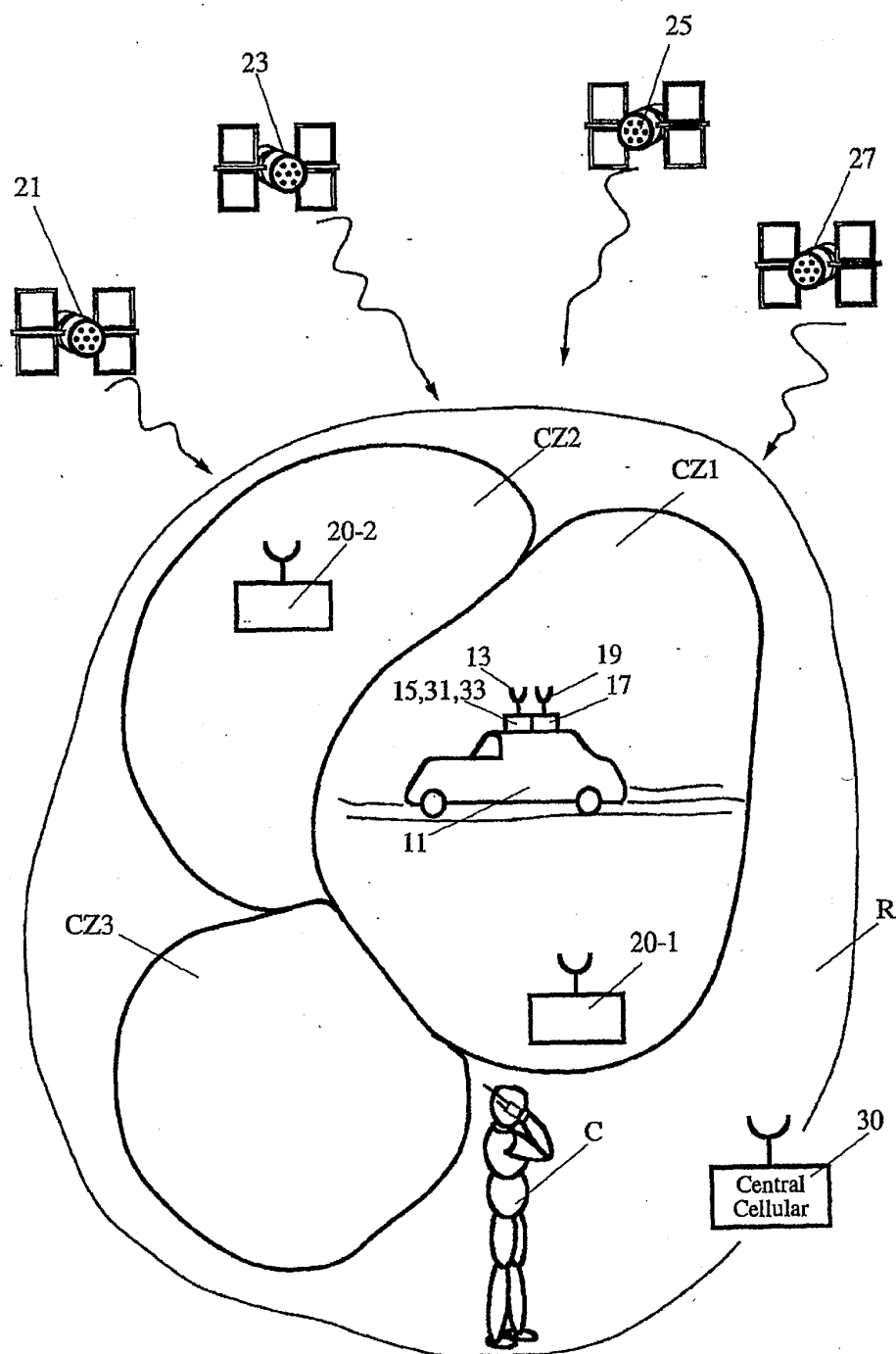


FIG. 1

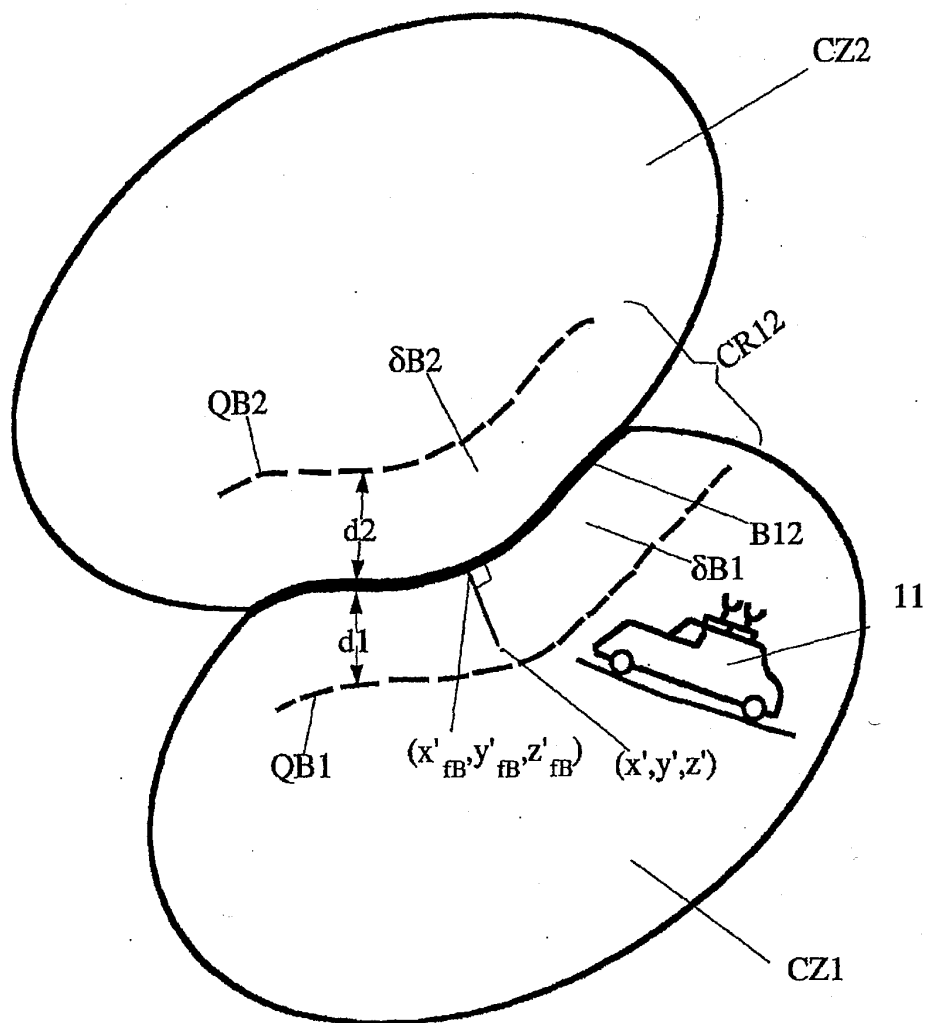


FIG. 2

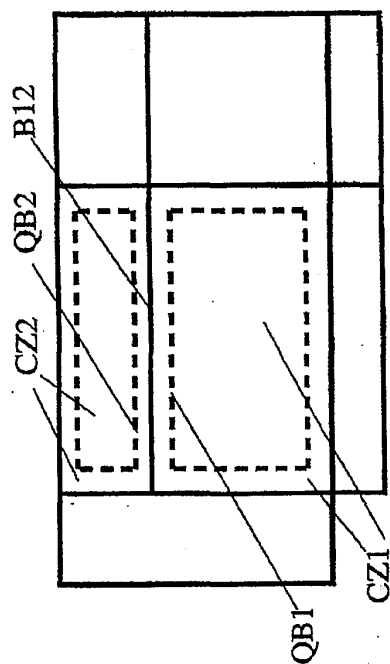


FIG. 3B

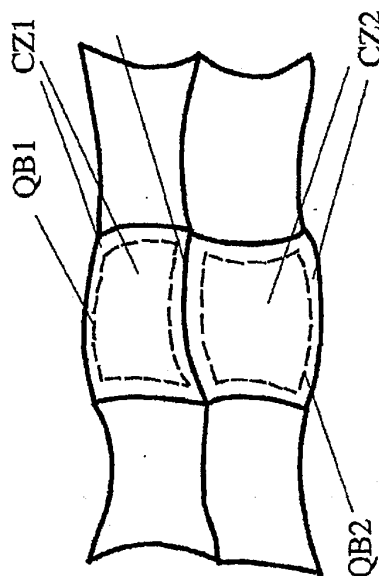


FIG. 3D

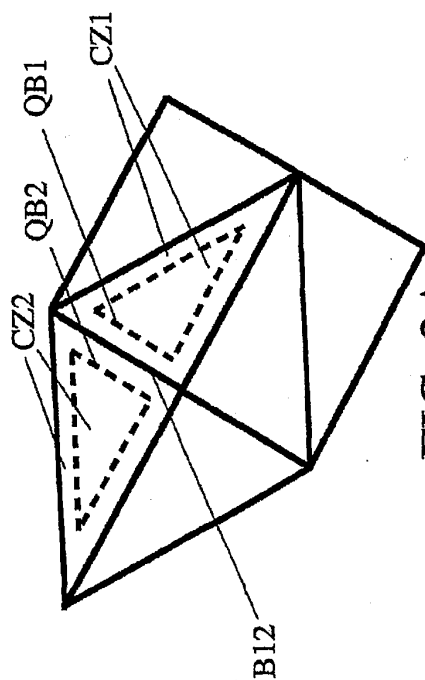


FIG. 3A

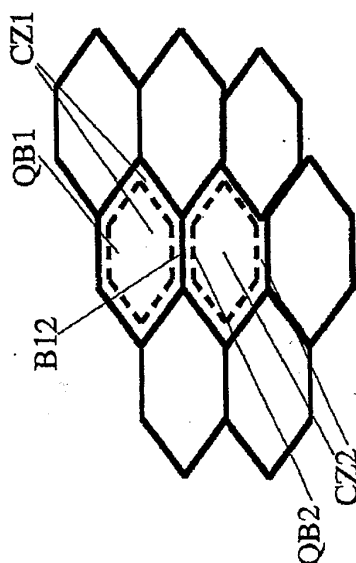


FIG. 3C

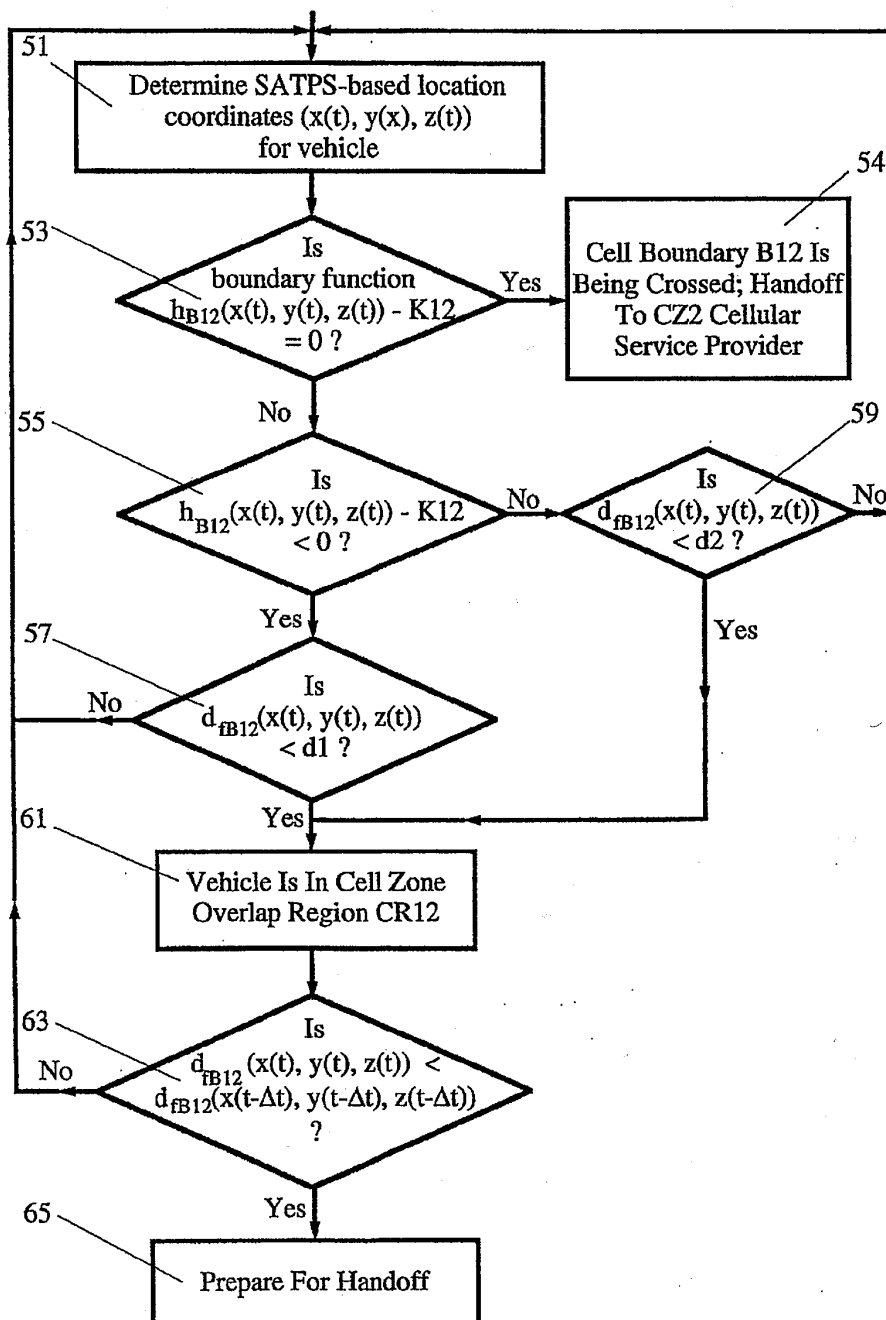


FIG. 4

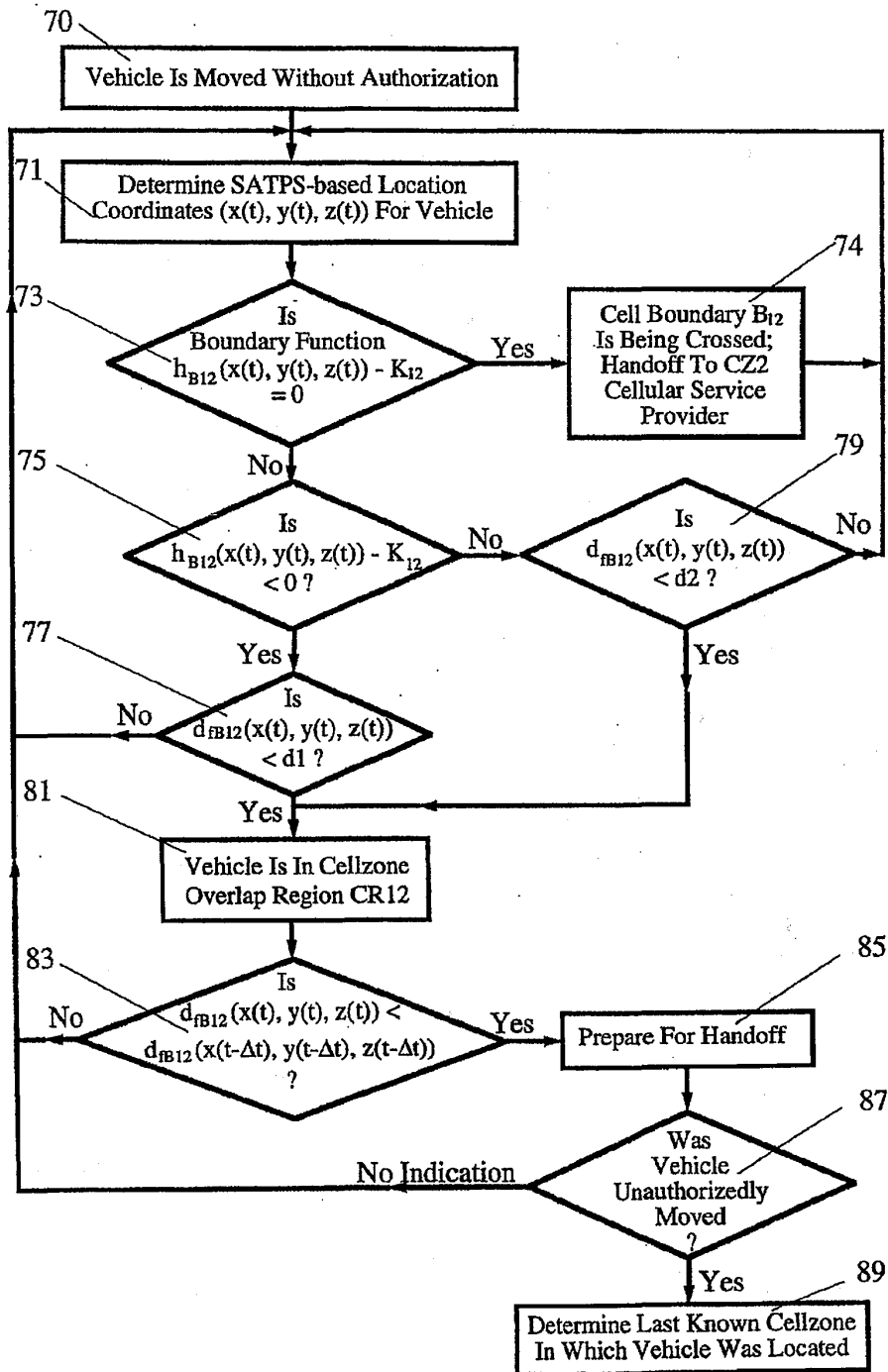


FIG. 5

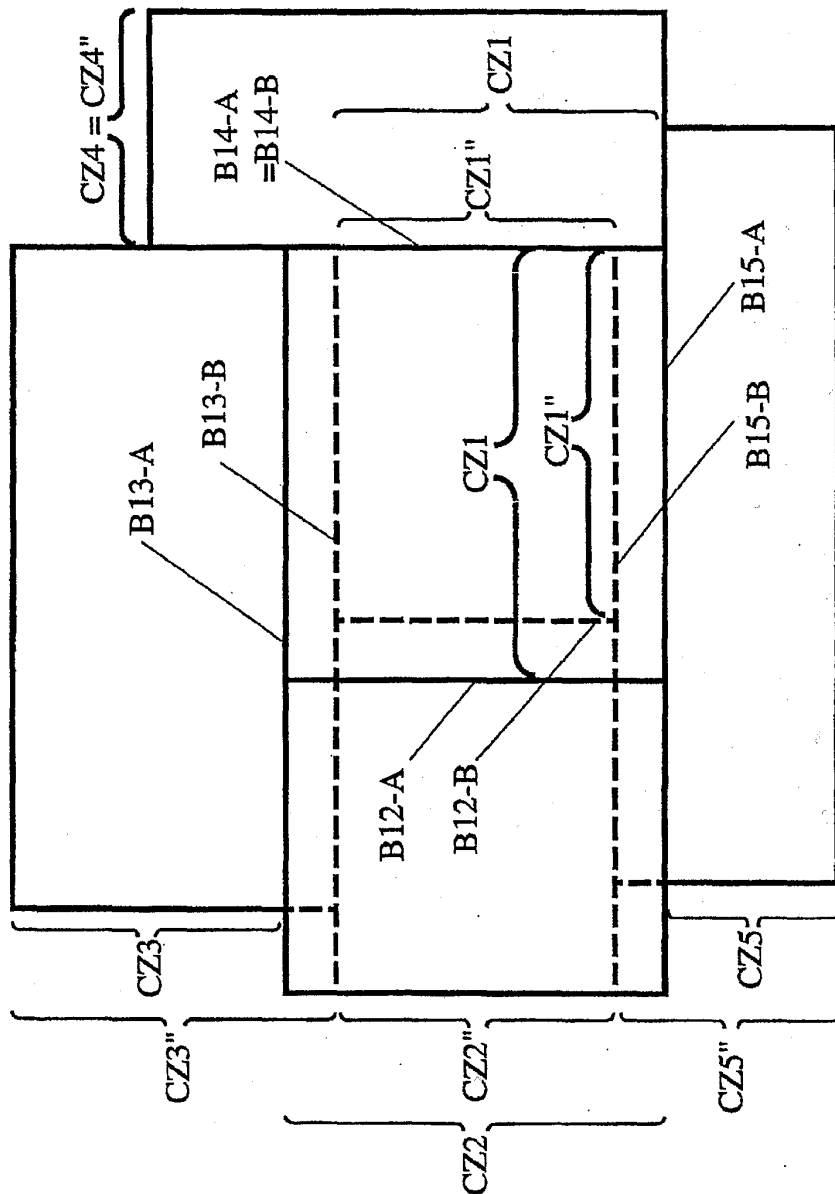


FIG. 6

AUTOMATIC CELLULAR PHONE TRACKING

FIELD OF THE INVENTION

This invention relates to determination of which service zone a roving or mobile cellular phone has entered and automatic transmission of this information to a cellular phone service provider.

BACKGROUND OF THE INVENTION

The number of cellular phone users in the U.S. is now estimated at about 17 million and continues to grow at a rate exceeding 20 percent per year. Most of this growth in use has occurred in and around cities and towns with populations of 20,000 or more and has caused saturation of the channels available for cellular communication in many of these urban areas. Cellular service zones, referred to herein as "cellzones" for convenience, each servicing about 800 cellular telephone communications, have decreased in size from several miles in diameter to a few hundred meters in diameter as the density of cellphone users has increased apace in urban and suburban areas.

A cellphone subscriber will typically register use of a cellphone in a home cellzone and will temporarily re-register in one or more nearby cellzones if the subscriber makes or receives cellphone calls in these other cellzones. However, even where the cellphone subscriber is already registered in one or more nearby cellzones, the operator of any cellzone will typically be unaware of the presence of this subscriber in this cellzone, unless this subscriber has either recently requested cellular service in this zone or has somehow notified the operator that the subscriber is currently present in this zone. Knowledge of the number of cellphone subscribers currently in a given cellzone, who are not all active users of the cellular phone service at any given moment, may allow the service operator to rationally plan its present provision, and future expansion, of cellular service to accommodate the increasing demands.

A personnel locator system is disclosed in U.S. Pat. No. 3,439,320, issued to Ward. Each person carries a sensor/transmitter that emits a unique frequency whenever that person enters any one of a plurality of selected areas in a facility, with each such area having a receiver that receives this signal and transmits this information to a central processor. The processor keeps track of the movements of each person from one selected area to another area so that, at any given time, the processor can identify the selected area a given person now occupies. This approach is limited to a relatively small geographic area and to a relatively small number of covered persons.

Serrano et al disclose a microprocessor-controlled interface for a cellular phone system to be carried in a vehicle, in U.S. Pat. No. 4,718,080. A telephone handset communicates with the cellular transceiver along a bus and through the microprocessor that interprets bus logic signals, including voice and data signals. No integration is disclosed of the on-board cellular system with any instrument that reports vehicle operating information upon command received from a remote site.

U.S. Pat. No. 4,797,671, issued to Toal et al, discloses a motor vehicle locator system that indicates the location of a parked vehicle within a controlled area, such as a large parking lot. Each parked vehicle carries a receiver and audio/visual signal emitter. The receiver responds only to receipt of a signal having a unique frequency and causes the emitter to emit an audible or visually perceptible signal that

indicates the present location of the parked vehicle. This approach requires that the vehicle be located within a controlled area of modest size, probably no larger than a city block.

Ando et al, in U.S. Pat. No. 4,837,700, disclose method and apparatus for processing and displaying the present location of a road vehicle, using a GPS receiver to provide data on vehicle location. This approach provides continuous information on vehicle location and vehicle orientation or vehicle movement vector based upon sensing the Earth's local geomagnetic field direction. An angular rate sensor determines, and optionally displays, the angular rate of change of vehicle orientation, and an odometer determines the distance the vehicle has moved over some predetermined time interval. The present vehicle location can be displayed graphically on an electronic map carried within the vehicle, with a sequence of maps being used to display the changing vehicle location. Map size can also be increased or decreased, and the displayed map can be automatically scrolled as vehicle position changes. A keyboard is available for entering instructions into a controller or processor. A reference location can be entered into the system, and vehicle location can be determined relative to this reference location. The location data can be stored if these data are acceptable and can be dumped into a bit bucket if these data are not acceptable.

In U.S. Pat. No. 4,924,402, Ando et al disclose a more detailed approach for determining and graphically displaying vehicle location using a GPS. This system uses a magnetic field sensor, an angular velocity sensor and a travel distance sensor together with GPS data and stores maps together with numerical data that describe useful features of the local terrain. Sensing of vehicle distance traveled and directional turns made is intended to be sufficiently accurate that the map displays the location of the vehicle relative to road intersections (i.e., approaching, passing through, turning, etc.). With reference to FIGS. 16-17, 22, 27-28 and 30 of the Ando et al patent, the invention appears to put a premium on receiving GPS data that are accurate to within one meter.

A paging system with paging request receivers that respond or are controlled differently, depending upon receiver location, is disclosed by Vrijkorte in U.S. Pat. No. 4,943,803. Using "angle modulation" whose operation is not explained, the paging request receiver is said to pick out the strongest transmission control signal from among simultaneously transmitted control signals and to respond to this signal, if the signal received includes the receiver's predetermined address code. The receiver goes into a "sleeper" mode if no signals specifically addressed to that receiver are received within a selected time interval. The receiver is activated for receiving a control message by receipt of a receiver activation signal that may vary with the geographic zone presently occupied by the receiver.

Nishikawa et al disclose a land vehicle navigation system in U.S. Pat. No. 4,949,268. A combination of three or more GPS satellites is selected, from among all available GPS satellites, that provides the best vehicle location data. Here, a figure of merit used is minimum position dilution of precision ("PDOP") associated with the data received from a given group of GPS satellites. This approach seeks to account for the possibility that one or more buildings or other structures of relatively great height may preclude satellite visibility. The height of the structures in that area may be stored as part of a map in a GPS processor on board the land vehicle whose location is to be determined. The on-board system seeks combinations with the highest num-

ber of satellites visible, then works from these combinations to minimize the PDOP or a similar figure of merit for GPS position data.

Scribner et al disclose a vehicle tracking system that records, but does not transmit, the location of a vehicle whenever one or more predetermined events occurs in U.S. Pat. No. 5,014,206. The vehicle carries sensors that respond to occurrence of a predetermined event and carries a GPS or LORAN navigational system that receives vehicle location information, such as longitude and latitude. This vehicle location information is stored in a memory on board the vehicle only when one or more of the predetermined events occurs. The vehicle location information is assumed to be read out periodically when the vehicle returns to a home base.

In U.S. Pat. No. 5,043,736, Darnell et al disclose use of a combined cellular telephone and GPS portable receiver system that provides latitude and longitude coordinate information for the receiver. The GPS receiver has a modem and transmitter connected thereto that transmit its position to an accessible cellular phone, which in turn notifies a stationary base unit of the location of the GPS receiver. The base unit graphically displays the present location of the GPS receiver. This patent does not disclose determination of the location of the cellular telephone with reference to a prescribed cellzone boundary.

On-board navigation apparatus, to be carried on a vehicle to compare present and immediate-past locations as determined from GPS data, is disclosed by Odagawa et al in U.S. Pat. No. 5,087,919. A map containing coordinates for all roads in a region of the Earth's surface is stored electronically in a navigation system on board the vehicle, as part of a "map" of the region. The navigation system apparently assumes that the vehicle stays on one of the roads. Using the continuously arriving GPS data, the system searches for the nearest road segment that is consistent with these data to determine present location of the vehicle. Only latitude and longitude data are needed here so that fewer than four satellites may be used to determine the present location. Elevation data are provided as part of the road description stored in the navigation system. This system would not work well for a vehicle, such as an off-road land vehicle or a marine vessel, that has no fixed system of roads or paths to follow. This approach would not be particularly useful in determining the location of a stolen vehicle, unless the thief could be relied upon to stay on the conventionally describable roads.

Lojack Corp. of Dedham, Massachusetts has demonstrated a vehicle location system using triangulation of radio signals transmitted from the vehicle by a large number of receivers that are strategically positioned around a community. The vehicle transmitter is remotely activated by a signal broadcast from elsewhere.

Selby, in U.S. Pat. No. 4,876,738, and Comroe et al, in U.S. Pat. No. 5,054, 110, disclose a registration procedure for a mobile cellular telephone user with one or more cellular phone service facilities that service zones in which the user operates. Where telephone contact with a cellphone user, who has not registered, is sought, the present location of this user must first be determined by area-wide paging. Registration of a cellphone user in a particular zone does not indicate that this user is presently in that zone.

Use of signals broadcast by a plurality of fixed site radio transmitters and received by a mobile cellphone user, to determine the user's present location by signal strength triangulation, is disclosed in U.S. Pat. No. 4,907,290, issued

to Crompton. Location of the mobile receiver by this means does not indicate which, if any, cellular service provider can provide cellular communications service, and the typical location inaccuracy of this approach is probably many tens of meters.

Lee, in U.S. Pat. Nos. 4,932,049 and 5,067,147, discloses use of a main antenna in each cell zone plus several subsidiary antennas located on the cell zone boundaries or elsewhere to determine when a mobile cellular phone user has left that cell zone. Signal strengths from the mobile cellular phone are measured at each antenna in the cell zone and are compared with one or more reference sets of signal strengths to determine when handoff to an adjacent cell zone is appropriate.

U.S. Pat. No. 4,966,715, issued to Marui et al, discloses a mobile cellular phone system in which the strength of a signal received from a mobile cellular user are compared against first and second threshold values. If the signal strength is less than the first threshold value but greater than the second threshold value, a cell zone boundary is being approached. If the signal strength is less than the second threshold value, the mobile cellular user is determined to have crossed the cell zone boundary.

A method of predicting cell zone handoffs for a satellite-based cellular phone communications system is disclosed by Bertiger et al in U.S. Pat. No. 5,161,248. The geographic location of a mobile cellular phone user within a cell zone is determined, by means not discussed in detail. For a mobile user near a cell zone boundary, bit error rates for the satellite signals are computed and used to enhance the accuracy of the mobile user's calculated location.

In U.S. Pat. No. 5,175,867, issued to Wejke et al, a system for neighbor-assisted cell zone handoff is disclosed. A cellular service provider in a first cell zone measures the strength of signals received from a mobile cellular user that is moving in a second, adjacent cell zone. When this signal strength rises above a selected threshold, the first cell zone service provider requests handoff of the mobile user from the second cell zone to the first cell zone.

Bamburak discloses a location registration system for cellular mobile phones and other personal communicators in U.S. Pat. No. 5,197,092. The personal communicator includes means for call forwarding and updating thereof, stored at a central station through which calls made to the communicator are directed. This patent includes a useful discussion of cellular phone location registration approaches.

A method of controlling cellular mobile phone handoff by monitoring the Rayleigh multipath fading of the strength of a signal transmitted by a mobile cellphone to estimate the velocity of the cellphone is disclosed by Kanai in U.S. Pat. No. 5,239,667. This velocity estimate is used to estimate a difference between a reference signal strength level and the present signal strength level. When this difference reaches a selected threshold, cellphone handoff is implemented.

U.S. Pat. No. 5,241,685, issued to Bodin et al, discloses a load sharing technique for a mobile cellular phone system. Adjacent cellphone cell boundaries are defined in terms of relative signal strength. Thresholds for handoff, stated in terms of relative signal strengths, are dynamically adjusted in times of heavy communication traffic to lower the load on an overloaded cell and to increase the load on adjacent, less heavily loaded cells, by decreasing the area covered by the most overloaded cell.

Bissell et al, in U.S. Pat. No. 5,243,645, disclose a system for automatic forwarding of phone calls to a mobile recipient

of such calls. When, or if, the recipient engages in a commercial transaction, such as use of a credit card or of an Automatic Teller Machine, that indicates the recipient's present location, this present location information is communicated to a central database. Phone calls are then automatically forwarded to the most recently communicated "present location" of the recipient. If the recipient has not engaged in such a commercial transaction, no present location information is available for call forwarding.

Koma et al disclose a cellular phone system with time display in which the mobile cellphone user continually receives a signal identifying the area code of the present cellzone of the user, in U.S. Pat. No. 5,258,964. If an Area Code boundary is crossed and this crossing involves a time zone change, this time change is entered manually initially and stored for possible future use. If this zone crossing occurs again. However, no details are disclosed for determining the present location of the cellphone or the Area Code zone in which the cellphone is located.

A mobile cellular phone registration system is disclosed in U.S. Pat. No. 5,289,527, issued to Tiedemann. A mobile user registers in a new cell whenever the user's distance from a selected location in the cell of present registration is greater than a threshold distance. This appears to require that all cells be of similar shape (e.g., regular hexagons) and size and does not necessarily provide an accurate indication of when the mobile user has crossed a cell boundary line. Relative range measurements are also used to determine the proper cell zone in U.S. Pat. No. 4,667,202, issued to Kammerlander et al.

In U.S. Pat. No. 5,293,643, Israelsson discloses a method for determination of handoff between two mobile cellular phone cell zones. When handoff from a first cell zone to another cell zone is allowed but not required, the correlation of a signal strength vector, whose vector components are the measured strengths of signals received from each of two or more adjacent cells at the mobile unit, with two or more reference signal strength vectors is calculated. These correlation values are compared to determine when, and to which cell zone, handoff is required. This approach requires careful determination of correlation threshold values for several representative locations within several cell zones, and adjustment of one or more cell zone boundaries may require remeasurement of many of these threshold values.

Sawyer et al, in U.S. Pat. No. 5,307,400, disclose a mobile cellular phone call routing approach that relies upon voluntary registration of the mobile user in a visited cell zone that is not the home cell zone. After voluntary registration in the visited cell is completed, the cellular service provider for the visited cell advises the home cell zone of this registration. The home cell zone cellular service provider then temporarily routes all phone calls for the mobile user to the visited cell zone cellular service provider. A somewhat similar approach is disclosed in U.S. Pat. No. 4,972,456, issued to Kaczmarek et al.

These patents disclose use of GPS or radiowave technology for determination of location or orientation of a person or vehicle continuously or at discrete times, without regard to which of several geographically defined zones the person or vehicle may have last entered. What is needed is a system that automatically tracks the movement of a vehicle or person, such as a cellphone subscriber, who moves from one cellzone to another, irrespective of whether a given cellphone subscriber is actively using cellular phone service, as a boundary is crossed between two adjacent cellzones. Preferably, this system should accurately determine which

cellzone a given subscriber currently moves in and should be flexible enough to cover cellzones of arbitrary and changeable sizes, shapes and densities.

SUMMARY OF THE INVENTION

These needs are met by the invention, which provides a system that may be local or global for automatically tracking the movements of a plurality of cellphone subscribers from one cellzone to another. The invention might be characterized as "Where Am I?". A cellphone system carried by a subscriber (or by the subscriber's vehicle) includes a Satellite Positioning System (SATPS) antenna and receiver/processor and carries a transmitter that uses a preselected frequency not within the cellular transmission bands. The SATPS receiver/processor includes an electronic map with the coordinates of the boundary curves of each cellular exchange or cellzone within a selected region R, which region can be a portion or all of a town, city, county, state, country or continent.

Each time the subscriber crosses such a boundary curve, from a first cellzone to a second cellzone, a cellular telephone service provider in one or both of these cellzones is advised of the subscriber's new cellzone location. When a telephone caller seeks to reach a cellular phone subscriber, the initial inquiry is directed to a central cellular station, such as a mobile cellular telephone switching office (MCTSO) that communicates with all cellular phone exchanges within the region R. The central MCTSO transmits or broadcasts an inquiry and is informed of the cellzone in which the subscriber is presently located. The central MCTSO need not separately inquire about the present location of a given subscriber or estimate the subscriber's present location from recent cellphone calls, if any, made or received by the subscriber. Because each of two cellzones service providers is aware of the subscriber's present cellzone, loss or compromise of this information by one of these cellzone service providers does not preclude response to the central MCTSO's inquiry by the other cellzone service provider.

The central MCTSO receives a response, identifying the cellzone where the subscriber is presently located, and patches the call through from the telephone caller to the subscriber in this cellzone. This system can also be used to automatically provide a cellular system with information on the present cellzone location of a vehicle that has been moved without authorization, without requiring the vehicle owner to first inquire about the missing vehicle's location. The time a vehicle last crossed a boundary between two adjacent cellzones can also be noted, to provide a time stamp indicating the relative "staleness" of this cellzone information. The cellzone in which the vehicle is presently located is identified. In an urban setting, the cellzones may be relatively small, as small as a few urban blocks on a side.

This system can also be used to relieve a situation in which a severe overload in cellular service demand has developed in a given cellzone, by dynamically changing the cellzone boundary curve(s) between the given cellzone and at least one adjacent cellzone, based on the relative cellzone loads.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates use of the invention in a cellular communications environment.

FIG. 2 illustrates some of the geometric configurations useful in determining when a vehicle crosses a cellzone boundary.

FIGS. 3A, 3B, 3C and 3D illustrate particular boundary curves and quasi-boundary curves that can be used for the invention.

FIGS. 4 and 5 are flow charts illustrating embodiments of the invention for tracking a mobile cellular user across one or more cellzone boundaries.

FIG. 6 illustrates use of two alternate sets of boundary curves defining a given cellzone.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1, a land or marine vehicle 11 or other unit carrying a mobile cellular telephone user, moving within a cellzone CZ1 contained in a larger region R, carries a Satellite Positioning System (SATPS) antenna 13 and associated SATPS receiver/processor 15 that receive and analyze SATPS signals transmitted by a plurality of SATPS satellites 21, 23, 25 and 27. An SATPS signal received by the antenna 13 and receiver/processor 15 is first identified according to the SATPS satellite that transmitted this signal. The pseudorange or (uncorrected) measured distance from this satellite to the vehicle 11 is determined by determination of the time elapsed from signal transmission by the satellite to signal receipt by the antenna, using well known principles of analysis for satellite-based location determination by a Global Positioning System (GPS) or a Global Orbiting Navigational Satellite System (GLO-NASS). The GPS and GLO-NASS location determination systems are discussed below in some detail.

If, as here, the antenna 13 continuously receives SATPS signals from a plurality of satellites, the associated receiver/processor 15 can determine the present location coordinates and time of observation of the antenna when these signals are received. The vehicle or mobile cellphone user 11 carries a cellular telephone module 17, including a cellphone antenna/transmitter 19 that can communicate with cellular phone service providers 20-1 and 20-2 for the cellzones CZ1 and CZ2, respectively. The vehicle also carries a microcomputer 31 and associated memory 33, which can be part of the receiver/processor 15, that is provided with an electronic map of the region R in which the vehicle operates. This electronic map delineates the boundaries of a plurality of nearby cellzones CZ1, CZ2, CZ3, etc. in the region R, using SATPS-defined cellzone boundary coordinates that are part of the electronic map.

In FIG. 2, the vehicle or mobile cellphone user 11 approaches a portion of a boundary curve B12, which is preferably a closed curve that bounds a cellzone CZ1 and separates this cellzone from at least one adjacent cellzone CZ2. The cellzones CZ1 and CZ2 are preferably contiguous so that all points in a neighborhood of the boundary curve B12 belong to the cellzone CZ1, to the cellzone CZ2, or to both cellzones. The boundary curve B12 may be a single continuous or connected curve (not necessarily closed) or may be a collection of two or more continuous curve components. With the exception of points on the boundary curve B12, the cellzones CZ1 and CZ2 are preferably mutually exclusive and non-overlapping.

The boundary curve B12 is defined in the electronic map stored in the memory 33 by a collection of points in R with spatial location coordinates (x,y,z) that satisfy an equation

$$h_{B12}(x_{B12}, y_{B12}, z_{B12}) = K12 \text{ (constant)}, \quad (1)$$

and the receiver/processor 15 compares the present location of the antenna 13 with this collection of boundary location

coordinates at a sequence of times, using the SATPS-determined location coordinates of the antenna. The constant K12 may be zero or non-zero. Two quasi-boundary curves QB1 and QB2 are defined with reference to the boundary curve B12 and are located distances d1 and d2, respectively, from the boundary curve B12 but on opposite sides of the curve B12. The distances d1 and d2 may be the same or may be different and may each lie in a range from 10M (meters) to a few hundred M, depending in part on the sizes of the cellzones CZ1 and CZ2. The quasi-boundaries QB1 and QB2 are also defined by collections of points with spatial location coordinates $(x_{QB1}, y_{QB1}, z_{QB1})$ ($i=1, 2$) in the electronic map stored in the memory 33. Preferably, the distance $d_{min} = \min(d1, d2)$ is much less than the statistically defined 2σ inaccuracy associated with the present location coordinates of the SATPS antenna 13. The distances d1 and/or d2 can be different for boundary curves between different cellzones.

Let δB_i denote the one-sided region between the boundary curve B12 and the quasi-boundary curve QB_i ($i=1, 2$), which region locally has a width of d_i . The regions δB_1 and δB_2 together with the boundary curve B12 may be considered to be an overlap or common region CR12 between the contiguous cellzones CZ1 and CZ2, where each of two cellular phone service facilities can serve a cellphone user. The overlap or common region CR12 may include the regions δB_1 and δB_2 and the boundary curve B12. As a cellphone user moves from a non-overlap portion CZ1' (points in CZ1 but not in CR12) of the cellzone CZ1 through the common region CR12 to the non-overlap portion CZ2' (points in CZ2 but not in CR12) of the cellzone region CZ2, the cellular service facility for cellzone CZ1 will at some point hand off the responsibility for providing cellular service for this user to the cellular service facility for the cellzone CZ2, in a well known manner.

Each point with coordinates (x,y,z) within the region δB_i ($i=1,2$) has at least one "perpendicular foot" on the boundary curve B12, with coordinates $(x_{PB12}, y_{PB12}, z_{PB12})$, for which

$$\min_{(x,y,z) \in \delta B_i} \{(x-x_{PB12})^2 + (y-y_{PB12})^2 + (z-z_{PB12})^2\}^{1/2} = \{(x-x_{PB12})^2 + (y-y_{PB12})^2 + (z-z_{PB12})^2\}^{1/2} \quad (2)$$

A perpendicular footer of a point, with spatial location coordinates (x',y',z'), on a curve B12 is a point, with spatial location coordinates $(x'',y'',z'') = (x_{PB12}, y_{PB12}, z_{PB12})$ on the curve B12 such that a line drawn between the points with coordinates (x',y',z') and (x'',y'',z'') is perpendicular to the curve B12, or has the shortest distance to the curve B12, at the point of intersection (x'',y'',z'') on the curve B12. A point, such as (x',y',z'), may have one or many perpendicular footers on a given curve, such as B12, if the curve is smooth. Here, the two constraints

$$h_{B12}(x,y,z) - K12 < 0, \quad (3)$$

and

$$d_{PB12}(x,y,z) = \{(x-x_{PB12})^2 + (y-y_{PB12})^2 + (z-z_{PB12})^2\}^{1/2} < d1, \quad (4)$$

together imply that the point with location coordinates (x,y,z) lies in the interior of the region δB_1 ; and the two constraints

$$h_{B12}(x,y,z) - K12 > 0, \quad (5)$$

and

$$d_{PB12}(x,y,z) = \{(x-x_{PB12})^2 + (y-y_{PB12})^2 + (z-z_{PB12})^2\}^{1/2} < d2, \quad (6)$$

together imply that the point with location coordinates (x,y,z) lies in the interior of the region δB_2 .

Assume, for the sake of definiteness, that the vehicle or mobile cellphone user 11, with spatial location coordinates $(x(t), y(t), z(t))$ that can change with increasing values of the time variable t , passes through the region $\delta B1$ before the vehicle passes across the boundary curve $B12$ and into the region $\delta B2$. As the vehicle 11 passes across the quasi-boundary $QB1$ and into the interior of the region $\delta B1$, the receiver/processor 15 determines the present location coordinates $(x(t), y(t), z(t))$ of the vehicle (or of the SATPS antenna 13) and the coordinates $(x_{B12}(t), y_{B12}(t), z_{B12}(t))$ of the perpendicular footer of the vehicle location on the boundary $B12$ and determines that these two coordinate triples satisfy Eqs. (3) and (4).

If the perpendicular footer distance $d_{B12}(x(t), y(t), z(t))$ is decreasing with increasing values of the time variable t , the receiver/processor 15 senses that the vehicle is heading toward, and will probably cross, the boundary curve $B12$. In this instance, the receiver/processor readies itself for an imminent change of cellzone as the signum of the location variable $h_{B12}(x(t), y(t), z(t)) - K12$ changes from negative to positive (or from positive to negative). If the perpendicular footer distance $d_{B12}(x(t), y(t), z(t))$ is increasing with increasing values of the time variable t , the receiver/processor 15 senses that the vehicle is heading away from the boundary curve $B12$. In this instance, the receiver/processor 15 senses that the vehicle or mobile cellphone user 11 will not soon cross the boundary curve $B12$ and that no change of cellzone is imminent.

When the vehicle or mobile cellphone user 11 first crosses the quasi-boundary curve $QB1$ into the region $\delta B1$ from the non-overlap portion $CZ1'$ of the cellzone $CZ1$ and heads toward the boundary curve $B12$, the SATPS receiver/processor 15 senses this development, activates the cellphone transmitter 19, and causes the cellphone transmitter to communicate this information to the first cellular service provider 20-1. The first cellular service provider 20-1 communicates this information to the second cellular telephone service provider 20-2 so that a cellular telephone service handoff to the second service provider 20-2 can be arranged. This handoff can occur at any time the vehicle of cellphone user 11 (or the SATPS antenna 13) is within the overlap or common region $CR12$, but it is preferable for this handoff to occur within the region $\delta B2$, after the vehicle has crossed the boundary curve $B12$, or near or at the boundary curve $B12$. The first and second service providers 20-1 and 20-2 each enter this transaction in their respective ledgers, replacing any earlier transactions involving the location of the vehicle 11: The vehicle has left the cellzone $CZ1$ and has subsequently entered the cellzone $CZ2$. Alternatively, or additionally, a central mobile cellular telephone switching office (MCTSO) 30 (FIG. 1) can be notified directly or indirectly when the vehicle 11 leaves the cellzone $CZ1$ and passes into the cellzone $CZ2$, including an indication of which cellzone the vehicle has last entered. The formalism described here extends to any two adjacent cellzones, such as $CZ1$ and $CZ3$, or $CZ2$ and $CZ3$, in FIG. 1.

If the vehicle or mobile cellphone user 11 does not subsequently leave the cellzone $CZ2$, and if a telephone caller later seeks to contact the cellphone in this vehicle, the central MCTSO 30 will broadcast an inquiry and will be informed by the first service provider 20-1 and/or by the second service provider 20-2 that the vehicle 11 and associated cellphone is (or is believed to be) in the cellzone $CZ2$. The central MCTSO 30 will then cause the telephone caller to be connected, through the second service provider 20-2, to the target cellphone in the vehicle 11 in the cellzone $CZ2$. Alternatively, if the central cellular station 30 has already

been notified of the movement of the vehicle 11 from cellzone $CZ1$ to cellzone $CZ2$, the central MCTSO 30 can consult its own records and can determine the cellzone where the vehicle 11 is believed to be presently located.

As an additional feature, the central MCTSO 30 can maintain a log of M vehicles or mobile cellphone users, such as 11 (M a large, fixed, positive integer), most recently located by SATPS signals within the cellzones and within a selected time interval, such as $\Delta t(\text{cache}) = 12$ hours. If, within the selected time interval, a selected caller seeks to reach the cellular communications device within a selected vehicle, the central MCTSO 30 first consults its cache or list of recent cellular telephone contacts and determines if this selected caller is included on its the central station's cache or list; if this target vehicle is included on the cache or list, the central MCTSO 30 uses the cellzone for this target vehicle shown by the most recent cellular telephone contact, notifies an appropriate cellzone service provider, and attempts to provide cellular communication between the selected caller and the target vehicle. Operated in this way, the list of locations of the (at most) M most recent cellphone contacts is similar to a cache operating as a separate, fast-acting memory unit in a computer. The number M of recent cellular telephone contacts in the cache or list may be made so large that the only practical limit on the number of most recent cellular telephone contacts included in the cache or list is the time interval length $\Delta t(\text{cache})$ chosen.

FIGS. 3A, 3B and 3C illustrate the use of regular or irregular triangles, rectangles and regular hexagons, respectively, as boundary curves $B12$ of cellzones in a tessellation of a region of a plane or other two-dimensional surface. Each closed dotted curve, $QB1$ and $QB2$, representing a quasi-boundary, within a cellzone thus defined can be chosen to be the same shape as the boundary curve $B12$ here; and the distance d between each linear segment of a quasi-boundary curve QB and the corresponding linear component of the defining boundary curve $B12$ is the width of that portion of the quasi-boundary region δB .

Alternatively, a region of a plane or other two-dimensional surface can be decomposed into cellzones $CZ1$ ($i=1, 2, \dots$) by a sequence of closed curves, each of which includes one, two or more curvilinear segments. FIG. 3D illustrates use of such patterns where the curvilinear segments are portions of circles, ellipses and general ovals. More general boundary curves $B12$ can also be used here. Preferably, the vehicle relies on a differential SATPS to determine its present location. Differential SATPS, which is discussed below, provides greater accuracy than ordinary SATPS in location determination.

FIG. 4 is a flow chart illustrating the cellzone notification procedure discussed above. In step 51, the system determines SATPS-based present location coordinates $(x(t), y(t), z(t))$, as a function of time t , for a cellphone user carrying cellphone/SATPS apparatus constructed and operated according to the invention. The system determines which cellzone the cellphone user is presently located in and calls up the collection of boundary curves for that cellzone. In step 53, the system determines whether a boundary function $\{h_{B12}(x(t), y(t), z(t)) - K12\}$ for any boundary curve such as $B12$ of that cellzone for is zero (or more generally satisfies $|h_{B12}(x(t), y(t), z(t)) - K12| \leq \epsilon$ for a selected small number ϵ). If the answer is "yes", the system proceeds to step 54, where the system concludes that a cellzone boundary is being crossed: the cellzone indicia is changed and handoff to a cellular telephone service provider for the new cellzone is implemented.

If the answer to the question is "no", the system proceeds to step 55 and inquires if each boundary curve function

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$h_{B12}(x(t), y(t), z(t)) - K12 < 0$ (or, more generally, whether $h_{B12}(x(t), y(t), z(t)) - K12 < -\epsilon$)? All boundary curve functions for a particular cellzone will be < 0 if the vehicle is located within that cellzone.

If the answer to the question in step 55 is "yes", the system proceeds to step 57 and inquires if the perpendicular footer function $d_{B12}(x(t), y(t), z(t))$ is $< d1$ for the present spatial location coordinates $(x(t), y(t), z(t))$? If the answer to the question in step 57 is "yes", the system proceeds to step 61 and concludes that the cellphone user present location is in a cellzone overlap region CR12, discussed above. If the answer to the question in step 57 is "no", the system concludes that the cellphone user present location is not in a cellzone overlap region CR12 but is within the original cellzone CZ1, and the system returns to step 51 for analysis of the next present spatial location coordinates of the cellphone user.

If the answer to the question in step 55 is "no", the system concludes that $h_{B12}(x(t), y(t), z(t)) - K12 > 0$ (or, more generally, that $h_{B12}(x(t), y(t), z(t)) - K > \epsilon$) so that the cellphone user is not in the original cellzone CZ1. The system then proceeds to step 59 and inquires if the perpendicular footer distance function satisfies $d_{B12}(x(t), y(t), z(t)) < d2$? If the answer to the question in step 59 is "yes", the system proceeds to step 61 as before. If the answer to the question in step 59 is "no", the system concludes that the present location is not in a cellzone overlap region CR12 but is within an adjacent cellzone CZ2, and the system returns to step 51 for analysis of the next present location coordinates of the cellphone user.

From step 61, the system proceeds to step 63 and inquires if the perpendicular footer function $d_{B12}(x(t), y(t), z(t))$ is less than the preceding footer function $d_{B12}(x(t-\Delta t), y(t-\Delta t), z(t-\Delta t))$, where Δt is a small positive time increment? If the answer to the question in step 63 is "yes", the system concludes, in step 65, that the cellphone user is approaching a cellzone boundary within a cellzone overlap region, and the system prepares for cellzone change and handoff. If the answer to the question in step 63 is "no", the system returns to the step 51. After cellzone change and handoff occurs, the system returns to step 51 and the procedure repeats. A given cellular service provider can provide cellular service for more than one cellzone.

This system is also useful if a vehicle 11 containing the cellphone is moved without authorization by the vehicle owner. If the vehicle 11 is moved across one or more cellzone boundaries, the system, unless it is disabled, will automatically notify each cellular phone service provider for a cellzone that is adjacent to a crossed boundary that the vehicle has just entered, or has just left, that cellzone. This procedure creates an electronic trail that indicates the cellzone in which the missing vehicle is presently located. Preferably, the presence of a system that automatically notifies cellular telephone service providers that a cellzone boundary is being crossed should be concealed on the vehicle so that the system is not disabled by whoever unauthorizedly moves the vehicle.

A suitable procedure for use of the invention to determine the present location of a vehicle that may have been unauthorizedly moved is illustrated in FIG. 5, most of whose steps are parallel to the steps of FIG. 4. In step 70, a vehicle is moved without the knowledge or consent of the owner. In step 71, the system automatically determines SATPS-based present location coordinates $(x(t), y(t), z(t))$, as a function of time t , for a vehicle that carries cellphone/SATPS apparatus constructed and operated according to the invention. The system determines which cellzone the vehicle is presently

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located in and calls up the collection of boundary curves for that cellzone. In step 73, the system determines whether a boundary function $h_{B12}(x(t), y(t), z(t)) - K12$ for any boundary curve such as B12 of that cellzone for is zero (or more generally satisfies $|h_{B12}(x(t), y(t), z(t)) - K12| \leq \epsilon$ for a selected small number ϵ). If the answer to the question in step 73 is "yes", the system proceeds to step 74, where the system concludes that a cellzone boundary is being crossed: the cellzone indicia is changed and handoff to a cellular telephone service provider for the new cellzone is implemented.

If the answer to the question in step 73 is "no", the system proceeds to step 75 and inquires if each boundary curve function $h_{B12}(x(t), y(t), z(t)) - K12 < 0$ (or, more generally, whether $h_{B12}(x(t), y(t), z(t)) - K12 < -\epsilon$)? All boundary curve functions for a particular cellzone will be < 0 if the vehicle is located within that cellzone.

If the answer to the question in step 75 is "yes", the system proceeds to step 77 and inquires if the perpendicular footer function $d_{B12}(x(t), y(t), z(t))$ is $< d1$ for the present spatial location coordinates $(x(t), y(t), z(t))$? If the answer to question in step 77 is "yes", the system proceeds to step 81 and concludes that the vehicle present to the question location is in a cellzone overlap region CR12, discussed above. If the answer in step 77 is "no", the system concludes that the vehicle present location is not in a cellzone overlap region CR12 but is within the original cellzone CZ1, and the system returns to step 71 for analysis of the next present spatial location coordinates of the vehicle.

If the answer to the question in step 75 is "no", the system concludes that $h_{B12}(x(t), y(t), z(t)) - K12 > 0$ (or, more generally, that $h_{B12}(x(t), y(t), z(t)) - K12 > \epsilon$) so that the vehicle is not in the original cellzone CZ1. The system then proceeds to step 79 and inquires if the perpendicular footer function satisfies $d_{B12}(x(t), y(t), z(t)) < d2$? If the answer to the question in step 79 is "yes" the system proceeds to step 81 as before. If the answer to the question in step 79 is "no", the system concludes that the vehicle present location is not in a cellzone overlap region CR12 but is within an adjacent cellzone CZ2, and the system returns to step 71 for analysis of the next present location coordinates of the vehicle.

From step 81, the system proceeds to step 83 and inquires if the perpendicular footer function $d_{B12}(x(t), y(t), z(t))$ is less than the preceding footer function $d_{B12}(x(t-\Delta t), y(t-\Delta t), z(t-\Delta t))$, where Δt is a small positive time increment? If the answer to the question in step 83 is "yes", the system concludes, in step 85, that the vehicle is approaching a cellzone boundary with a cellzone overlap region, and the system prepares for cellzone change and handoff. If the answer to the question in step 83 is "no", the system returns to step 71.

This procedure continues until the vehicle owner (or owner's representative) realizes that the vehicle has been moved without authorization and attempts to determine where the vehicle is presently located. In step 87, the vehicle owner contacts the central MCTSO 30 or other cellular service station and inquires about the present location of the missing vehicle. In step 89, the owner is informed that the vehicle location was last reported in a specified cellzone (e.g., CZ1 or CZ2 or CZ3), and the owner takes action to recover possession of the vehicle. While the owners' request for information on the present location of the missing vehicle is being processed, the central station keeps a present account of the cellzone in which the vehicle is presently located.

If the present spatial location of the vehicle needs to be determined with greater accuracy, the cellular phone plus GPS system disclosed in U.S. patent application Ser. No.

07/978,272 (now U.S. Pat. No. 5,418,537), entitled "Location Of Missing Vehicles" and assigned to the assignee of this application, can be used.

If the cellular phone service provider in a target cellzone is currently overloaded with demand for cellular phone service so that the channels are collectively saturated, the boundary curves for the target cellzone can be changed to reduce the area covered by the target cellzone and to partly equalize the load on these cellzones. This usually requires prior negotiation or arrangement with the cellular service providers for cellzones that are contiguous with the target cellzone. Boundary curve collections for a first definition {B12-A, B13-A, B14-A, B15-A} and a second (distinct) definition {B12-B, B13-B, B14-B, B15-B} of the boundary between a cellzone CZ1 and adjacent cellzones CZ2, CZ3, CZ4 and CZ5 in a region R can be included as alternative electronic maps, as illustrated in FIG. 6. Here, for simplicity of illustration, all the cellzone shapes are shown as rectangles. However, the shape of each of the cellzones can be chosen independently, as long as the cellzones in any definition fit together appropriately.

In an exchange of one electronic map for another, a boundary curve for at least two adjacent cellzones is changed to reduce the geographical area covered by at least one of these cellzones. In most instances, if the boundary curve B12 between cellzones CZ1 and CZ2 is changed to produce new or alternative cellzones CZ1' and CZ2', one of original cellzones, such as CZ1, will properly contain the corresponding alternative cellzone CZ1', and another alternative cellzone, such as CZ2', will properly contain the corresponding original cellzone CZ2. A cellzone CZ1' is properly contained in a cellzone CZ1 if the cellzone CZ1 contains all points in CZ1' and contains at least one point not in CZ1'.

If cellzone CZ1, whose geographical extent is defined by the boundary curves B12-A, B13-A, B14-A and B15-A in a first electronic map, is found to be in a severe cellular service overload condition, and if the adjacent cellzones CZ2, CZ3, CZ4 and CZ5 are not overloaded, or are not overloaded as severely, the central MCTSO 30 or another cellzone boundary authority notifies the cellular service providers that the boundary curves B12-A, B13-A, B14-A and B15-A are being temporarily replaced by the respective boundary curves B12-B, B13-B, B14-B and B15-B in a second electronic map, in order to (partly) relieve the overload condition extant in cellzone CZ1. This replacement is preferably implemented by replacing the first electronic map by the second electronic map. After this replacement, the cellzone CZ1 has a smaller geographical area and, it is assumed, has fewer mobile cellular units to service within a new or alternative cellzone CZ1'. One or more of the adjacent new or alternative cellzones CZ2', CZ3', CZ4' and CZ5' will acquire additional mobile cellular units to service, as a result of this replacement.

Each of these cellzones then notifies all mobile cellular units presently in any of these cellzones, and any mobile cellular unit that subsequently enters any of these cellzones, that, until further notice, the boundary curves that define the cellzones CZ1, CZ2, CZ3, CZ4 and CZ5 no longer include the boundary curves B12-A, B13-A, B14-A and/or B15-A but include instead the respective boundary curves B12-B, B13-B, B14-B and/or B15-B. Preferably, this notification is implemented by advising such mobile cellular units to replace the first electronic map (A) by the second electronic map (B). Each mobile cellular unit has the electronic map A and the electronic map B in the database of its SATPS receiver/processor or microprocessor or CPU so that this

change of boundary curves can be made quickly and efficiently. Optionally, each cellzone, such as CZ1, has at least three electronic maps, each containing a set of alternate boundary curves that define that cellzone: a first set, for use in normal operations; a second set, for use when that cellzone CZ1 experiences a severe service overload condition; and a third set, for use where an adjacent cellzone experiences a severe cellular service overload condition that is not also experienced by the cellzone CZ1. Preferably, each set of boundary curves has its corresponding set of quasi-boundary curves, as illustrated in FIGS. 2 and 3A-3D. The cellzone boundary curves can be moved back and forth dynamically or "on the fly" as overload conditions develop and are relieved in various cellzones.

A Satellite Positioning System (SATPS) is a system of satellite signal transmitters, with receivers located on the Earth's surface or adjacent to the Earth's surface, that transmits information from which an observer's present location and/or the time of observation can be determined. Two operational systems, each of which qualifies as an SATPS, are the Global Positioning System and the Global Orbiting Navigational System.

The Global Positioning System (GPS) is part of a satellite-based navigation system developed by the United States Defense Department under its NAVSTAR satellite program. A fully operational GPS includes up to 24 satellites approximately uniformly dispersed around six circular orbits with four satellites each, the orbits being inclined at an angle of 55° relative to the equator and being separated from each other by multiples of 60° longitude. The orbits have radii of 26,560 kilometers and are approximately circular. The orbits are non-geosynchronous, with 0.5 sidereal day (11.967 hours) orbital time intervals, so that the satellites move with time relative to the Earth below. Theoretically, three or more GPS satellites will be visible from most points on the Earth's surface, and visual access to two or more such satellites can be used to determine an observer's position anywhere on the Earth's surface, 24 hours per day. Each satellite carries a cesium or rubidium atomic clock to provide timing information for the signals transmitted by the satellites. Internal clock correction is provided for each satellite clock.

Each GPS satellite transmits two spread spectrum, L-band carrier signals: an L1 signal having a frequency $f_1=1575.42$ MHz and an L2 signal having a frequency $f_2=1227.6$ MHz. These two frequencies are integral multiples $f_1=1540 f_0$ and $f_2=1200 f_0$ of a base frequency $f_0=1.023$ MHz. The L1 signal from each satellite is binary phase shift key (BPSK) modulated by two pseudo-random noise (PRN) codes in phase quadrature, designated as the C/A-code and P-code. The L2 signal from each satellite is BPSK-modulated by only the P-code. The nature of these PRN codes is described below.

One motivation for use of two carrier signals L1 and L2 is to allow partial compensation for propagation delay of such a signal through the ionosphere, which delay varies approximately as the inverse square of signal frequency f (delay $\propto f^{-2}$). This phenomenon is discussed by MacDoran in U.S. Pat. No. 4,463,357, which discussion is incorporated by reference herein. When transit time delay through the ionosphere is determined, a phase delay associated with a given carrier signal can be determined.

Use of the PRN codes allows use of a plurality of GPS satellite signals for determining an observer's position and for providing navigation information. A signal transmitted by a particular GPS signal is selected by generating and matching, or correlating, the PRN code for that particular

satellite. All PRN codes are known and are generated or stored in GPS satellite signal receivers carded by ground observers. A first PRN code for each GPS satellite, sometimes referred to as a precision code or P-code, is a relatively long, fine-grained code having an associated clock or chip rate of $10 f_0 = 10.23$ MHz. A second PRN code for each GPS satellite, sometimes referred to as a clear/acquisition code or C/A-code, is intended to facilitate rapid satellite signal acquisition and hand-over to the P-code and is a relatively short, coarser-grained code having a clock or chip rate of $f_0 = 1.023$ MHz. The C/A-code for any GPS satellite has a length of 1023 chips or time increments before this code repeats. The full P-code has a length of 259 days, with each satellite transmitting a unique portion of the full P-code. The portion of P-code used for a given GPS satellite has a length of precisely one week (7,000 days) before this code portion repeats. Accepted methods for generating the C/A-code and P-code are set forth in the document GPS Interface Control Document ICD-GPS-200, published by Rockwell International Corporation, Satellite Systems Division, Revision B-PR, 3 Jul. 1991.

The GPS satellite bit stream includes navigational information on the ephemeris of the transmitting GPS satellite and an almanac for all GPS satellites, with parameters providing corrections for ionospheric signal propagation delays suitable for single frequency receivers and for an offset time between satellite clock time and true GPS time. The navigational information is transmitted at a rate of 50 Baud. A useful discussion of the GPS and techniques for obtaining position information from the satellite signals is found in Tom Logsdon, *The NAVSTAR Global Positioning System*, Van Nostrand Reinhold, N.Y., 1992.

A second configuration for global positioning is the Global Orbiting Navigation Satellite System (GLONASS), placed in orbit by the former Soviet Union and now maintained by the Russian Republic. GLONASS also uses 24 satellites, distributed approximately uniformly in three orbital planes of eight satellites each. Each orbital plane has a nominal inclination of 64.8° relative to the equator, and the three orbital planes are separated from each other by multiples of 120° longitude. The GLONASS circular orbits have smaller radii, about 25,510 kilometers, and a satellite period of revolution of $8/17$ of a sidereal day (11.26 hours). A GLONASS satellite and a GPS satellite will thus complete 17 and 16 revolutions, respectively, around the Earth every 8 days. The GLONASS system uses two carrier signals L1 and L2 with frequencies of $f_1 = (1.602 + 9 k/16)$ GHz and $f_2 = (1.246 + 7 k/16)$ GHz, where $k = 0, 1, 2, \dots, 23$ is the channel or satellite number. These frequencies lie in two bands at 1.597–1.617 GHz (L1) and 1,240–1,260 GHz (L2). The L1 code is modulated by a C/A-code (chip rate = 0.511 MHz) and by a P-code (chip rate = 5.11 MHz). The L2 code is presently modulated only by the P-code. The GLONASS satellites also transmit navigational data at a rate of 50 Baud. Because the channel frequencies are distinguishable from each other, the P-code is the same, and the C/A-code is the same, for each satellite. The methods for receiving and analyzing the GLONASS signals are similar to the methods used for the GPS signals.

Reference to a Satellite Positioning System or SATPS herein refers to a Global Positioning System, to a Global Orbiting Navigation System, and to any other compatible satellite-based system that provides information by which an observer's position and the time of observation can be determined, all of which meet the requirements of the present invention.

A Satellite Positioning System (SATPS), such as the Global Positioning System (GPS) or the Global Orbiting

Navigation Satellite System (GLONASS), uses transmission of coded radio signals, with the structure described above, from a plurality of Earth-orbiting satellites. A single passive receiver of such signals is capable of determining receiver absolute position in an Earth-centered, Earth-fixed coordinate reference system utilized by the SATPS.

A configuration of two or more receivers can be used to accurately determine the relative positions between the receivers or stations. This method, known as differential SATPS positioning, is far more accurate than absolute positioning, provided that the distances between these stations are substantially less than the distances from these stations to the satellites, which is the usual case. Differential SATPS positioning can be used for survey or construction work in the field, providing location coordinates and distances that are accurate to within a few centimeters.

In differential SATPS position determination, many of the errors in the SATPS that compromise the accuracy of absolute position determination are similar in magnitude for stations that are physically close. The effect of these errors on the accuracy of differential position determination is therefore substantially reduced by a process of partial error cancellation.

An SATPS antenna receives SATPS signals from a plurality (preferably four or more) of SATPS satellites and passes these signals to an SATPS signal receiver/processor, which (1) identifies the SATPS satellite source for each SATPS signal, (2) determines the time at which each identified SATPS signal arrives at the antenna, and (3) determines the present location of the SATPS antenna from this information and from information on the ephemerides for each identified SATPS satellite. The SATPS signal antenna and signal receiver/processor are part of the user segment of a particular SATPS, the Global Positioning System, as discussed by Tom Logsdon in *The NAVSTAR Global Positioning System*, Van Nostrand Reinhold, 1992, pp. 33–90.

I claim:

1. A method for providing handoff between at least two cellzones for a mobile cellphone user, the method comprising the steps of:

providing a cellphone user with a cellular telephone that can communicate with a selected telephone through a first cellular telephone service provider, when the cellular telephone is located within a first cellzone, and can communicate with the selected telephone through a second cellular telephone service provider, when the cellular telephone is located within a second cellzone that is adjacent to the first cellzone;

providing the cellphone user with a Satellite Positioning System (SATPS) antenna and SATPS receiver/processor and with a transmitter, to receive SATPS signals from a plurality of SATPS satellites, to determine the present location of the SATPS antenna from analysis of these SATPS signals, and to transmit information on the present location of the SATPS antenna to a cellular telephone service provider for a cellzone in which the antenna is presently located;

providing the cellphone user with a microprocessor and associated memory, connected to the cellular telephone and to the SATPS receiver/processor, that contains an electronic map of at least the first and second cellzones;

providing a cellzone boundary curve B12 between the first and second cellzones, where B12 is defined on the electronic map by an equation $h_{B12}(x_{B12}, y_{B12}, z_{B12}) = 0$, where $(x_{B12}, y_{B12}, z_{B12})$ are the spatial location coordinates of a point lying on the boundary curve B12, where the equation $h_{B12}(x, y, z) < 0$ indicates that a point

with coordinates (x,y,z) is within a first region including the first cellzone and not including the second cellzone, and where the equation $h_{B12}(x,y,z) > 0$ indicates that the point with coordinates (x,y,z) is within a second region including the second cellzone and not including the first cellzone;

providing a first quasi-boundary curve QB1 within the first cellzone that is defined on the map by a curve of points with coordinates $(x_{QB1}, y_{QB1}, z_{QB1})$ within the first cellzone for which the perpendicular footer distance $d_{B12}(x,y,z)$ of each point $(x_{QB1}, y_{QB1}, z_{QB1})$ on the curve QB1 to its perpendicular footer on the curve B12 satisfies the relation $d_{B12}(x_{QB1}, y_{QB1}, z_{QB1}) = d1$, where $d1$ is a selected positive distance;

providing a second quasi-boundary curve QB2 within the second cellzone that is defined on the map by a curve of points with coordinates $(x_{QB2}, y_{QB2}, z_{QB2})$ within the second cellzone for which the perpendicular footer distance $d_{B12}(x,y,z)$ of each point $(x_{QB2}, y_{QB2}, z_{QB2})$ on the curve QB2 to its perpendicular footer on the curve B12 satisfies the relation $d_{B12}(x_{QB2}, y_{QB2}, z_{QB2}) = d2$, where $d2$ is a selected positive distance;

defining a region CR12 of points lying between the first quasi-boundary curve QB1 and the second quasi-boundary curve QB2, including at least a portion of the boundary curve B12;

when the SATPS antenna is within at least one of the first cellzone and the second cellzone, determining the antenna's spatial location coordinates $(x(t), y(t), z(t))$, which may vary with time t ;

determining whether the SATPS antenna's spatial location coordinates satisfy the two relations $h_{B12}(x(t), y(t), z(t)) < 0$ and $d_{B12}(x(t), y(t), z(t)) \geq d1$, and when these two relations are both satisfied, determining that the cellphone user is presently in the first cellzone;

when the SATPS antenna is within the first cellzone and not within the region CR12, providing cellular telephone service for the cellphone user with the first cellular telephone service provider;

determining whether the SATPS antenna's spatial location coordinates satisfy the two relations $h_{B12}(x(t), y(t), z(t)) < 0$ and $d_{B12}(x(t), y(t), z(t)) < d1$, and when these two relations are both satisfied and the distance $d_{B12}(x(t), y(t), z(t))$ is decreasing with increasing time t , notifying at least one of the first and second cellular telephone service providers that the cellphone user will soon pass from the first cellzone into the second cellzone; and

determining whether the SATPS antenna's spatial location coordinates satisfy the relation $h_{B12}(x(t), y(t), z(t)) > 0$, and when this relation is satisfied and the distance $d_{B12}(x(t), y(t), z(t))$ is increasing with increasing time t , notifying at least one of the first and second cellular telephone service providers that the cellphone user has passed from the first cellzone into the second cellzone.

2. The method of claim 1, further comprising the steps of: when said SATPS antenna is within said second cellzone and not within said region CR12, (1) providing cellular telephone service for said cellphone user with said second cellular telephone service provider, and (2) communicating with a cellular telephone switching office and advising the office that cellular telephone service is now provided by said second cellular telephone service provider.

3. The method of claim 1, further comprising the step of: when said SATPS antenna is within said first cellzone and not within said region CR12, (1) providing cellular

telephone service for said cellphone user with said first cellular telephone service provider, and (2) communicating with a cellular telephone switching office and advising the office that cellular telephone service is now provided by said first cellular telephone service provider.

4. The method of claim 1, further comprising the step of: when said SATPS antenna's spatial location coordinates satisfy the relations $h_{B12}(x(t), y(t), z(t)) < 0$ and $d_{B12}(x(t), y(t), z(t)) < d1$ and the distance $d_{B12}(x(t), y(t), z(t))$ is decreasing with increasing time t , causing said second cellular telephone service provider to begin providing cellular telephone service for said cellphone user.

5. The method of claim 1, further comprising the step of: determining whether said SATPS antenna's spatial location coordinates satisfy the two relations $h_{B12}(x(t), y(t), z(t)) < 0$ and $d_{B12}(x(t), y(t), z(t)) < d1$, and when these two relations are both satisfied and the distance $d_{B12}(x(t), y(t), z(t))$ is increasing with increasing time t , determining that the cellphone user will not soon pass from the first cellzone into the second cellzone.

6. The method of claim 1, wherein said step of providing said cellzone boundary curve B12 comprises the step of choosing said boundary curve B12 to be at least a portion of a curve drawn from the class of closed curves consisting of a triangle, a rectangle and a hexagon.

7. The method of claim 1, wherein said step of providing said cellzone boundary curve B12 comprises the step of choosing said boundary curve B12 to be at least a portion of a curve drawn from the class of closed curves consisting of a circle, an ellipse and an oval.

8. The method of claim 1, further comprising the step of allowing said cellphone user to communicate with a selected telephone user using said first cellular telephone service provider, when said cellphone user is determined to be within said first cellzone.

9. The method of claim 1, further comprising the step of allowing said cellphone user to communicate with a selected telephone user using said second cellular telephone service provider, when said cellphone user is determined to be within said second cellzone.

10. The method of claim 1, further comprising the steps of:

providing a second electronic map containing a second cellzone boundary curve B12' between a first alternative first cellzone and an alternative second cellzone, where the first alternative first cellzone is properly contained in said first cellzone and said second cellzone is properly contained in the alternative second cellzone; where B12' is defined on the second electronic map by an equation $h_{B12}(x_{B12}, y_{B12}, z_{B12}) = 0$, where $(x_{B12}, y_{B12}, z_{B12})$ are the spatial location coordinates of a point lying on the boundary curve B12', where the equation $h_{B12}(x,y,z) < 0$ indicates that a point with coordinates (x,y,z) is within a third region including the first alternative first cellzone and not including the alternative second cellzone, and where the equation $h_{B12}(x,y,z) > 0$ indicates that the point with coordinates (x,y,z) is within a fourth region including the alternative second cellzone and not including the first alternative first cellzone; and

when said first cellular service provider is determined to be overloaded with demands for cellular communications service, changing said first cellzone and said second cellzone boundary curves according to the following procedure:

replacing said first electronic map, containing said first cellzone and said second cellzone, by the second

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electronic map, containing the first alternative first cellzone and the alternative second cellzone, respectively.

11. The method of claim 1, further comprising the step of: recording an estimated time and said cellzone that said SATPS antenna is entering ("destination cellzone"), for at least one time that said SATPS antenna crosses said cellzone boundary.

12. The method of claim 11, further comprising the step of: when a telephone caller seeks to contact said cellphone user, consulting a list of said recorded times of cellzone boundary crossings and destination cellzones to determine at least one of (1) said destination cellzone, if any, that said cellphone user has most recently entered and (2) said estimated time, if any, that said cellphone user has most recently entered said destination cellzone.

13. A method for tracking and providing information on the present location of a missing vehicle, the method comprising the steps of:

providing a vehicle with a cellular telephone that can communicate with a selected telephone through a first cellular telephone service provider, when the cellular telephone is located within a first cellzone and can communicate with the selected telephone through a second cellular telephone service provider, when the cellular telephone is located within a second cellzone that is adjacent to the first cellzone, where the first and second cellular telephone service providers may be the same and may be different;

providing the vehicle with a Satellite Positioning System (SATPS) antenna and SATPS receiver/processor and with a transmitter, to receive SATPS signals from a plurality of SATPS satellites, to determine the present location of the SATPS antenna from analysis of these SATPS signals, and to transmit information on the present location of the SATPS antenna to a cellular telephone service provider for a cellzone in which the antenna is presently located;

when the vehicle is determined to be missing, communicating with at least one cellular service provider to determine the cellzone in which the vehicle was last known to be located, using information obtained from a cellular telephone service provider for a cellzone and from the SATPS signals; and

determining that the approximate present location of the missing vehicle is in the cellzone in which the vehicle was last known to be located;

where the steps of determining the present location of the SATPS antenna and transmitting information on the present location of the antenna comprise the steps of:

providing the vehicle with a microprocessor and associated memory, connected to the cellular telephone and to the receiver/processor, that contains an electronic map of at least the first and second cellzones;

providing a cellzone boundary curve B12 between the first and second cellzones, where B12 is defined on the map by an equation $h_{B12}(x_{B12}, y_{B12}, z_{B12})=0$, where $(x_{B12}, y_{B12}, z_{B12})$ are the spatial location coordinates of a point lying on the boundary curve B12, where the equation $h_{B12}(x, y, z) < 0$ indicates that a point with coordinates (x, y, z) is within a first region including the first cellzone and not including the second cellzone, and where the equation $h_{B12}(x, y, z) > 0$ indicates that the point with coordinates (x, y, z) is within a second region including the second cellzone and not including the first cellzone;

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providing a first quasi-boundary curve QB1 within the first cellzone that is defined on the map by a curve of points with coordinates $(x_{QB1}, y_{QB1}, z_{QB1})$ within the first cellzone for which the perpendicular footer distance $d_{B12}(x, y, z)$ of each point $(x_{QB1}, y_{QB1}, z_{QB1})$ on the curve QB1 to its perpendicular footer on the curve B12 satisfies the relation $d_{B12}(x_{QB1}, y_{QB1}, z_{QB1})=d1$, where d1 is a selected distance;

providing a second quasi-boundary curve QB2 within the second cellzone that is defined on the map by a curve of points with coordinates $(x_{QB2}, y_{QB2}, z_{QB2})$ within the second cellzone for which the perpendicular footer distance $d_{B12}(x, y, z)$ of each point $(x_{QB2}, y_{QB2}, z_{QB2})$ on the curve QB2 to its perpendicular footer on the curve B12 satisfies the relation $d_{B12}(x_{QB2}, y_{QB2}, z_{QB2})=d2$, where d2 is a selected distance;

defining a region CR12 of points lying between the first quasi-boundary curve QB1 and the second quasi-boundary curve QB2, including the boundary curve B12;

when the SATPS antenna is within at least one of the first cellzone and the second cellzone, determining the antenna's spatial location coordinates $(x(t), y(t), z(t))$, which may vary with time t;

determining whether the SATPS antenna's spatial location coordinates satisfy the two relations $h_{B12}(x(t), y(t), z(t)) - K12 < 0$ and $d_{B12}(x(t), y(t), z(t)) \leq d1$, and when these two relations are both satisfied, determining that the vehicle is presently in the first cellzone;

when the antenna is within the first cellzone and not within the region CR12, providing cellular telephone service for the vehicle cellular phone with the first cellular telephone service provider;

determining whether the antenna's spatial location coordinates satisfy the two relations $h_{B12}(x(t), y(t), z(t)) < 0$ and $d_{B12}(x(t), y(t), z(t)) < d1$, and when these two relations are both satisfied and the distance $d_{B12}(x(t), y(t), z(t))$ is decreasing with increasing time t, notifying at least one of the first and second cellular telephone service providers that the vehicle will soon pass from the first cellzone into the second cellzone;

determining whether the SATPS antenna's spatial location coordinates satisfy the two relations $h_{B12}(x(t), y(t), z(t)) > 0$ and $d_{B12}(x(t), y(t), z(t)) < d2$, and when these two relations are both satisfied and the distance $d_{B12}(x(t), y(t), z(t))$ is increasing with increasing time t, notifying at least one of the first and second cellular telephone service providers that the vehicle has passed from the first cellzone into the second cellzone; and

when at least one of the first and second cellular service providers is communicated with by a cellular telephone switching office, advising the switching office of the cellzone in which the vehicle was last known to be located.

14. The method of claim 13, wherein said step of providing said cellzone boundary curve B12 comprises the step of choosing said boundary curve B12 to be at least a portion of a curve drawn from the class of closed curves consisting of a triangle, a rectangle and a hexagon.

15. The method of claim 13, wherein said step of providing said cellzone boundary curve B12 comprises the step of choosing said boundary curve B12 to be at least a portion of a curve drawn from the class of closed curves consisting of a circle, an ellipse and an oval.

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16. A method for providing flexible cellular service to a region, the method comprising the steps of:

providing a cellphone user with a cellular telephone that can communicate with a selected telephone through a first cellular telephone service provider, when the cellular telephone is located within a first cellzone, and can communicate with the selected telephone through a second cellular telephone service provider, when the cellular telephone is located within a second cellzone that is adjacent to the first cellzone, where the first and second cellular telephone service providers may be the same and may be different;

providing the vehicle with a Satellite Positioning System (SATPS) antenna and SATPS receiver/processor and with a transmitter, to receive SATPS signals from a plurality of SATPS satellites, to determine the present location of the SATPS antenna from analysis of these SATPS signals, and to transmit information on the present location of the SATPS antenna to a cellular telephone service provider for a cellzone in which the antenna is presently located;

providing the vehicle with a microprocessor and associated memory, connected to the cellular telephone and to the receiver/processor, that contains at least first and second electronic maps of the combined first and second cellzones;

providing a first electronic map containing a first cellzone boundary curve B12 between the first and second cellzones, where B12 is defined on the map by an equation $h_{B12}(x_{B12}, y_{B12}, z_{B12})=0$, where $(x_{B12}, y_{B12}, z_{B12})$ are the spatial location coordinates of a point lying on the boundary curve B12, where the equation $h_{B12}(x, y, z) < 0$ indicates that a point with coordinates (x, y, z) is within a first region including the first cellzone and not including the second cellzone, and where the equation $h_{B12}(x, y, z) > 0$ indicates that the point with coordinates (x, y, z) is within a second region including the second cellzone and not including the first cellzone;

providing a second electronic map containing a second cellzone boundary curve B12' between an alternative first cellzone and an alternative second cellzone, where the alternative first cellzone is properly contained in the first cellzone and the second cellzone is properly contained in the alternative second cellzone, where B12' is defined on the second electronic map by an equation $h_{B12'}(x_{B12'}, y_{B12'}, z_{B12'})=0$, where $(x_{B12'}, y_{B12'}, z_{B12'})$ are the spatial location coordinates of a point lying on the boundary curve B12', where the equation $h_{B12'}(x, y, z) < 0$ indicates that a point with coordinates (x, y, z) is within a third region including the alternative first cellzone and not including the alternative second cellzone, and where the equation $h_{B12'}(x, y, z) > 0$ indicates that the point with coordinates (x, y, z) is within a fourth region including the alternative second cellzone and not including the alternative first cellzone;

causing the first and second cellular telephone service providers to provide cellular telephone service within the first cellzone and within the second cellzone, respectively;

when the first cellular service provider is determined to be overloaded with demands for cellular communications service, replacing the first electronic map, containing the first cellzone and the second cellzone, by the second electronic map, containing the alternative first cellzone and the alternative second cellzone; and

causing the first and second cellular telephone service providers to provide cellular telephone service within

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the alternative first cellzone, and within the alternative second cellzone, respectively.

17. The method of claim 16, wherein said step of providing said cellzone boundary curve B12 comprises the step of choosing said boundary curve B12 to be at least a portion of a curve drawn from the class of closed curves consisting of a triangle, a rectangle and a hexagon.

18. The method of claim 16, wherein said step of providing said cellzone boundary curve B12 comprises the step of choosing said boundary curve B12 to be at least a portion of a curve drawn from the class of closed curves consisting of a circle, an ellipse and an oval.

19. A method for providing handoff between at least two cellzones for a mobile cellphone user, the method comprising the steps of:

determining location coordinates of a cellphone used by a cellphone user;

comparing the cellphone location coordinates with a cellzone map, and identifying a first cellzone on the cellzone map in which the cellphone is presently located, where the first cellzone is adjacent to a second cellzone, and the first cellzone and the second cellzone are separated by a cellzone boundary;

providing cellphone service for the cellphone by a cellphone service provider located within the first cellzone, when the cellphone location is within the first cellzone;

determining a distance d of the cellphone from the cellzone boundary, when the cellphone location is determined to be within the first cellzone;

when the distance d is less than a selected positive distance d1 and is decreasing with increasing time, and the cellphone location is within the first cellzone, preparing to hand off cellphone service for the cellphone to the cellphone service provider for the second cellzone; and

when the cellphone location is determined to have passed across the cellzone boundary, providing cellphone service for the cellphone by a cellphone service provider located within the second cellzone, when the cellphone location is within the second cellzone.

20. The method of claim 19, where said step of determining said cellphone location coordinates comprises the step of:

receiving Satellite Positioning System (SATPS) signals from a plurality of SATPS satellites at an SATPS signal antenna and receiver/processor that is connected to said cellphone and that determines present location of the SATPS antenna from analysis of the SATPS signals; and

transmitting information on the present location of the SATPS antenna to at least one of said cellphone service provider for said first cellzone and said cellphone service provider for said second cellzone.

21. A method for providing handoff between at least two cellzones for a mobile cellphone user, the method comprising the steps of:

determining location coordinates of a cellphone used by a cellphone user;

comparing the cellphone location coordinates with a cellzone map, and identifying a first cellzone on the cellzone map in which the cellphone is presently located, where the first cellzone is adjacent to a second cellzone, and the first cellzone and the second cellzone are separated by a cellzone boundary;

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providing cellphone service for the cellphone by a cellphone service provider located within the first cellzone, when the cellphone location is within the first cellzone; determining a distance d of the cellphone from the cellzone boundary, when the cellphone location is determined to be within the first cellzone; when the distance d is less than a selected positive distance d_1 and is increasing with increasing time, and the cellphone location is within the first cellzone, providing cellphone service for the cellphone by the cellphone service provider for the first cellzone; and when the cellphone location is determined to have passed across the cellzone boundary, providing cellphone service for the cellphone by a cellphone service provider located within the second cellzone, when the cellphone location is within the second cellzone.

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22. The method of claim 21, where said step of determining said cellphone location coordinates comprises the step of:

receiving Satellite Positioning System (SATPS) signals from a plurality of SATPS satellites at an SATPS signal antenna and receiver/processor that is connected to said cellphone and that determines present location of the SATPS antenna from analysis of the SATPS signals; and

transmitting information on the present location of the SATPS antenna to at least one of said cellphone service provider for said first cellzone and said cellphone service provider for said second cellzone.

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United States Patent [19]
Rubin et al.

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

[54] **GPS DATA ACCESS SYSTEM**

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[73] **Assignee:** **Philip A. Rubin and Associates, Inc.**,
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[*] **Notice:** This patent is subject to a terminal disclaimer.

[21] **Appl. No.:** **09/060,218**

[22] **Filed:** **Apr. 15, 1998**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/842,573, Apr. 15, 1997, Pat. No. 6,009,116, which is a continuation-in-part of application No. 08/437,424, May 5, 1995, Pat. No. 5,621,793.

[51] **Int. Cl.⁷** **H04L 27/30**

[52] **U.S. Cl.** **375/130; 348/10; 340/825.31; 340/825.34**

[58] **Field of Search** **375/250, 207, 375/350, 130; 348/10, 8, 9; 380/10, 20, 21; 340/825.31, 825.34; 455/4.2, 6.3**

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,789,131	1/1974	Harney .
3,826,863	7/1974	Johnson .
3,857,997	12/1974	Toonder .
3,882,266	5/1975	Walding .
3,882,289	5/1975	Walding et al. .
3,882,392	5/1975	Harney .
3,919,463	11/1975	Walding .
4,024,575	5/1977	Harney et al. .
4,054,860	10/1977	Henderson et al. .
4,112,464	9/1978	Guif et al. .
4,135,157	1/1979	den Toonder .
4,145,717	3/1979	Guif et al. .
4,215,366	7/1980	Davidson .
4,531,020	7/1985	Wechselberger et al. .
4,736,422	4/1988	Mason .

4,739,510	4/1988	Jeffers et al. .
4,802,215	1/1989	Mason .
4,807,256	2/1989	Holmes et al. .
4,993,067	2/1991	Leopold .
5,113,440	5/1992	Harney et al. .
5,144,663	9/1992	Kudelski et al. .
5,208,856	5/1993	Leduc et al. .
5,224,161	6/1993	Daniel et al. .
5,243,652	9/1993	Teare et al. .
5,282,249	1/1994	Cohen et al. .
5,295,188	3/1994	Wilson et al. .
5,345,504	9/1994	West, Jr. .
5,347,581	9/1994	Naccache et al. .
5,359,332	10/1994	Allison et al. .
5,373,557	12/1994	Diehl et al. .
5,379,045	1/1995	Gilbert et al. .
5,565,909	10/1996	Thibadeau et al. .
5,621,793	4/1997	Bednarek et al. .
5,636,122	6/1997	Shah et al. .

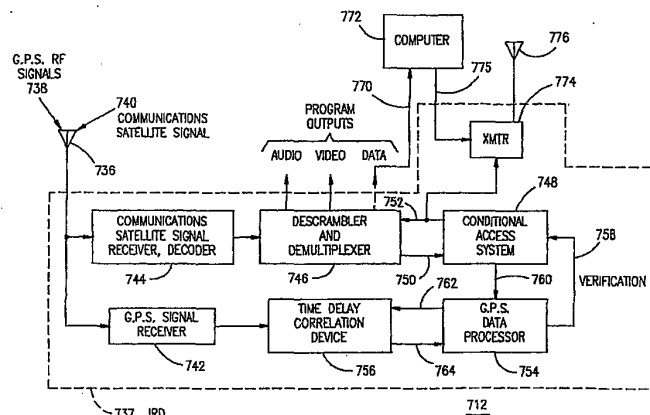
Primary Examiner—Don N. Vo

Attorney, Agent, or Firm—William L. Feeney; Miles & Stockbridge P.C.

[57] **ABSTRACT**

An integrated receiver decoder (IRD), commonly called a set-top box, has a global positioning system (GPS) receiver. The GPS receiver checks to see if the IRD is at an authorized location and allows descrambling of video signals only if the location is authorized. A central access control system, remote from the customers/viewers, has a high quality GPS receiver and sends some GPS data in the transmission medium used to send video signals to the customers. The set-top box, referred to as a customer access control, establishes different geographic restrictions on different of various video or data signals. Location-specific signals require that the set-top box be at a single fixed location for descrambling. Geographic filtering of data signals is provided. Region-specific signals are accessible only if the set-top box is in a geographic region authorized for reception, there being several such regions. Large area signals are accessible anywhere within a large area including the regions. Region-exclusion signals are accessible only if the set-top box is outside of one or more regions where reception is not allowed.

31 Claims, 18 Drawing Sheets



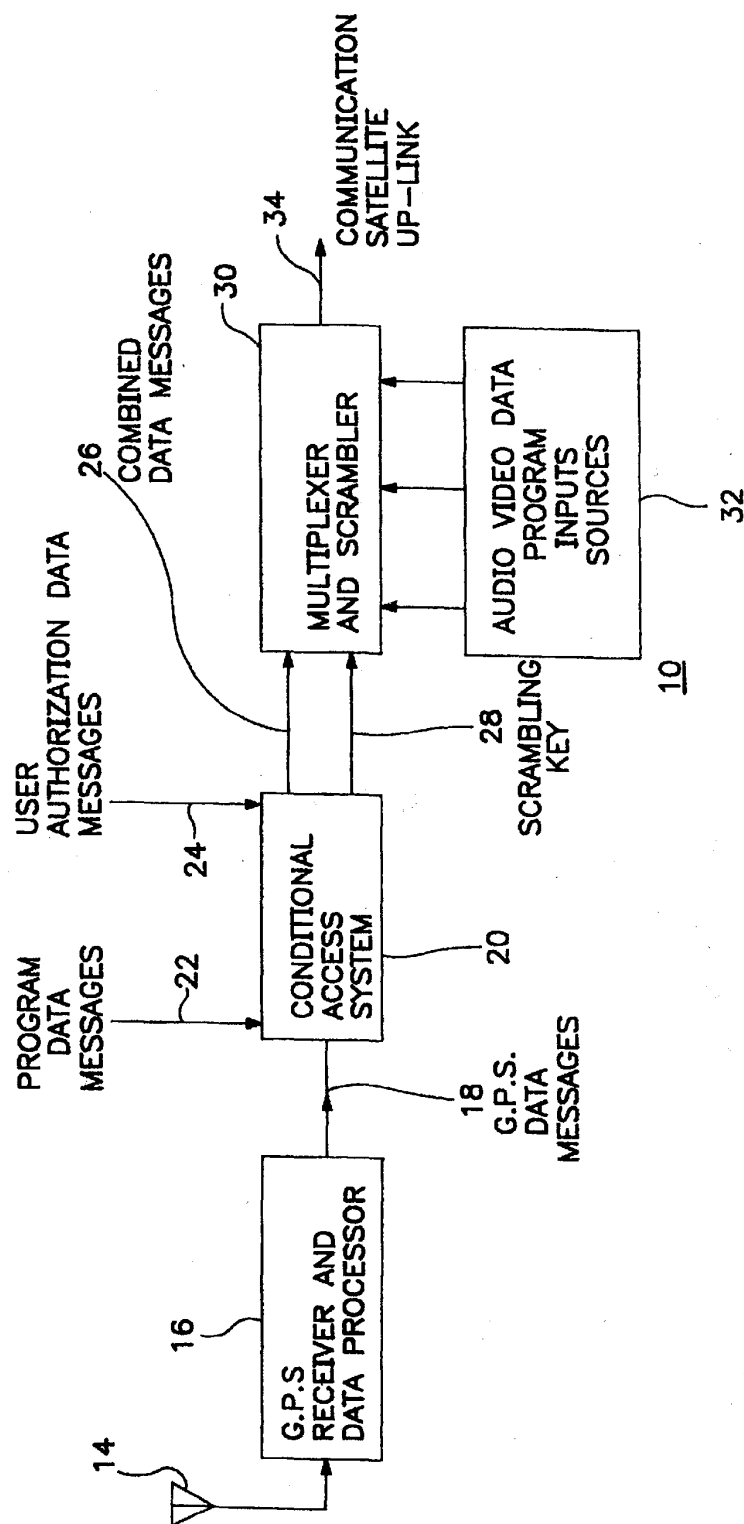


FIG. 1

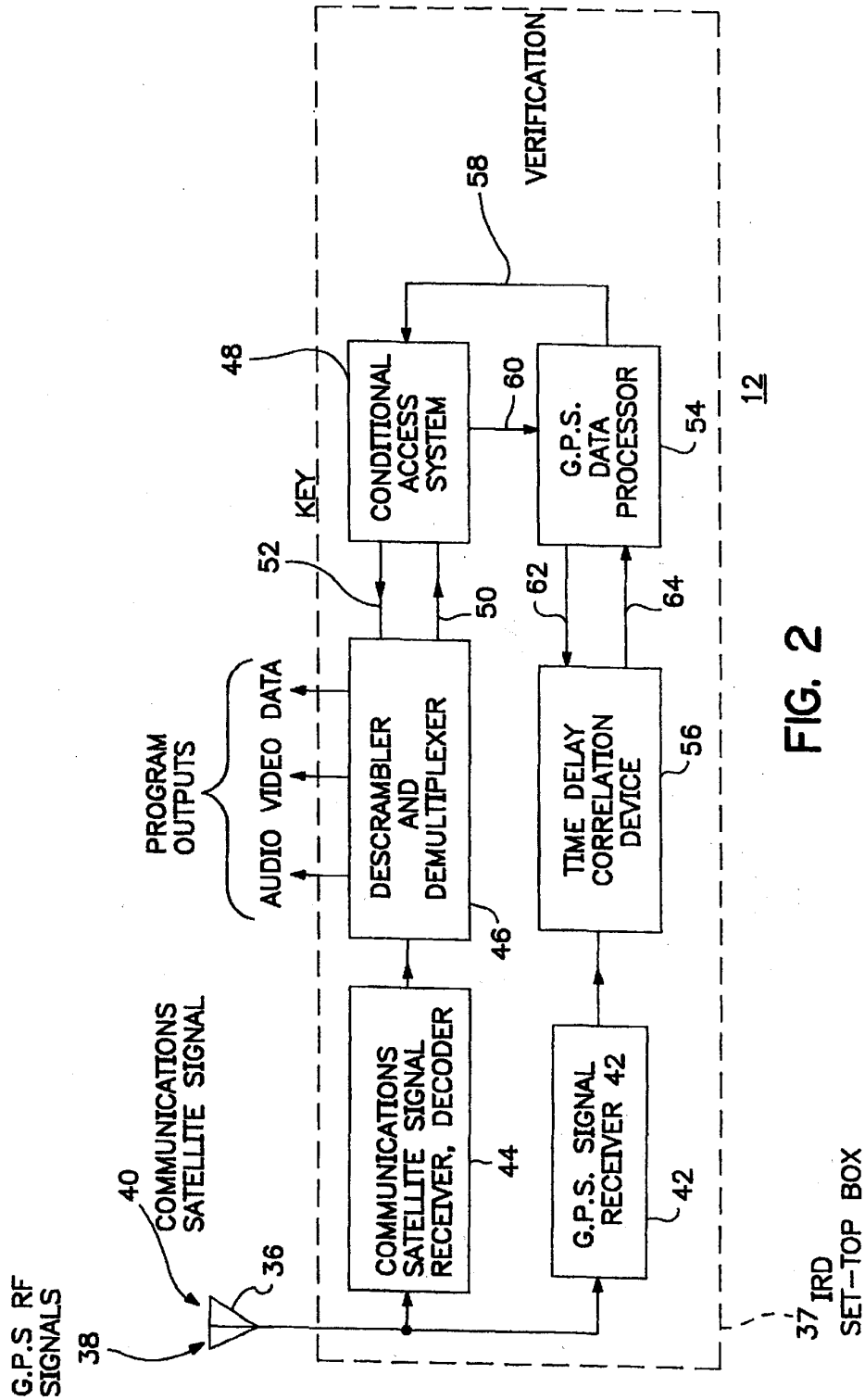
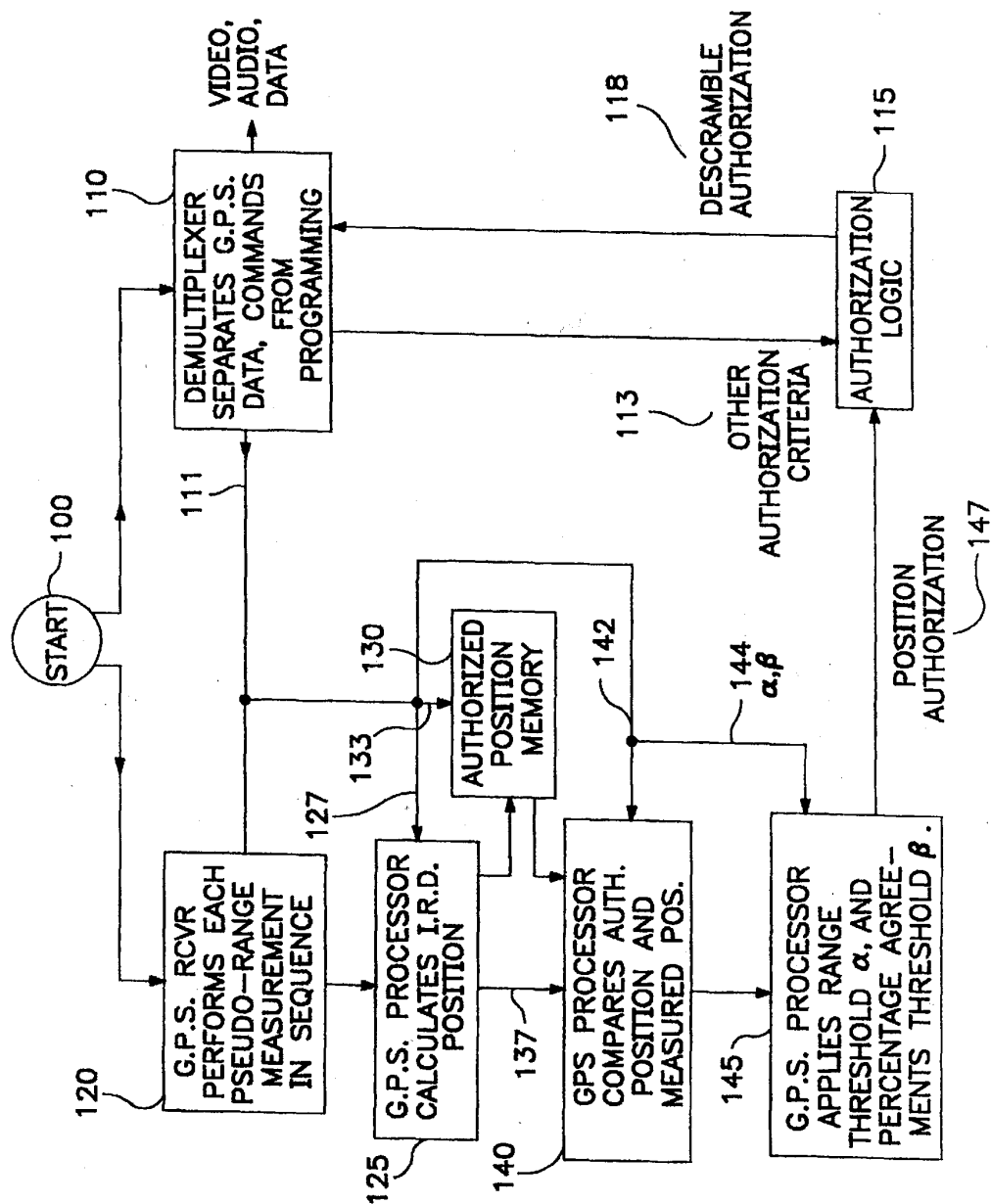


FIG. 2



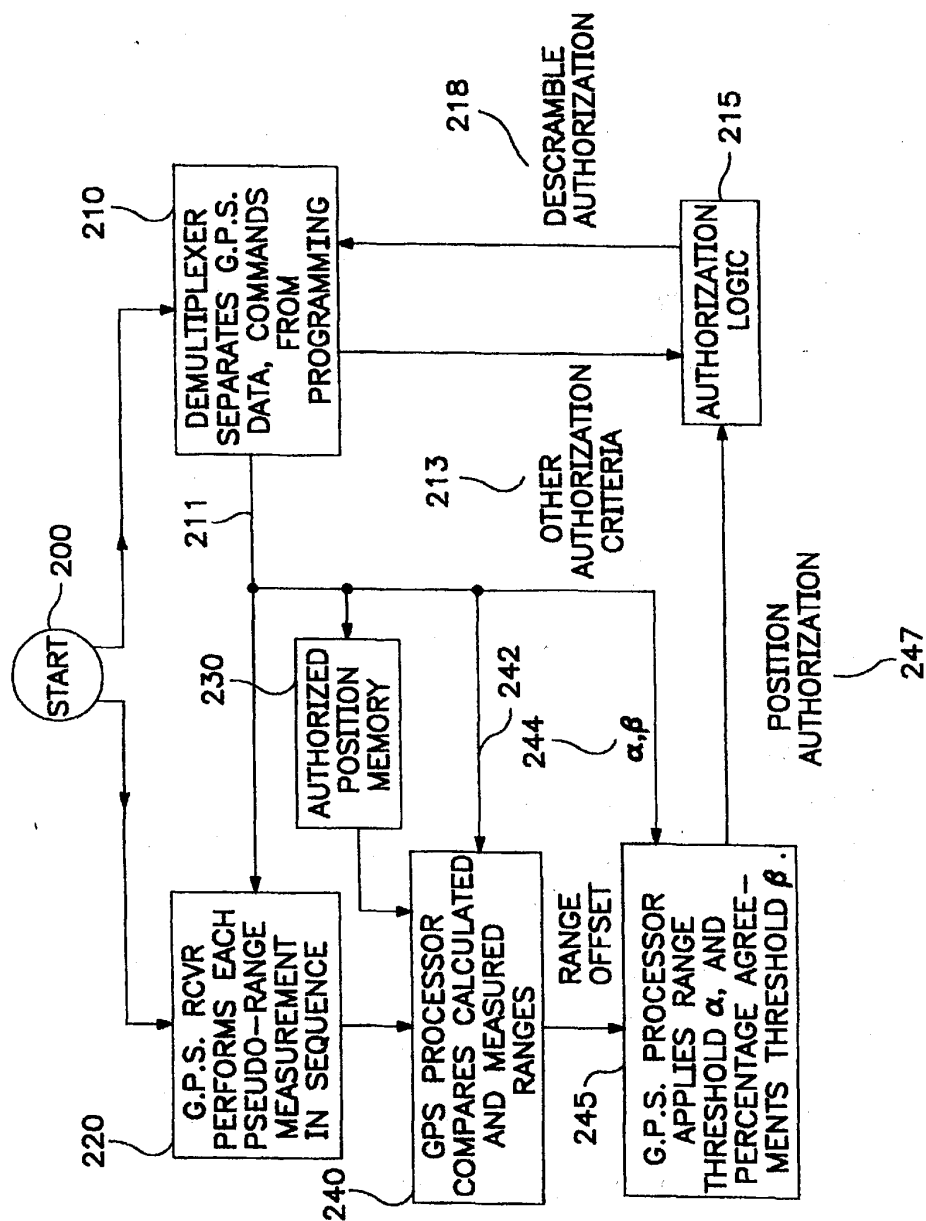


FIG. 4

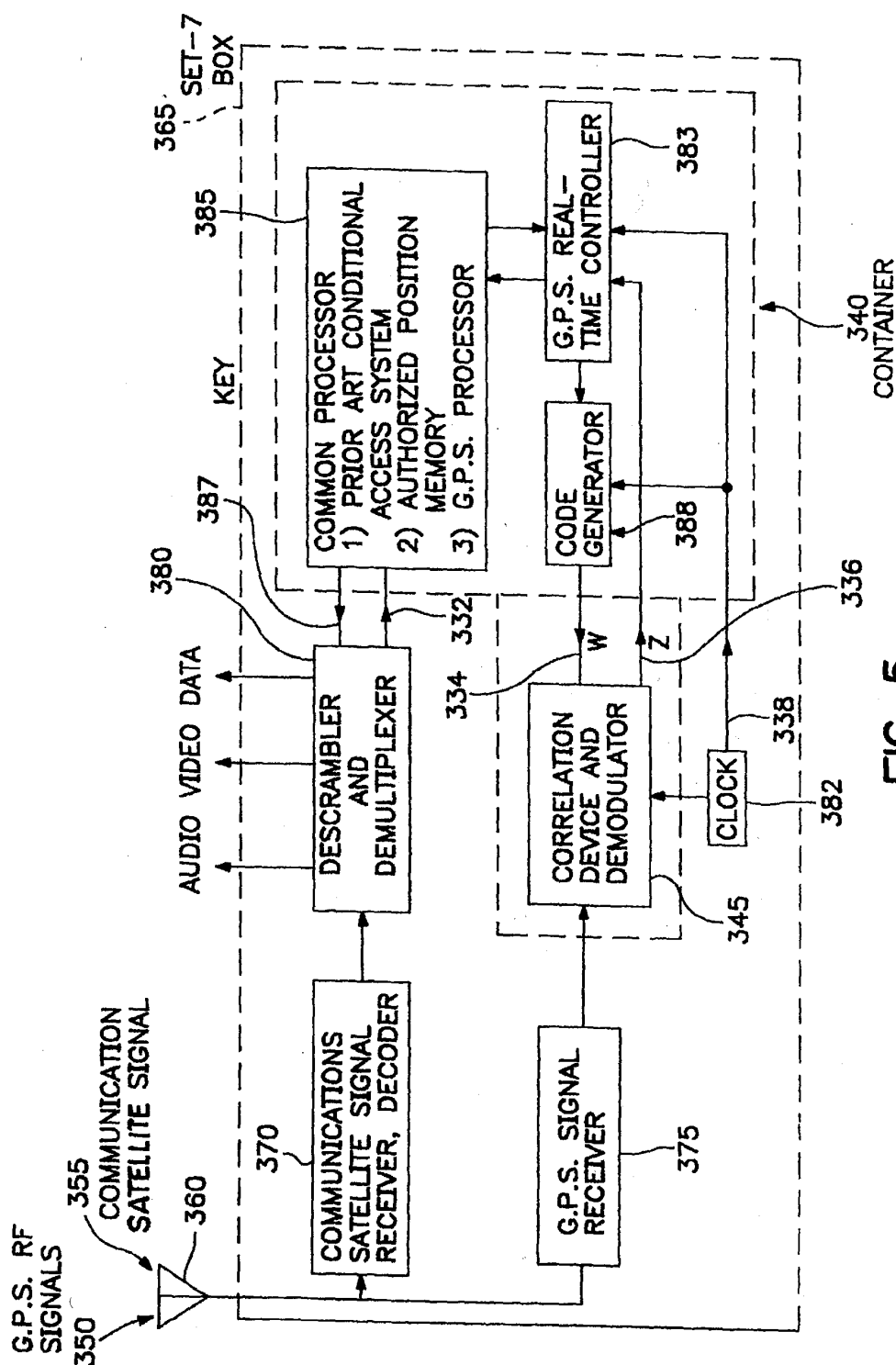


Fig. 5

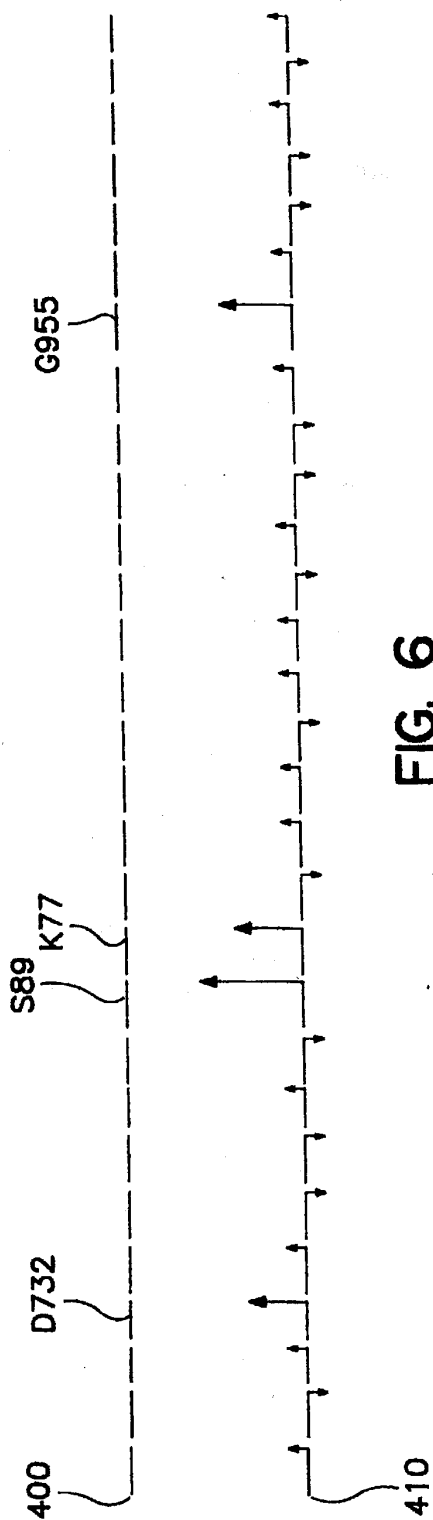


FIG. 6

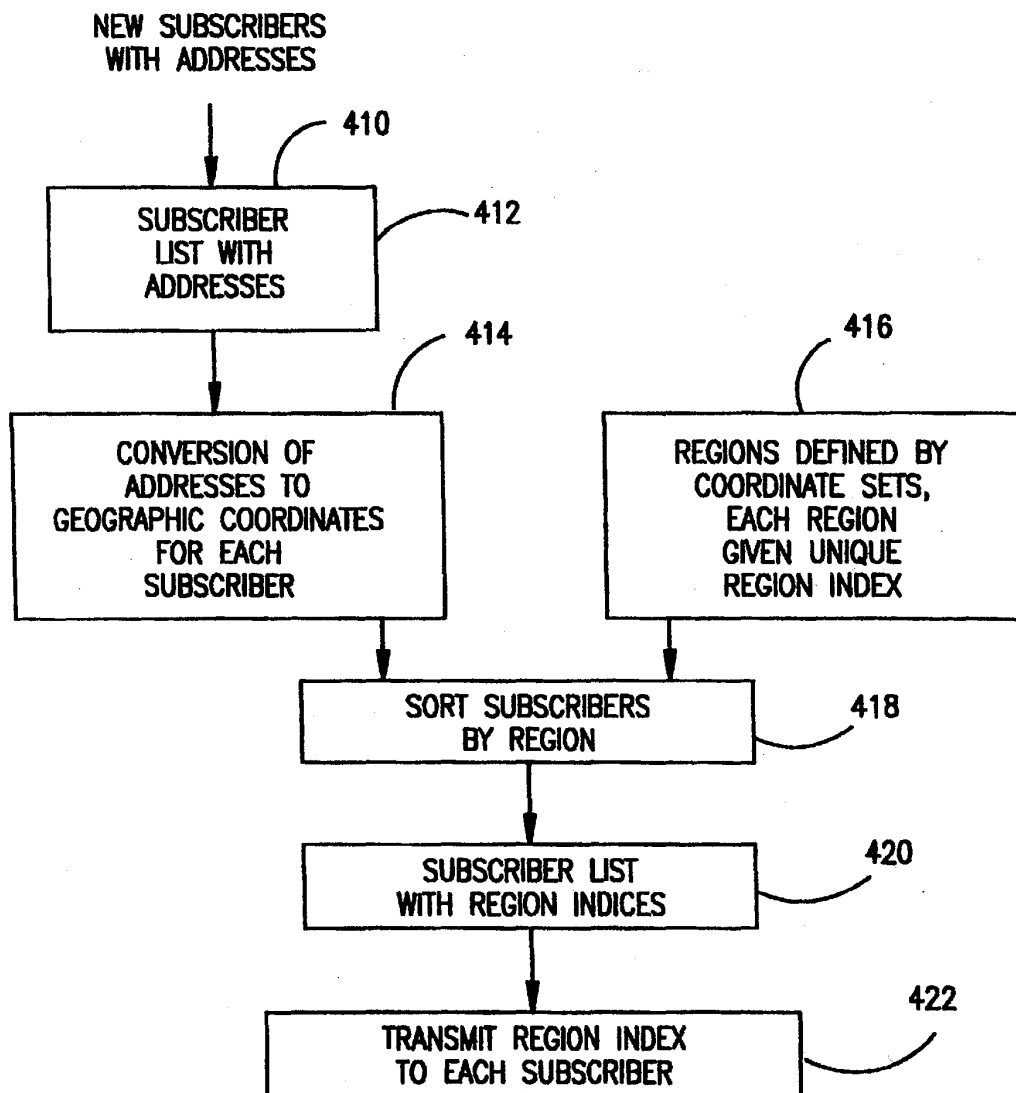


FIG. 7

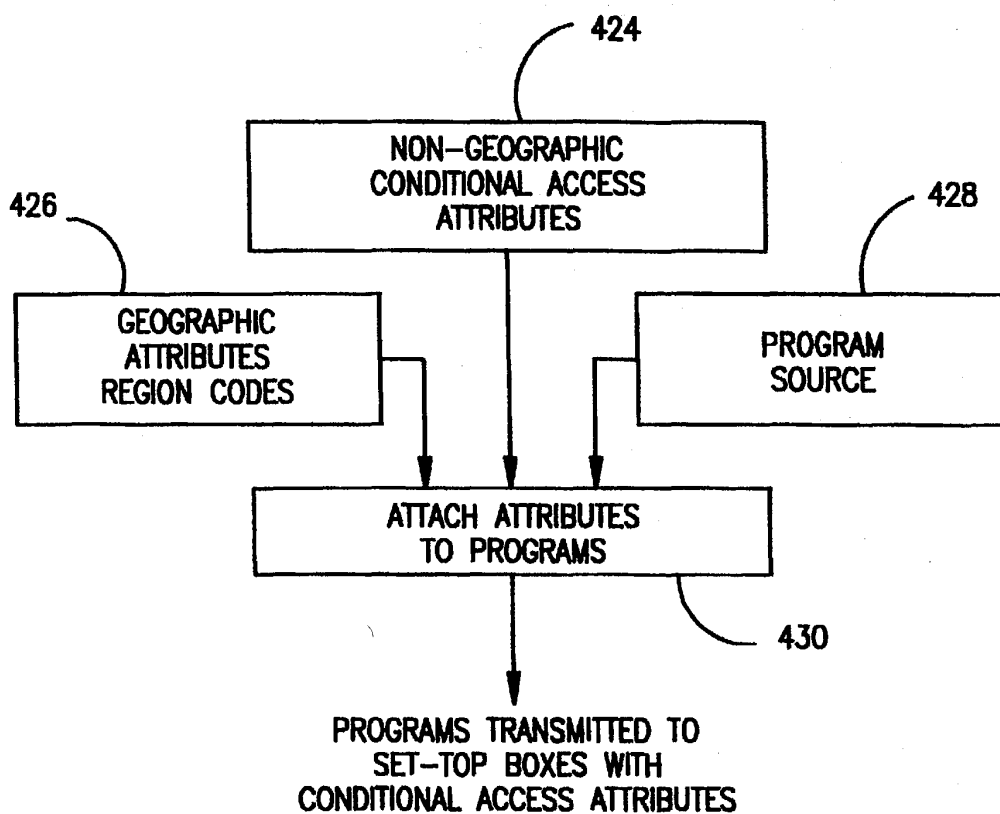


FIG. 8

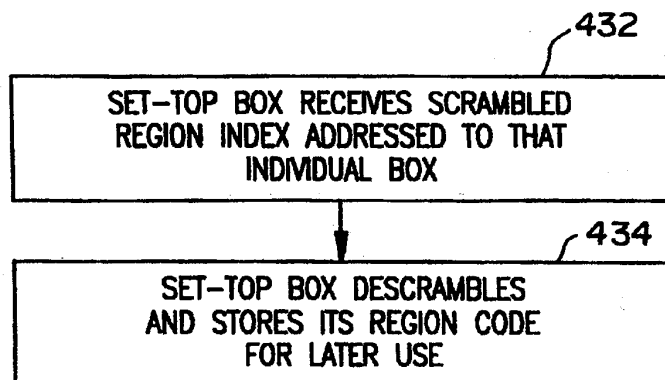


FIG. 9

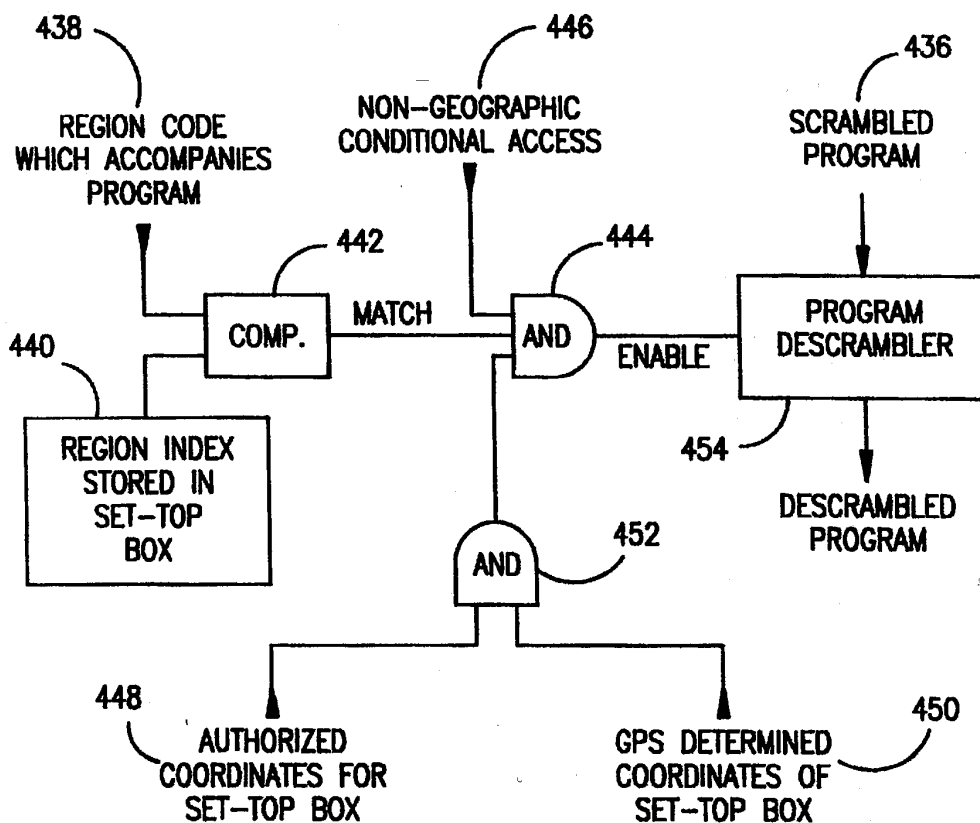
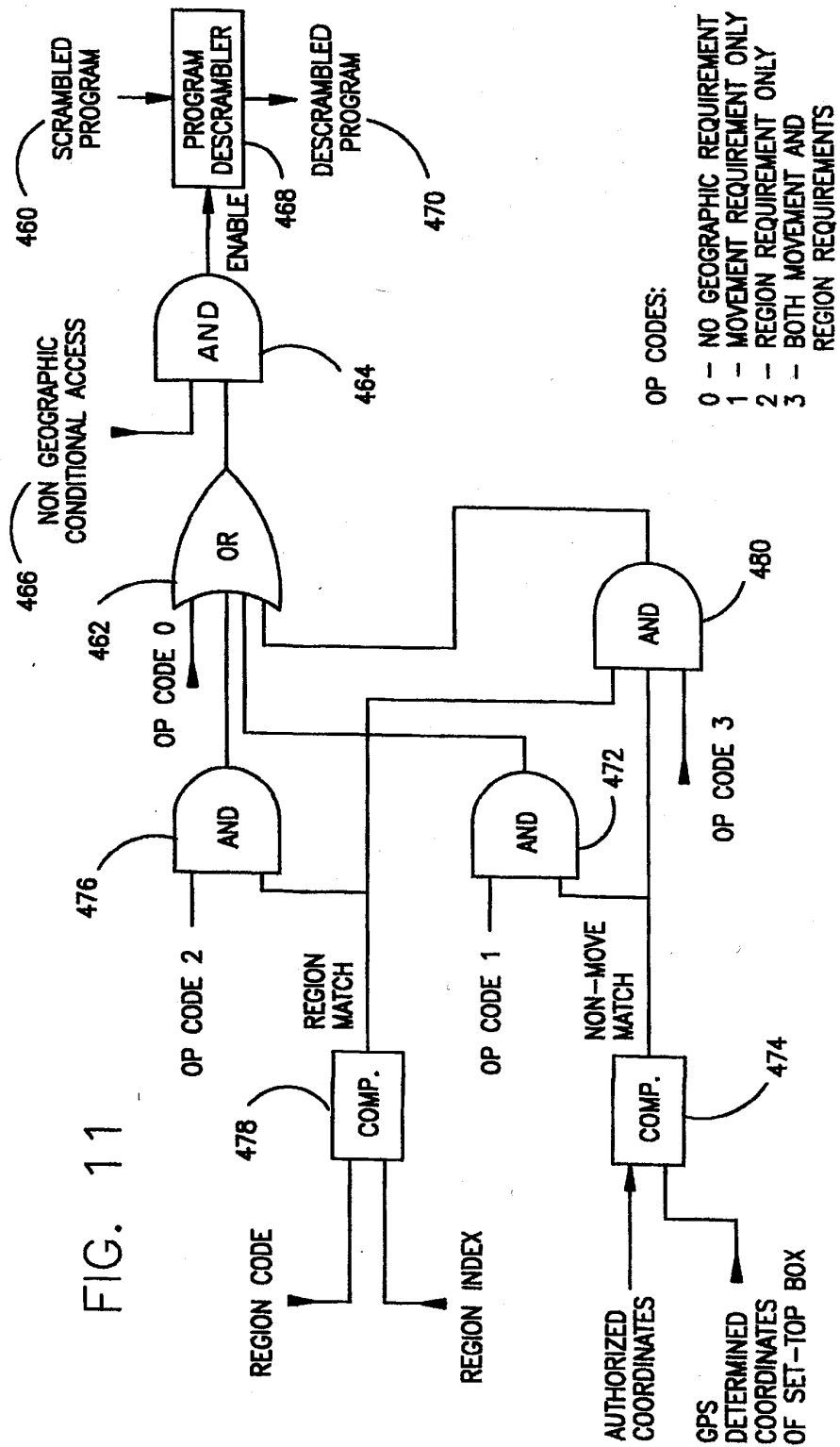
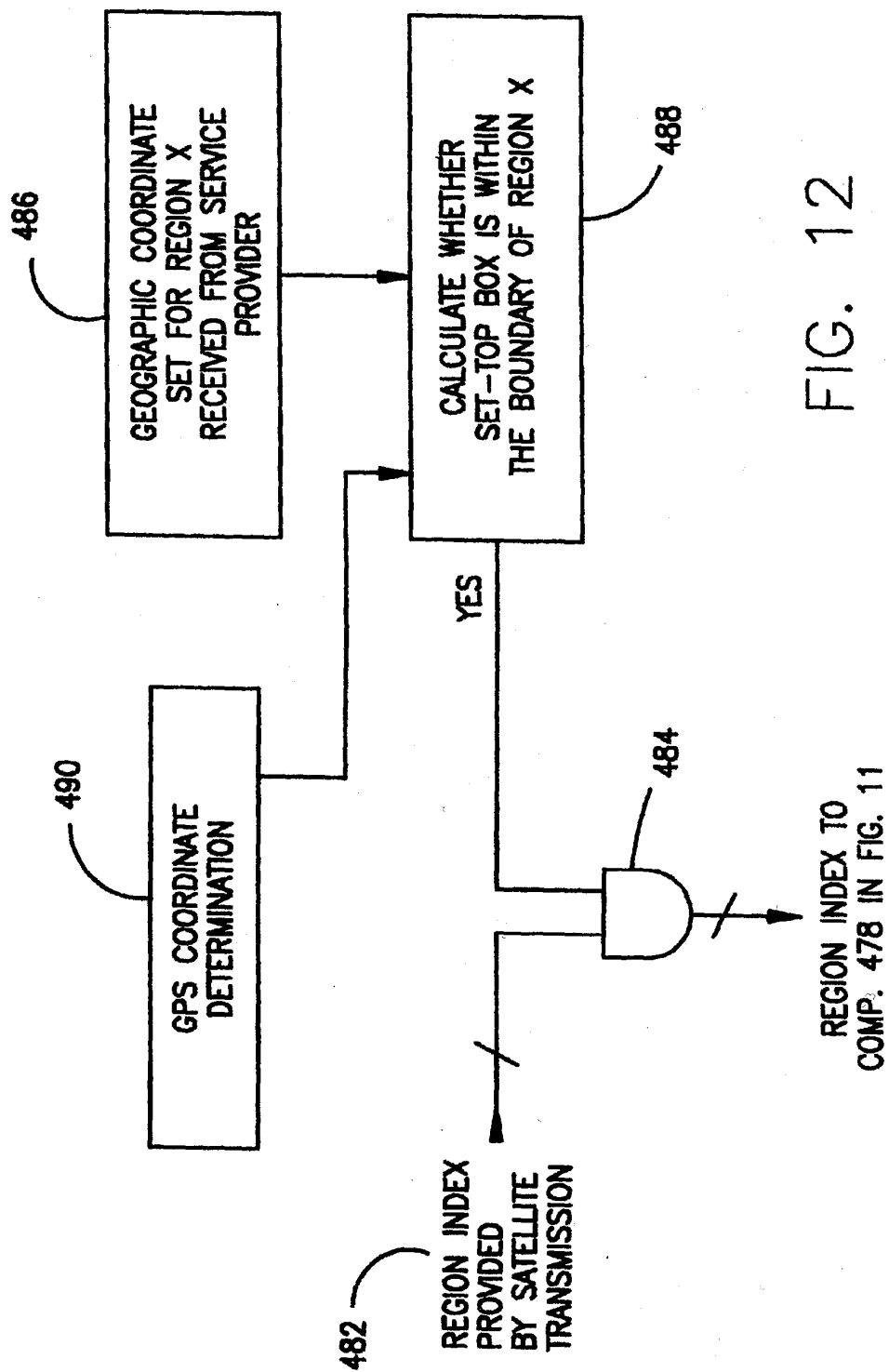


FIG. 10





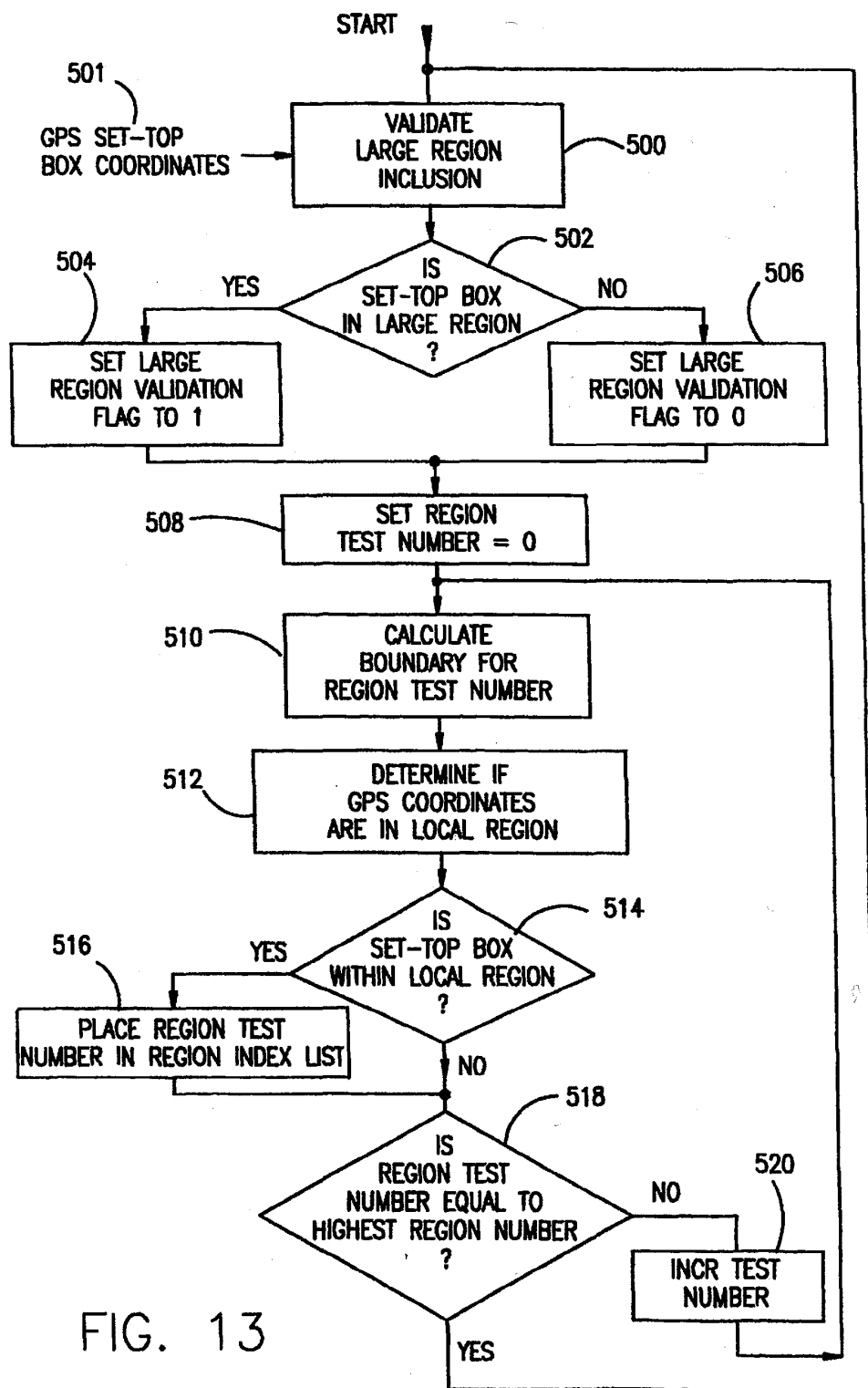


FIG. 14

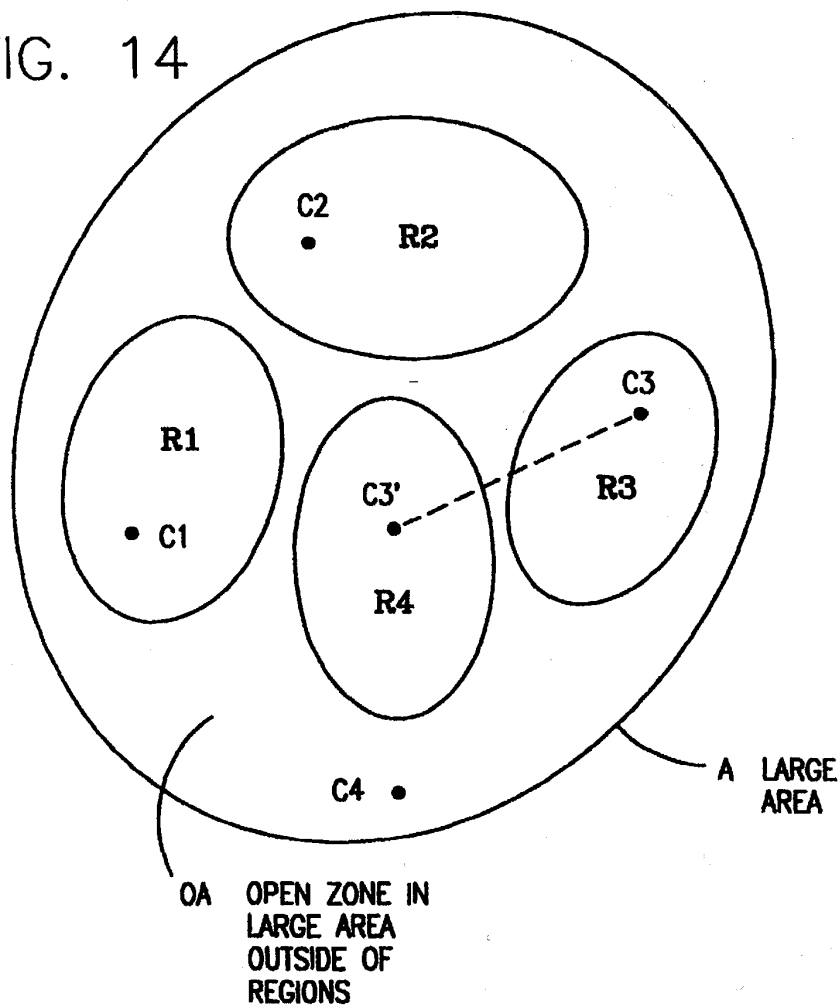
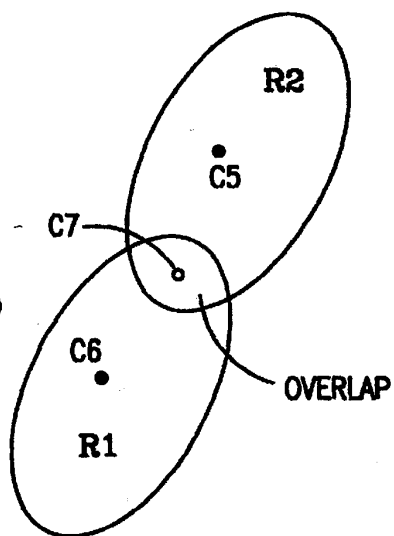


FIG. 15



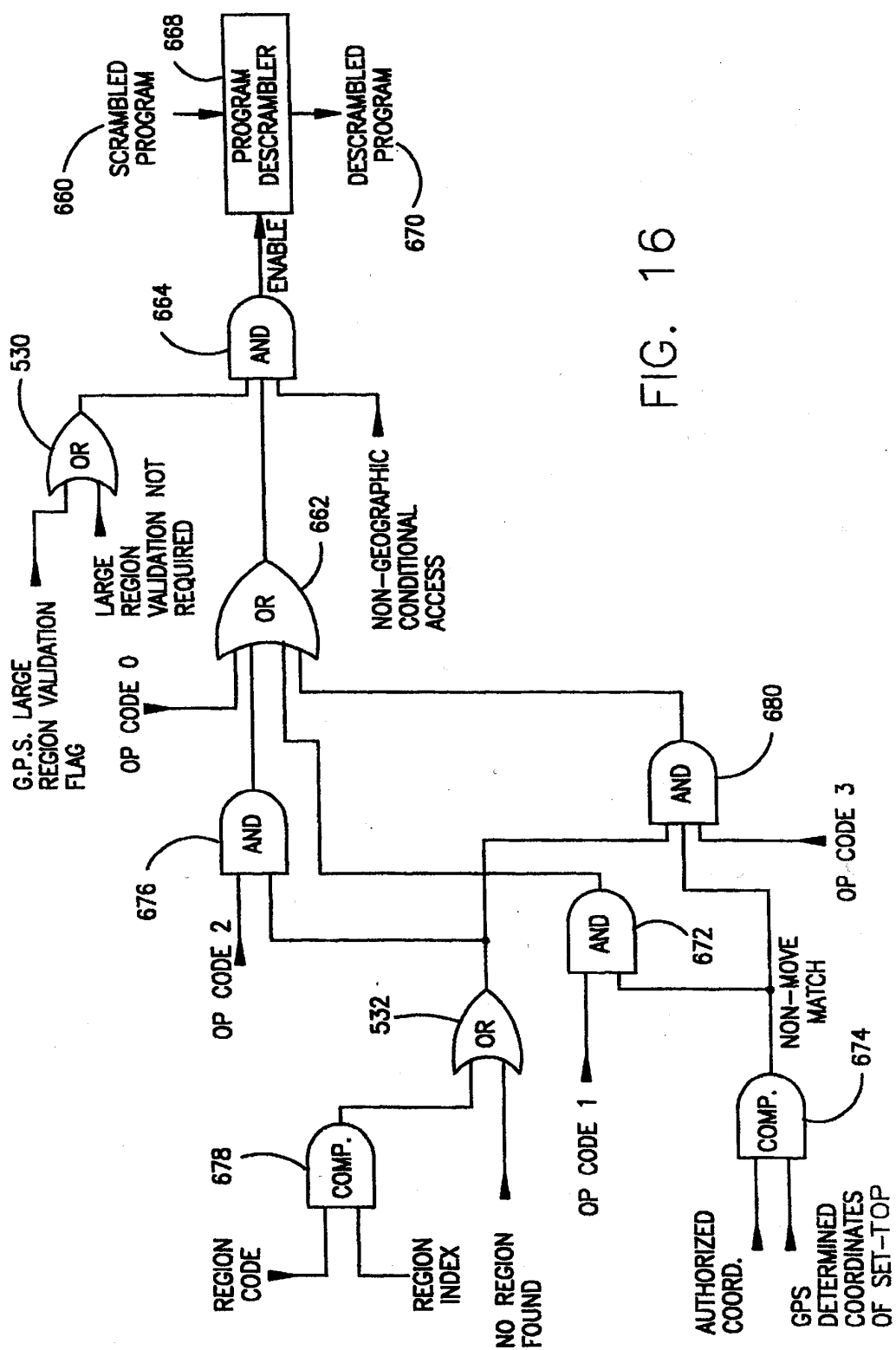


FIG. 16

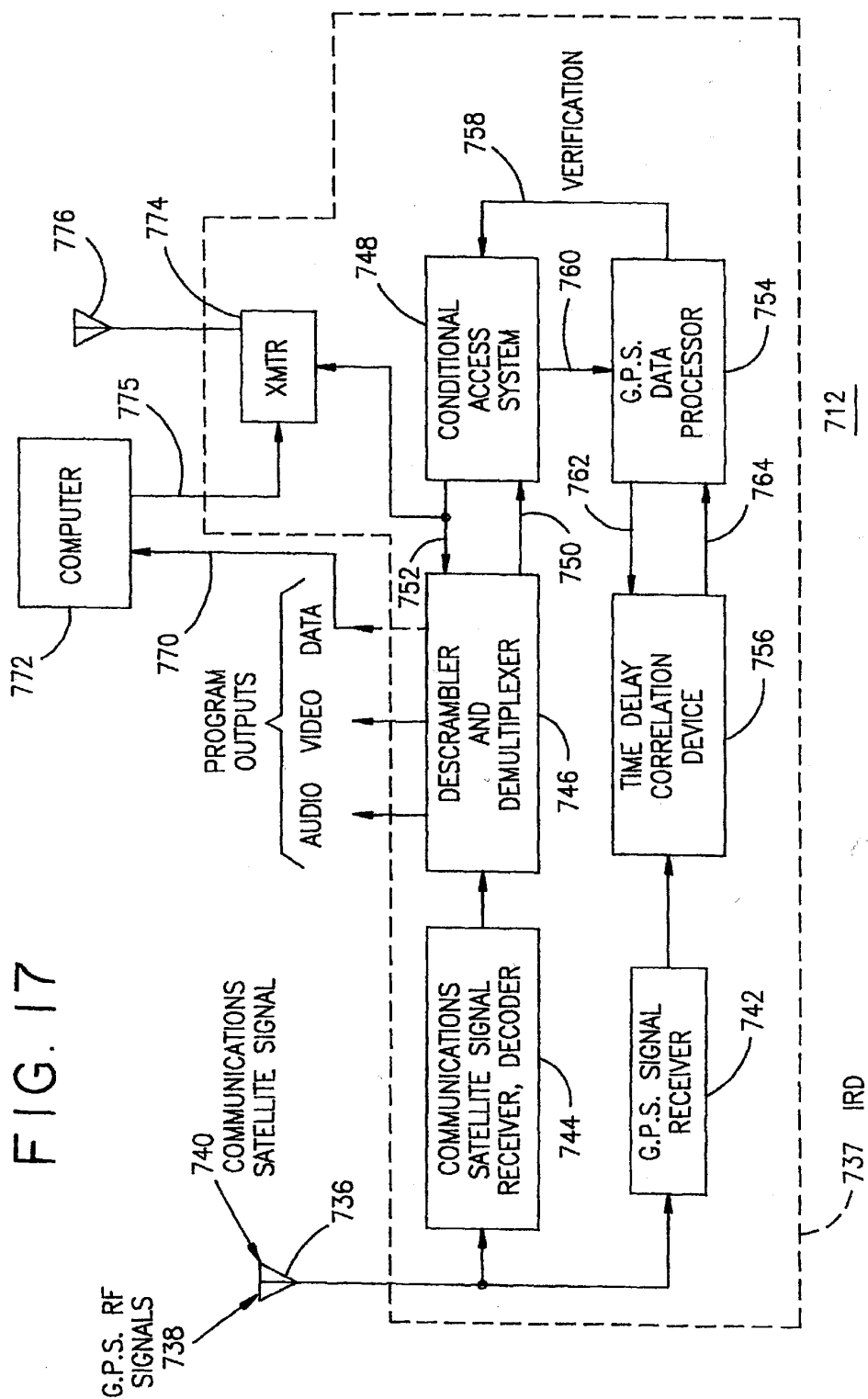


FIG. 18

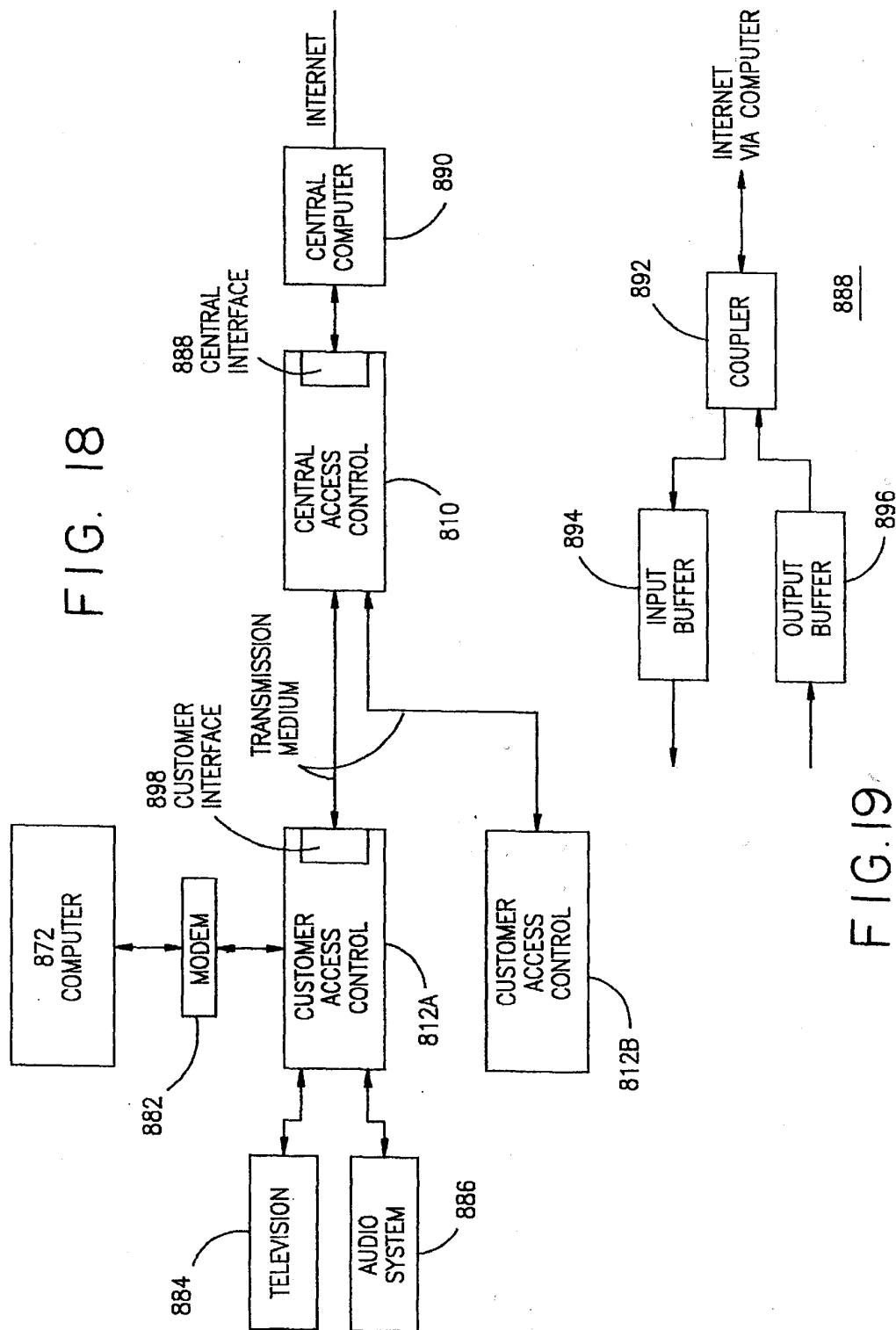
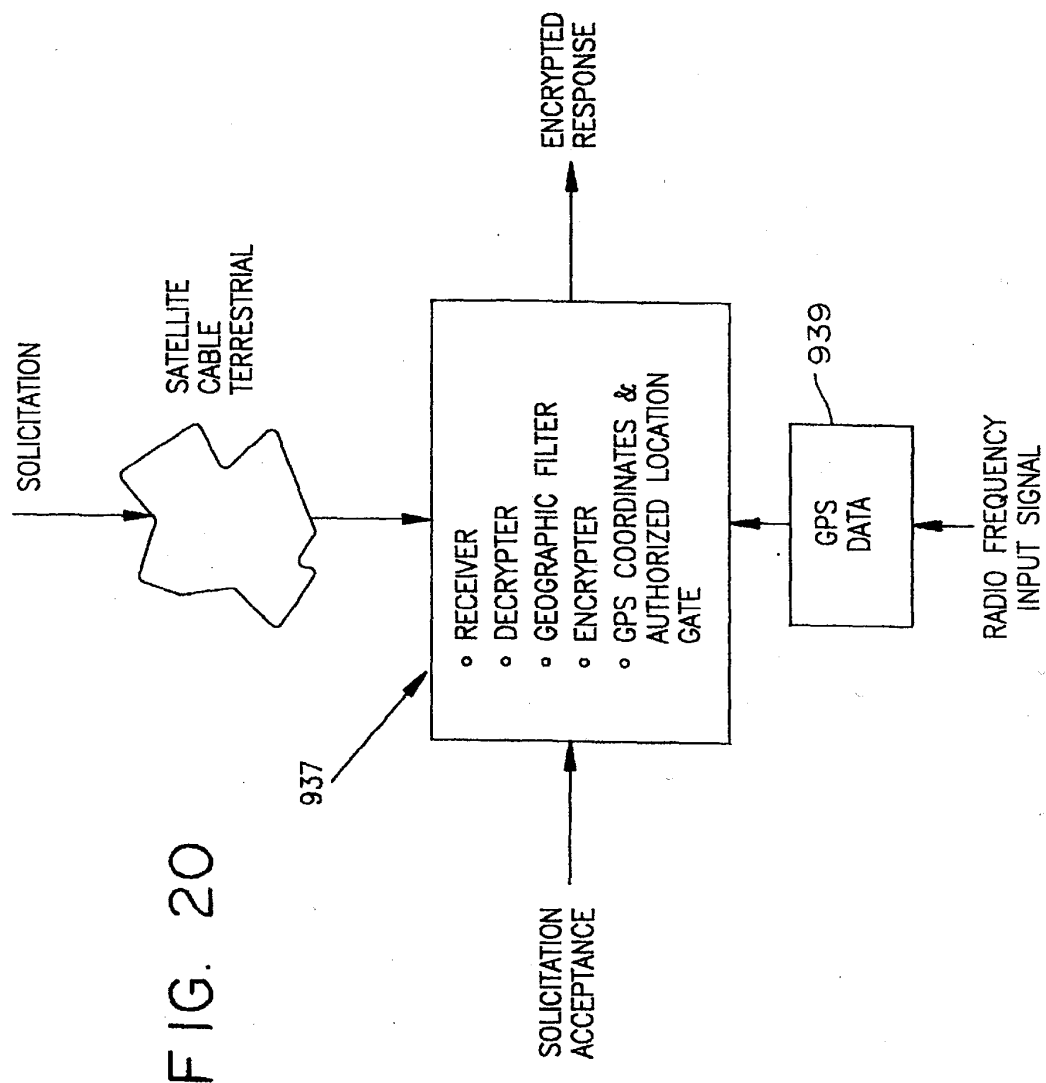


FIG. 19



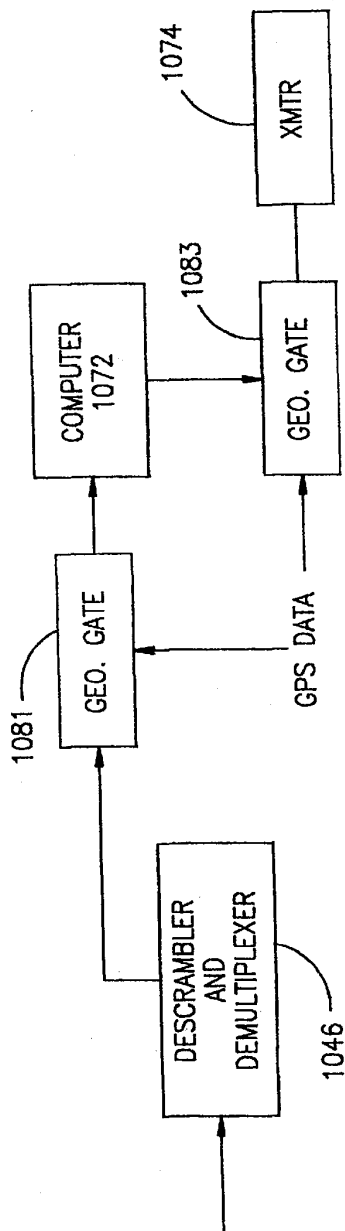


FIG. 21

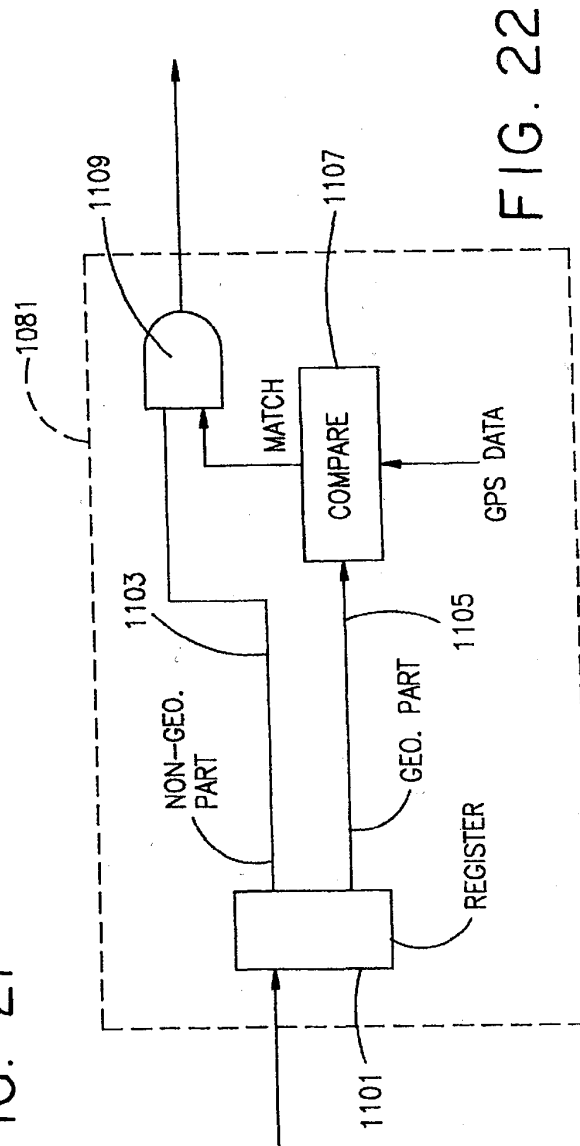


FIG. 22

GPS DATA ACCESS SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. No. 08/842,573 of the present inventors entitled "GPS TV Set Top Box With Regional Restrictions" filed Apr. 15, 1997 issued as U.S. Pat. No. 6,009,116 on Dec. 28, 1999. That application was in turn a continuation-in-part of U.S. patent application Ser. No. 08/437,424 of the present inventors entitled "TV Set Top Box Using GPS" filed May 5, 1995, issued as U.S. Pat. No. 5,621,793 on Apr. 15, 1997. Those patent applications, assigned to the assignee of the present application, are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates to a signal access control system. If the signals are video signals the system may be referred to as a tv or television set-top box. More specifically, the present invention relates to such a system where access to Internet or other computer network data signals from a remote source is allowed only if the system is in an authorized location. Additionally, access to some signals is more restricted geographically than access to other video signals.

Set-top integrated receiver decoder (IRD) boxes are now being used to allow persons to directly receive subscription and pay video transmissions from satellites using small outdoor antennas. Decoder boxes may also be used for encoded or scrambled over the air video signals (i.e., broadcast from ground transmitter to customer/viewer without passing through satellite therebetween) or for cable (i.e., wire or optical fiber) video signals. Since the functions of the set-top boxes can be realized also by components integrated into a television set, video cassette recorder, or other devices, the terms "customer access control" will be used herein for the components at the customer's location that control access.)

The satellite transmissions may be digitally compressed in order to accommodate many programs on a single carrier and multiple carriers on a single satellite. Many of the programs are authorized for distribution and reception only in certain geographic regions, particularly certain countries, where program rights have been obtained for their transmission and reception. Additionally, a set-top box may be authorized only for non-commercial personal use by consumers and not by hotels, theaters or other commercial activities. It is therefore useful for the operators of a video distribution system (whether satellite, over the air, or cable) that their set-top boxes are operable only at authorized locations and that the boxes inhibit authorization of program descrambling of the boxes at unauthorized locations. (As used herein, "cable" is a wire or optical fiber connection.)

Various patents have issued on IRDs. Although customer access controls such as decoders are usually separate from the television receiver (hence the common name set-top box), it should be understood that they could also be integral (in a common housing) with a television receiver, monitor, or video cassette recorder.

The following U.S. Patents, hereby incorporated by reference, only a few of which will be discussed below, are noted relative to access control for video signals or communications signals:

Inventor	Patent No.	Issue Date
Teare et al.	5,243,652	Sept. 07, 1993
Daniel et al.	5,224,161	June 29, 1993
Cohen et al.	5,282,249	Jan. 25, 1994
West, Jr.	5,345,504	Sept. 06, 1994
Mason	4,736,422	April 05, 1988
Jeffers et al.	4,739,510	April 19, 1988
Mason	4,802,215	Jan. 31, 1989
Kudelski et al.	5,144,663	Sept. 01, 1992
Leduc et al.	5,208,856	May 04, 1993
Wilson et al.	5,295,188	Mar. 15, 1994
Naccache et al.	5,347,581	Sept. 13, 1994
Diehl et al.	5,373,557	Dec. 13, 1994

The Teare patent shows use of a global position system (GPS) receiver to authorize release of an encryption key only when a location versus time track corresponds to a proper use. If the key is released, it allows the remote unit to view a scrambled video tape, which tape is at the remote unit. The remote unit is in an airplane which is allowed to show the video tape when it is in a given location or country and its position changes are consistent with the anticipated flight path.

Daniel shows video descrambling using a smart card and a pseudo-random generator.

Cohen discloses video descrambling using a smart card.

West shows cable television access regulated by a jamming signal.

In other developments, the NAVSTAR GPS achieved full initial operating capability in 1993 and provides precisely timed radio frequency signals from twenty-four orbiting satellites. A GPS receiver utilizes the transmission delay time from multiple orbiting satellites to make a determination of the position of the GPS receiver. The receiver must have a clock with good short term accuracy to lock onto and track a code message sent by a GPS satellite and further to make accurate pseudo-range measurements. A time-offset error between the highly accurate atomic standard clock in each satellite and a receiver can be removed by operating on the signal codes sent from four satellites rather than just three. The extra satellite signal permits a mathematical solution for the time offset as well as the ranges between satellites and receiver.

Some GPS receivers presently cost only a few hundred dollars, making them satisfactory for ships, aircraft and other vehicles where position determination is desired. The GPS receiver includes a microprocessor to perform calculations on measured data, special circuitry to calculate correlations, and requires a visual display, packaging, power supply, etc. Some of these items are already in the set-top box for other purposes and other functions can be simplified by performing a portion of the processing at the up-link site and transmitting the results along with commands over the same communication system providing the video, audio and data programming to the IRD's. The complexity of the IRD processing to accommodate the physical position validation can then be reduced to a level where the cost of electronic circuitry to implement these functions is acceptably small.

In the normal operation of a GPS receiver time-of-arrival measurements of code-division multiplexed radio signals from multiple GPS satellites are made by the receiver. These measurements are then converted to pseudo-range measurements using the radio wave propagation velocity. The range measurements are called pseudo-range because of a time bias error introduced by imperfect receiver time synchroni-

zation with the satellites' precise timing controlled by atomic clocks. The time bias is treated as an additional variable in the position calculations and one additional pseudo-range measurement is made to provide an additional equation to solve for this additional variable. Although the calculations to be performed are straight forward, a position solution must be iteratively calculated to converge on a solution. Additionally, corrections must be calculated for propagation effects in order to produce accurate position determination as normally required for airplanes, ships, boats, or other vehicles.

The following U.S. Patents, hereby incorporated by reference, show various GPS receivers and/or methods:

Inventor	Patent No.	Issue Date
Holmes et al.	4,807,256	Feb. 21, 1989
Allison et al.	5,359,332	Oct. 25, 1994
Gilbert et al.	5,379,045	Jan. 03, 1995

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to provide a new and improved signal access control system.

A more specific object of the present invention is to provide a signal access control which authorizes access to an Internet data signal or data signal from another computer network.

A more specific object of the present invention is to provide a signal access control which authorizes access to the signal only if the customer access control is at the authorized location.

A further object of the present invention is to provide customer access control using position wherein a GPS receiver is utilized.

A further object of the present invention is to provide customer access control wherein access to different signals can be restricted geographically to a given region.

A still further object of the present invention is to provide customer access control wherein access to different signals can be restricted geographically to different degrees. For example, some signals are accessible over a large area, whereas other signals are accessible only in a particular limited region. Other signals are excluded from access in certain regions.

A further object of the present invention is to provide customer access control using position wherein a GPS receiver is utilized.

Yet another object of the present invention is to provide simple, low cost customer access control using position wherein a simple GPS receiver or a single channel GPS receiver is utilized, such a receiver being suitable for authorization at a single fixed location.

A further object of the present invention is to provide signal access control using a central access control at a source of the signals and remote from the customers.

Yet another object of the present invention is to provide a signal access control system having central access control using a GPS receiver and wherein the central access control supplies position information to the transmission medium for transmission to customers.

A further object of the present invention is to provide a signal access control system using multiple criteria for

authorization including location and other factors such as payment for service, no black out (i.e., blocking of signal) resulting from parental restrictions on programming available to children, and no black out resulting from regional restrictions (e.g., sports event may be shown in areas only outside of the city, area, or state in which the event takes place).

A still further object of the present invention is to provide a signal access control system having a customer access control at a customer's place, wherein the customer access control is highly resistant to attempts to defeat access control.

It is desirable to have each and every set-top box perform signal descrambling only if it is physically located where it has been authorized. A system is herein described which uses the existing NAVSTAR Global Positioning System (GPS) to aid in validating the location of each set-top box and authorizing it to descramble program services ordered by the consumer, along with other criteria including payment for services, only if it is physically located where it was authorized. As used herein, GPS shall mean a system using a plurality of radio transmitters at different locations and a receiver which uses transmissions from the transmitters to determine or validate the location of the receiver. Of special concern is the ability of a position determining device within the set-top box to not be defeated by someone wishing to use the box at an unintended location. The system herein is resistant to insertion of false data which would cause the position to be determined as the one authorized while existing at an unauthorized position. Finally, it is required that the position determining device be as inexpensive as possible.

The present application presents more specifics of the data access control system. In particular, the use of the set-top box (more generally, customer access control) for controlling access to data such as Internet access.

The present invention provides methods of implementation for a flexible set of geographically restrictive conditions of reception of data or satellite broadcast signals. These conditions may be associated with certain program distribution rights connected with certain specific programs and these rights cover certain geographic areas, or conversely they may exclude certain geographic areas. As an example of programming which can cover only a specific geographic area, television networks authorize each of their network affiliated stations use of the network material only in a specific geographic area, usually a region around a specific city. Separate contractual arrangements are made with different entities for different geographic areas. As a result it is not permissible for one entity to broadcast its signals into the region of another entity. Although these conditions of geographically restricted zones are contractual, the usual case of terrestrial broadcast transmitters generally will be geographically limited simply as a result of the transmitter. That is, a terrestrial transmitter transmits a signal which is receivable only in a reception area sufficiently near to the transmitter. However, when the broadcast transmitter is on a satellite a similar contractual geographic limitation may hold. That is, the satellite transmitter which re-broadcasts the signal of the terrestrial transmitter may be similarly restricted by an existing legal contract. Signal reception of a terrestrial broadcast transmitter is physically limited in distance from the transmitter by earth curvature. The signal reception area for a satellite transmitter is determined largely by the satellite's transmitting antenna beam pattern which often covers a whole country, or more.

Beyond the geographic restrictions on video signals such as satellite transmission signals, some data signals may be

geographically restricted. For example, a news wire service may allow distribution of its data in one country via a given distributor and that distributor might be contractually forbidden from distributing the data in another country. In any case, the geographic restriction possibilities on video signals as discussed in the following are, under some conditions, applicable in various data program transmissions. The data may be the actual product that the customer wishes to view or access (i.e., as opposed to data to control distribution of video or audio signals), such as Internet data or other computer network data.

Satellites may provide spot beams, which cover narrower regions on the earth than normal satellite transmission patterns. However, such spot beams still usually cover a wider area than do terrestrial transmitters. An additional mechanism is required to cause the coverage area of the satellite transmitter to more closely coincide with that of the terrestrial transmitter. The customer access control or Set-Top box employing GPS can be made to provide this additional mechanism.

The present invention may be described as a signal access control system including a customer access control operable at a customer location. A signal input receives at least one signal from a remote source. A signal processor is operably connected to receive signals from the signal input. A conditional accesser is operably connected to the signal processor. A signal output is operably connected to the signal processor and provides a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source. A GPS signal receiver is operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser. The conditional accesser authorizes access only if the GPS signal receiver receives signals consistent with the customer access control being at an authorized location.

In one embodiment, the conditional accesser authorizes access only if the GPS signal receiver receives signals consistent with the customer access control being at a single fixed location authorized for service. The conditional accesser authorizes access using criteria to test for authorization in addition to information about the location of the customer access control.

The customer access control further includes a GPS processor operably connected to receive direct GPS information from the GPS receiver and a decoder operably connected to the signal input to provide indirect GPS signals received from a transmission medium carrying the at least one signal from a remote source. The GPS processor uses information from the indirect GPS signals to determine which GPS sources are to be used by the customer access control and the location of the determined GPS sources.

The system further includes a central access control remote from customers and has: a source of at least one signal; an output device for placing signals from the source onto a transmission medium for transmission to customers with the customer access control; a central GPS receiver operable to receive position information from remote sources and operably connected to apply data messages to the output device, the data messages corresponding to the position information and the output device supplying the position information to the transmission medium for transmission to customers.

The signal input receives signals from a transmission medium selected from the group consisting of satellite broadcast, non-satellite broadcast, and cable and the signals

received via the transmission medium selected from the groups consisting of audio signals, video signals, and data signals.

In one embodiment, the signals received via the transmission medium include video signals.

In another embodiment, the signal input receives data program signals. More specifically, the signal input receives data program signals corresponding to data from the Internet and the customer access control includes a customer output device operable to place outgoing signals on the Internet. The central access control further includes a central Internet interface and wherein the customer output device is operable to place outgoing signals on the Internet via the central Internet interface of the central access control. The transmission medium used by the central output device and the transmission medium used by the customer output device are the same transmission medium.

The invention may alternately be described as a signal access control system including a customer access control operable at a customer location and has: a signal input to receive at least one signal; a signal processor operably connected to receive signals from the signal input; a conditional accesser operably connected to the signal processor; a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source; and a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser, the conditional accesser authorizing access only if the GPS signal receiver receives signals indicating that the customer access control is at an authorized location; and wherein the conditional accesser authorizes access only if the GPS signal receiver receives signals consistent with the customer access control being at a single fixed location authorized for service. The signal input receives data program signals corresponding to data from the Internet. The customer access control includes a customer output device operable to place outgoing signals on the Internet.

The present invention alternately may be described as a signal access control system including a customer access control operable at a customer location and having: a signal input to receive at least one signal; a signal processor operably connected to receive signals from the signal input; a conditional accesser operably connected to the signal processor; a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source; and a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser. The conditional accesser authorizes access only if the GPS signal receiver receives signals indicating that the customer access control is at an authorized location; and wherein the conditional accesser uses criteria to test for authorization in addition to information about the location of the customer access control.

The present invention may alternately be described as a signal access control system including a central access control remote from customers and having: a source of at least one signal; an output device for placing signals from the source onto a transmission medium for transmission to customers; a central GPS receiver operable to directly receive position information from remote GPS sources, the remote sources being remote from both the central access control and the customers, and operably connected to apply

data messages to the output device. The data messages correspond to the position information and the output device supplying the position information to the transmission medium for transmission to customers. A central access control includes a central Internet interface operable to bi-directionally convey signals to and from the Internet based on interactive real-time actions of customers remote from the central access control.

The present invention may alternately be described as a signal access control system including a customer access control operable at a customer location and having: a signal input to receive at least one signal from a remote source; a signal processor operably connected to receive signals from the signal input; a conditional accesser operably connected to the signal processor; a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source; a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser. The conditional accesser authorizes access only if the GPS signal receiver receives signals consistent with the customer access control being at an authorized location. A region comparer is operable to compare a region code received with the at least one signal from the remote source with a region index stored at the customer location and operable to output a region comparer output, the region code being representative of a geographic region authorized to receive a signal and the region index being representative of a geographic region of the customer access control, there being different region codes for different geographic regions. The conditional accesser receives the region comparer output and conditions access to a given one(s) of the signals from the remote source upon the region comparer output indicating that those given one(s) of the signals are authorized for an access region of the customer access control.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features of the present invention will be more readily understood when the following detailed description is considered in conjunction with the accompanying drawings wherein like characters represent like parts throughout the several views and in which:

FIG. 1 is a simplified block diagram of a central access control used with a signal access control system according to the present invention;

FIG. 2 is a simplified block diagram of a customer access control used with the signal access control system;

FIG. 3 is a flow chart of a first embodiment customer access control which calculates its position;

FIG. 4 is a flow chart of a second embodiment customer access control which validates its position;

FIG. 5 is a block diagram of a customer access control having a tamper resistant feature which may use the techniques of either FIGS. 3 or 4;

FIG. 6 shows a sequence of correlation results for different Gold codes generated in a portion of FIG. 5;

FIG. 7 is a simplified block diagram of a supplemental portion of the central access control of FIG. 1;

FIG. 8 is a simplified block diagram of a further supplemental portion of the central access control of FIG. 1;

FIG. 9 is a simplified block diagram of a supplemental portion of the customer access control of FIG. 2;

FIG. 10 is a simplified block diagram of a further supplemental portion of the customer access control of FIG. 2,

which portion is a first embodiment geographically flexible customer access control;

FIG. 11 is a simplified block diagram of a second embodiment geographically flexible customer access control;

FIG. 12 is a region determiner arrangement which may be used with any of several embodiments of geographically flexible customer access control;

FIG. 13 is a flow chart for a third embodiment geographically flexible customer access control;

FIG. 14 is an illustration of geographic regions within a large area and used for explaining operations of the present invention;

FIG. 15 is another illustration of geographic regions used for explaining operations of the present invention;

FIG. 16 is a simplified block diagram of the third embodiment geographically flexible customer access control;

FIG. 17 is a simplified block diagram of a customer access control used with the signal access control system for Internet or other computer network connections;

FIG. 18 is a simplified block diagram of the customer access control of FIG. 17 coupled to a central access control for providing Internet or other computer network connections;

FIG. 19 is a simplified block diagram of an interface that may be used in FIG. 18;

FIG. 20 is a simplified block diagram of a geographic data limitation technique;

FIG. 21 is a simplified modification of parts of FIG. 17 showing a geographic gating technique of the present invention; and

FIG. 22 is a block diagram of a geographic gate of the present invention.

DETAILED DESCRIPTION

With reference to FIGS. 1 and 2, a signal access control system includes a central access control or system 10 of FIG. 1 and a customer access control or system 12 of FIG. 2. The discussion will initially emphasize distribution of video signals, but is applicable to data and/or audio signals as well.

The central access control 10 is remote from customers who subscribe to the various programs. An antenna 14 receives global positioning system (GPS) information from GPS satellites (not shown) and is connected to a central (i.e., remote from the customers/subscribers) GPS receiver/data processor 16, which may operate in known fashion to provide GPS data messages 18 to a central conditional access system or control 20. Specifically, GPS receiver/processor 16 is preferably a code division multiplex multiple channel receiver. The received signals are all at the same radio frequency, but each GPS satellite's signals has a different repeating code which differentiates it from the other signals.

GPS receiver/processor 16 is a high quality standard unit, but it determines which GPS satellites are best to use for position fixing at the sites where the customer access control systems 12 are. That is, a normal GPS receiver determines which satellites it should be using for position determination. GPS receiver/processor 16 will instead determine which satellites should be used at customers' sites. If the geographic coverage area of the various customers' sites is sufficiently large, GPS receiver/processor 16 will provide multiple determinations for different regions. For example given geographic regions A and B, the best satellites for receiving GPS data in region A may be different at a given

time from the best satellites for receiving GPS data in region B. Accordingly, GPS receiver/processor 16 may, using a known central or median geographic location in region A, readily determine the best satellites for receiving GPS data in region A. Likewise, GPS receiver/processor 16 may, using a known central or median geographic location in region B, readily determine the best satellites for receiving GPS data in region B. Given knowledge of the location of such central or median geographic location of a given region, known techniques readily allow determination of the best satellites to use at a given location.

The transmitters of the GPS satellites send 50 bit-per-second data superimposed on their output signals which are so called Gold codes (named after an individual) corresponding to a particular satellite. As known, these Gold or GPS codes are usually one mega-chip per second codes. The data is decoded to using known techniques to determine the precise position and velocity (vector) information, collectively called ephemeris data, of each satellite which will be used for verifying or determining location of the customer access control system 12 in a manner discussed in detail below. (As readily known, the velocity vector is the time rate of change of the position vector.) The correction data for the expected velocity of propagation is also decoded in known fashion.

GPS data messages 18 (i.e., signals on electrical connection lines 18), including the position, velocity, and correction data relative to the various satellites, are supplied by receiver/processor 16 to a central conditional access system 20, which may also be called a central conditional access system. Depending on the bandwidth at the output of system 10 and other considerations, the GPS data messages 18 may simultaneously include data on all satellites used for all regions or time multiplex data from one satellite and/or groups of satellites (e.g., all satellite data from satellites used for region A for a short interval followed by all satellite data from satellites used for region B for a short interval). In the example with regions A and B, the data from satellites to be used for region A can be addressed to the various customer access control systems 12 (FIG. 2 only) within region A, whereas the data from satellites to be used for region B can be addressed to the various customer access control systems 12 within region B.

System 20 also receives program data messages 22 and user authorization data messages 24 supplied by sources (not shown) in a known fashion. Central conditional access system 20 supplies combined data messages 26 (the various inputs to system 20 output in encrypted form) and a scrambling key 28 to multiplexer/scrambler/transmitter 30, which may be called an output unit. The output unit 30 receives audio, video, and data signals from program sources 32 and which supplies outputs 34 to a transmission medium. In known fashion, the outputs 34 include scrambled versions of the various audio, video, and data program signals. The outputs 34 also incorporate the data input to system 20, this being placed on the transmission medium in an unscrambled, but encrypted form. The combined data messages 26 and outputs 34 would incorporate the various GPS data as discussed and using known techniques.

Although the outputs 34 are shown as being provided to an up-link for a communication satellite, the outputs could be applied to any transmission medium for transmission (directly or indirectly) to customers. For example, the central access control system 10 may alternately supply the outputs 34 over the air (non-satellite televisions broadcast) and/or by cable (wires or optical fiber). In any case, the signals will be scrambled and descrambling will only take

place if one of the customer access control systems 12 of FIG. 2 is at an authorized location as discussed below.

The multiplexer/scrambler/transmitter 30 may be, for example, a standardized MPEG2 system multiplexer which operates on a packet basis, receiving audio, video, and data packets and combining them into a formatted serial data stream to issue to the communication satellite up-link. As well known, MPEG2 is a particular digital video compression system or technique which accommodates multiple video, audio, and data signals to be combined and transmitted on a single radio frequency carrier.

By having the important features related to the high quality, multiple channel GPS receiver/processor 16 at the system 10, the system 12 discussed below can be simpler than otherwise. Specifically, the advantageous feature of retransmitting the discussed GPS data, while not a necessary part of the present invention in its broadest respects, allows for a much simpler and less expensive system 12. Since a customer access control system 12 must be at each customer/subscriber location, it is useful to hold down costs and complexity of the customer access control system 12, whereas making the central access control system 10 more complex does not involve great expense since there would only be one or a relatively low number. Since the conditional access system 20 operates in known fashion (except for receiving and incorporating in its output the GPS data messages 18), details of the system 20 including components of known conditional access systems which ordinarily cause the scrambling keys to be changed and to be de-codable by authorized IRDs (such as the customer access control system 12) need not be shown or presented.

As an alternative to the transmission of the described GPS data, system 10 may alternately send only the identity of the satellites to be used by the customer access control 12, instead of including the position and velocity information. However, that would require more complex operations by the customer access control 12.

Turning now to the customer access control system 12 of FIG. 2, an antenna 36 receives both direct (i.e., not relayed from a central system such as 10 of FIG. 1) GPS signals 38 from a satellite and communications satellite signals 40 which include the indirect (i.e., relayed through central system 10) GPS signals and correspond to signals 34 of FIG. 1 following their up-link to one or more communications satellites and down-link to the customer access control system 12. In theory, the same satellite (not shown) could provide both some direct GPS signals and the communications signals 40, but satellites usually do not combine GPS and communications functions. The antenna 36 may be a small satellite dish type antenna. Although not shown, separate antennas for direct GPS signals and for communications signals could be used instead of the single reception antenna 36.

The signals received by antenna 36 are sent to an integrated receiver decoder (IRD) 37 and are filtered (filter not shown) using known techniques such that the direct GPS signals 38 go to GPS signal receiver 42 and the communications signals 40 go to the communications satellite receiver/decoder 44 (which serves as a signal input device). The output of receiver/decoder 44 is a demodulated and decoded baseband signal corresponding to the signals 34 of FIG. 1 and this output is supplied to descrambler/demultiplexer 46. The descrambler/demultiplexer 46 operates in known fashion to de-multiplex and direct signal packets for a customer conditional access system 48 along a connection 50 to the customer conditional access system 48.

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Packets corresponding to program audio, video, and data are descrambled by component 46 if a descramble key is supplied at connection 52 by the system 48. The system 48 provides the correct descramble key only if all the criteria for authorization are satisfied. Known IRDs allow access upon satisfaction of criteria based on the program data messages 22 and user authorization data messages 24 of FIG. 1. Common or standard operational details of known components 44, 46, and 48 need not be discussed, but having GPS data as one of the criteria for release of the descramble key and other aspects in which components 44, 46, and 48 differ from the usual prior systems will be emphasized hereafter.

The system 12 will not have the conditional access system 48 release the correct key on 52 unless (in addition to criteria based on other factors such as payment for service, no black out resulting from parental restrictions on programming available to children, and no black out resulting from regional restrictions) the IRD 37 is at its authorized geographic position. Whether it is in proper geographic position is determined by a GPS data processor 54 connected to GPS signal receiver 42 by way of a time delay correlation device 56. Processor 54 performs calculations of pseudo-range and time bias as discussed hereafter and will provide a position authorized binary signal on line 92 only if the geographic position of IRD 37 is consistent with the expected or previously authorized location.

The GPS processor 54 works in conjunction with the time delay auto-correlation device 56. Device 56 uses a known comparison technique involving a locally generated code for the satellite which is to be used. (The satellites to be used are supplied by the indirect GPS data and passed on line 60 to processor 54.) The locally generated code is supplied on line 62 to device 56 for shifting in time until it matches in time the same code transmitted from the GPS satellite. The value of time shift is then passed back to the processor 54 on line 64 for pseudo-range calculations using the ranging equation:

$$(X_s - X_i)^2 + (Y_s - Y_i)^2 + (Z_s - Z_i)^2 = (R - R_b)^2$$

where X_s , Y_s , and Z_s represent satellite position coordinates and X_i , Y_i , and Z_i represent position coordinates of the IRD 37. The range between the satellite and the IRD 37 at a particular time is represented by R , whereas R_b is the range bias due to the IRD clock (not separately shown) instability.

Since the indirect GPS data preferably supplied to IRD 37 includes satellite position coordinates at a given time and the three velocity components at that time, X_s , Y_s , and Z_s may be readily determined by processor 54 at a later (relatively short time delay) time. Alternately, if a more complex IRD is used, the direct GPS data can generate these values independent of any indirect GPS data other than the identity of the satellites to be used.

Evaluating the ranging equation for two different satellites (doing the equation twice) allows one to check for consistency with an authorized location. As used herein, such a consistency check shall be referred to as position validation. Considering that X_s , Y_s , and Z_s representing position coordinates of the IRD 37 may be taken as at the authorized location meaning that the proper range R will be known, a first application of the equation yields a value for R_b , the range bias due to offset of the IRD clock from the satellite clock. A second application of the equation is then performed by processor 54 using a different satellite to check if the right and left sides of the equation are equal. If the right and left sides of the equation are equal, the range is proper and the position is highly likely to be valid since an equal

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range is unlikely. (Even if a range is equal to the proper range at a given moment, movement of the IRD satellites means that shortly thereafter, the range will be invalid unless the IRD is at an authorized position.) If the right and left sides of the equation are not equal, processor 54 will not supply the verification on line 58 such that conditional access 48 does not provide the descramble key on line 52 and usable program output(s) are not supplied by component 46.

Instead of simply validating the IRD position as described above, an alternative has the IRD 37 operate in a position determination mode. In this mode, the equation above is calculated four times to solve for four unknowns: range bias R_b and X_i , Y_i , and Z_i representing position coordinates of the IRD 37. A Taylor series or other known iterative technique can be used to solve for the four unknowns. The determined IRD position coordinates may then be compared to previously stored authorized IRD coordinates. If they are equal (or within a given tolerance range), the verification will be supplied on line 52. If they are not equal (or not within a given tolerance range), the verification is not supplied such that conditional access 48 does not provide the descramble key on line 52 and usable program output(s) are not supplied by component 46.

The advantage of using the position validation technique is that it may be simpler (with associated lower costs and less processing power needed) than having position determination in the IRD. An advantage of IRD position determination is that it may be used for self-initialization at the customers site. That is, the authorized location can be initialized where the customer first sets up the IRD. This will avoid the need for the company providing the IRD to determine and initialize the IRD values for proper location. This prevents descrambling at other locations, but the company may still need to check somehow to insure that the customer did not initially take the IRD to an unauthorized location. On the other hand, this technique of self-initialization of the position may be quite useful if an employee of the company delivers the IRD to the customer.

Still further details are shown in FIG. 3 of a first embodiment. The processing shown herein is limited to the operation of the GPS and its interface with the MPEG2 or other programming delivery system. Included in this embodiment is the GPS processing of four pseudo-range measurements to explicitly determine the IRD position. FIG. 4 differs from FIG. 3 in that the GPS processing in the IRD in FIG. 4 performs only a range validation (which, over time, is position validation) after the programming delivery system has supplied the IRD with the GPS coordinates of the authorized location.

In FIG. 3 start block 100 leads to block 110 where the demultiplexor provides that portion of the programming signal which is directed to GPS commands and data at line 111 supplied to block 120. At block 120, the GPS receiver receives the command from the lines 111 (this could be by way of the conditional access system of FIG. 2) to perform a pseudo-range measurement and identify the particular GPS satellite. At 120, the receiver performs the correlations required to obtain the pseudo-range and passes the pseudo-range to the GPS processor at block 125. The GPS coordinates of the GPS satellite used for the measurement are delivered from demultiplexor block 110 at input 127 of block 125. Delivery via the programming channel aids the system in that the GPS receiver 42 of FIG. 2 need not necessarily demodulate this data from the GPS signal directly and is therefore able to quickly move on to the next GPS satellite signal to be processed. It also avoids a need for

the GPS receiver requiring more than a single GPS signal to be processed at a time, thus saving on the amount of hardware required.

At the time of IRD initialization a first position determination is stored in an authorized position memory as indicated at block 130 via data path 135. Subsequent position determinations will compare new position determinations with the position stored in memory. This comparison is performed in block 140 wherein the present measured position is received from the GPS processor 54 of FIG. 2. The authorized position is normally received via path 138. However, the system allows a position check to be made with a position communicated via the programming channel via path 142. The system operator has the choice of validating the position with reference to a position he sends to the IRD if he desires. This system of FIG. 3 is capable of making an initial position determination by itself so that it need not be provided over the programming channel. The ability to later validate this initial position provides insurance that the initial position measurement was made at the authorized location and not at some unauthorized location.

The output of block 140 is the range error between the currently measured position and the authorized position and is delivered to block 145. Block 145 performs processing which first determines if the range error is less than a prescribed threshold value, alpha. The value of alpha, and also the later used threshold, beta, is provided from the programming channel via path 144. A binary result from this operation occurs such that a "one" is produced for a range error equal to or less than alpha and a binary zero is produced for a range error which exceeds alpha.

So that any single range error produced by the GPS measurement process will not disable the IRD from descrambling the program material a second threshold value called beta is used. This process requires that a pre-determined percentage of the range errors are within the threshold alpha. Said pre-determined percentage is governed by the threshold value of beta.

The output of processing block 145 is the binary position authorization signal at 147. The signal at 147 is one input component to the authorization logic block 115. Other authorization criteria are delivered to 115 via path 113. The logic in block 115 essentially requires that signal 147 authorize descrambling, along with the other criteria of 113 for the descramble authorization 118 to be asserted and allow the programming to be viewed.

The logic block 113 is more complex than a simple AND gate in that the programming channel can cause the descramble authorization to be enabled or disabled regardless of the state of position authorization signal 147. This gives the system flexibility to not require position verification in some instances.

A further capability of this system permits certain geographic areas to be excluded from providing a position authorization. In this case the demultiplexor 110 provides the excluded area in terms of GPS coordinates to processor 140 via path 142. Processor 140 then compares the excluded area with the position held in memory 130. If the position in memory 130 is within the excluded area sent via path 142, then block 140 sends the maximum range error possible to block 145 which responds by not authorizing the position at its output 147.

FIG. 4 shows a second embodiment of the invention wherein the IRD does not make any position determinations. In this embodiment only range verifications are performed utilizing pseudo-range measurements made at the IRD and an authorized position delivered to the IRD via the program-

ming channel. An advantage of this embodiment is the saving in the hardware and software associated with the processing of pseudo-range measurements in an iterative fashion using four simultaneous non-linear equations. The GPS receiver operation 220 in FIG. 4 is the same as receiver operation 120 in FIG. 3. Also the same between FIGS. 3 and 4 are blocks 100 and 200, blocks 110 and 210, blocks 115 and 215, and blocks 145 and 245.

In particular in FIG. 4 block 230 involving the authorized position memory differs from that shown in FIG. 3 in that the authorized position can only be entered from the programming channel in FIG. 4, and that the processing in block 240 performs only range verifications. Processor 140 in FIG. 4 performs a range computation between the GPS satellite being measured and the IRD based upon the authorized position coordinates in memory 230 and the coordinates passed to it via path 242 from demultiplexor operation block 210. Alternatively, the GPS satellite position coordinates can be demodulated from the GPS data, but this requires that the single channel receiver, 220, remain synchronized with a single GPS satellite for a longer period of time. The result of the range calculation is then subtracted from the range determined from the measured data. This yields the range offset value directly which is the needed output to send block 245. The remaining processing in FIG. 4 corresponds to that already described in FIG. 3.

An important aspect of the invention is that the set-top box not be fooled into thinking it is at an authorized position when in reality it has been moved to an unauthorized position. The IRD may be in the hands of someone who wants to cause the GPS receiver to think it is receiving time delay measurements consistent with the authorized position but in reality is receiving artificial time delay measurements consistent with the authorized location but not its actual location. It must be assumed that the general design of the IRD will become known to those skilled in the art of electronic circuit design (following any commercial release of the IRD), particularly those with experience in set-top boxes and conditional access systems. If the set-top box is opened to expose the circuit components then electronic signals which travel between components such as integrated circuits can be readily observed with test measurement equipment. Further, it is possible to break certain connections and substitute other signals. With reference to FIG. 2, it can be seen that the authorization system shown could be readily defeated (absent a feature discussed below) by tampering with the verification signal 92. If the signal connection 92 to conditional access system 85 was broken and instead tied to the voltage level corresponding to correct position verification then the GPS system would be totally bypassed and its purpose defeated.

The set-top box system employing the GPS can be made resistant to tampering by placing all of the circuitry relating to the conditional access system and the GPS inside a sealed container. Such a container might be an integrated circuit or a smart card, for example. The container is designed such that an attempt to pen it for internal signal measurement purposes effectively destroys the container's internal circuitry. This implementation permits visibility of only encrypted data passing into the container and only the descrambling keys, which are rapidly changed, appearing at the output pins of the container. It is desirable to be able to renew the conditional access system should the security of the system be broken by one technique or another by the straight forward method of replacing only the smart card. However, it is relatively expensive to discard all of the GPS circuitry should it be co-located inside a replaced smart card.

A method is next disclosed wherein certain of the GPS circuitry is located inside a sealed container such as a smart card and other parts of the GPS circuitry outside the sealed container. The circuitry parts outside the sealed container are not replaced when a smart card is changed.

FIG. 5 shows the method for using the GPS circuitry to resist defeat by tampering methods yet place certain portions of the GPS circuitry permanently in the set-top box which need not be replaced when a smart card is replaced. Several elements of FIG. 5 perform the same functions as in FIG. 2. Specifically, elements 350, 355, 360, 370, 375, 380 and 387 in FIG. 5 correspond to elements 38, 40, 36, 44, 42, 46, and 52 respectively in FIG. 2. Since the functions performed are the same, these elements will not be described a second time.

In FIG. 5 the dashed line, 340, shows the elements which are co-located inside of the sealed container. The signals which are visible passing into and out of the sealed container are as follows. First, the encrypted GPS and conditional access data 332 from the descrambler and demultiplexor 380 pass into container 340. Second, the stable clock 382, which resides in the set-top box or IRD, send signals to container 340 via path 338. This clock has sufficient short term stability to operate the GPS receiver processing system. Third, the key 387 for descrambling the video, audio and data programming exits the container. This key is the correct key only if all authorization criteria including the GPS position criteria have been met.

Next the baseband code W, 334, exits container 340 to operate correlation device and demodulator, 345. This is the one mega-chip per second GPS code corresponding to the code of one of the GPS satellites. It is a desirable countermeasure to place the circuitry which creates the code sequence corresponding to a particular GPS satellite inside the container. This has the effect of requiring the attacker of the system to determine which satellite is being interrogated by correlating the bit stream with several bit streams of GPS satellites which are visible. An additional problem for the attacker is to also measure the particular time delay of the code being used. These two processes require measurement equipment and measurement time. If the code generator 388 were outside of the container 340, it should be presumed that the attacker could readily determine the particular code and code time delay being used by the IRD. The attacker would be aided by observation of the code generator 388 state machine either directly or the loading word which is used to load a starting state into said generator. Since the GPS code generator uses the well known Gold codes to generate the matching satellite codes a knowledge of the state of the state machine provides the attacker the information as to the particular code being used. It is therefore desirable to hide the code generator 388 inside container 340.

It is beneficial from a security standpoint to also place the correlation device 345 in the container 340 in FIG. 5, this being illustrated by the dashed lines there around. This then precludes visibility of the code W, 334, and the output correlation result Z, 336, by the attacker. This provides a very high level of security relative to spoofing the GPS system. This embodiment of the invention can be used in a systems especially where container 340 is seldom removed from set-top box 365.

In a more cost sensitive embodiment and/or where container 340 can be expected to be renewed more often, the correlation device and demodulator 345 can be placed outside of the container 340. This permits the radio frequency (RF) processing in 345 to be performed outside the container 340, and removes the need for the RF signal from GPS signal receiver 375 to be passed through a connector

pin of container 340. Further, it allows the local RF oscillator which is modulated by the code W, 334, and which heterodynes the RF signal down to a frequency which can be demodulated by a Costas, or equivalent, phase locking loop and signal demodulator to be placed outside said container. To minimize the expense of the renewable portion of the IRD, the circuitry of block 345 would be placed in the IRD box 365 outside of said container.

Two methods of the invention to greatly reduce the visibility as to the GPS satellite being correlated with a locally generated code are next disclosed. The first method randomly changes the waveform W, 334 in FIG. 5, between the GPS satellites. In this way, the satellites are not addressed in any particular order which increases the difficulty of someone trying to spoof the system. Satellites which are not visible also are included so as to cause the attacker even more additional effort and confusion in trying to sort out what the IRD system is doing. It is practical to add such diverting tactics since the actual position does not need to be repeatedly validated with any great haste.

The second method involves the random order of testing specific time delays of a GPS code to a particular GPS satellite. This procedure will cause the successful time correlation between the locally generated code W, 334 in FIG. 5, and the signal from the GPS satellite to occur at random time intervals. The time correlation result, Z, 336 in FIG. 5, is reported back to the common processor 385 in container 340. This is the last of the five signals passing into or out of the container, 340. This signal is checked by said processor at all of the possible correlation result times to determine if a correlation match has or has not occurred. If a successful match occurs when it should not occur, or when it is inconsistent with the authorized IRD position, the processor registers an incorrect position. Thus the signal, Z, is dynamic in that successful correlations occur at random times. Also, times at which the processor expects no positive correlation are checked for the negative result. A positive correlation at a time when one is not expected is registered as an error.

FIG. 6 shows a sequence of correlations wherein different Gold codes generated at W, 334 in FIG. 5, corresponding to actual different GPS satellites and to some fictitious satellites or satellites which are not currently visible on the same side of the earth are generated and the resulting correlations which are reported back via signal, Z, 336 in FIG. 5. The time line 400 in FIG. 6, represents time proceeding from left to right. The line is divided into a plurality of individual correlation periods. Four of these periods result in positive correlations and are labeled as D732, S89, K77 and G955 respectively. The letter in each designation corresponds to the particular GPS satellite. The number in each designation corresponds to the time delay used for the code of the GPS satellite. The other correlation periods in FIG. 6 do not result in positive correlations but include various time delays for the codes of other GPS satellites.

The time line 410 in FIG. 6 shows the results of the correlations performed along line 400 and show those resulting in positive correlations. These positive correlations corresponding to those periods along line 400 over which the satellite and time delay designations occur. Both the absence of a positive correlation and the presence of a positive correlation are checked and reported by signal Z, 336 in FIG. 5. Any person attempting to cause the authorized position to register with the processor 385 inside container 385 has to produce this randomly varying waveform.

In FIG. 5, a common processor 385 is shown, which carries out the tasks of storage of the authorized position in

GPS coordinates and GPS processing, and known conditional access. The processor 385 works in conjunction with the GPS real time controller 383, to which the processor can provide instructions in terms of data words. The controller will implement the real time sequential operations according to states timed by the clock 338. Controller 383, processor 385, and code generator 388 could be implemented on the same integrated circuit chip for a minimum cost processor.

The above discussed figures are those shown and described in the parent application, whereas FIGS. numbered 7 and higher did not appear in the parent application. Those FIGS. will be discussed hereafter, it being understood that they complement the arrangements of FIGS. 1-6.

It will be understood that the preferred embodiment of the parent application provided a geographic restriction to a given single fixed location. The arrangements discussed hereafter are modifications to the customer access control or Set-Top box that allow some of the signals to be accessible with differing geographic restrictions. The arrangements provide the geographic restrictions on reception for satellite signals consistent with the various contractual restrictions for territory or regions associated with the signals. Three different arrangements or methods are next described which give the Set-Top box this capability with various degrees of flexibility.

A first method to provide flexible geographic conditional access has a first part of the method performed at the location of the Service Provider as shown in FIGS. 7 and 8 and a second part the remaining second part at the Set-Top box as shown in FIGS. 9 and 10.

Referring initially to FIG. 7, the Service Provider is required to have in his possession the address for each new subscriber 410, which he enters into his database of subscribers and addresses 412. The Subscriber Database 412 is converted to a database where geographic coordinates are created for each subscriber 414. This geographic position information of each Set-Top box must have sufficient accuracy to determine in which of several regions (discussed in more detail below) each individual Set-Top box belongs. Geographic regions, which may be specific television broadcast markets such as a city and its surrounding area, are defined by coordinate sets in 416. Each region is assigned a unique Region Index and the coordinate sets for a given region define the boundaries for that region. The coordinate sets may be orthogonal linear coordinates, angles and corresponding radius lengths from a given center point, or any other type of set that can be used for defining a boundary, either with or without interpolation. A given region may be identified as coinciding with the coverage area of a local broadcast terrestrial transmitter. Next, in block 418, each subscriber's coordinates are used to determine in which region the subscriber is located. The coordinate sets defined in 416 are interpolated so as to determine a boundary for a particular region. (Although not separately shown, it will be understood that a do loop process of iterating the region index may be performed so that a customer's location is tested against each of several coordinate sets.) The subscriber's coordinates are then checked to determine if said coordinates are inside of the region. When the correct Region is determined for a subscriber the Region Index is tagged to that subscriber. The tagged subscribers are entered into the List 422. Each subscriber is individually addressable by the Conditional Access System and the operation shown in 422 serves to transmit the appropriate Region Index to each subscriber in a secure scrambled fashion. The Region Index may be transmitted as part of the user authorization data messages of FIG. 1.

A region may correspond to one particular country but not another country. Alternately, a region may be legally predefined around a certain metropolitan area. Still another example is a Region to be excluded, or blacked-out.

FIG. 8 shows the addition of Conditional Access information to each program to be scrambled and broadcast by the satellite. Non-geographic conditions are formed in 424 to be included in the composite Conditional Access. These include premium channels and the other program groups in which this particular program is assigned from a subscription standpoint. The geographic attributes are added in 426 and serve to indicate which regions are eligible to receive this program. Region codes are used as attributes which may later be matched with a Region Index at the Set-Top box.

Finally, the program source 428 itself is included such that all attributes and the program are assembled for transmission in 430. The combination of the program and the attributes are uplinked to a satellite and then downlinked in the manner discussed for FIG. 1 with the modification that the data messages include the Region Code for a given program.

The second part of this method occurs at the customer access control such as the FIG. 2 Set-Top box 37 as modified according to the following discussion. Conditional access which results in descrambling the program for use occurs (i.e., access is granted) when all of the following conditions are met:

1. The Region Code which accompanies scrambled programming must match the Region Index previously transmitted by the Service Provider and securely stored in the box.
2. The GPS must indicate, per the discussion relative to the parent application and as discussed for FIGS. 1-6 above, the Set-Top box has not been moved from its authorized location.
3. Other conditional access criteria which includes the customer subscription to the particular programming and satisfactory account status.

There may be programming which is not to be restricted to a region such as a particular metropolitan area but which may be received and used outside of the region or metropolitan area. In this case the programming shall be transmitted to the Set-Top box with the special Region Code carrying the meaning of all regions. That is, any region can access it. For this case item one above is automatically satisfied and the system operates like the system of the parent patent application and FIGS. 1-6 above, which embodies only conditions 2) and 3) above.

FIG. 9 shows the individual Set-Top box operation of receiving the Region Index intended for the box. The scrambled Region Index is received in 432 and passed to 434 where it is subsequently de-scrambled and securely stored for later use in comparison with the Region codes attached to each program.

FIG. 10 shows the process of enabling the de-scrambling of a scrambled program 436. As previously described with reference to FIG. 8 the scrambled program has attached to it one or more Region Codes. In FIG. 10 these Region Codes are stripped from the scrambled program 436 to become the separated codes 438. A Region Code 438 is compared with the Region Index 440 stored as in FIG. 9, this comparison being performed by a region comparer 442. The region comparer 442 could, for example, be a plurality of AND gates which compare the Region Code(s) and the Region Index bit-by-bit. As with the gates and other hardware components illustrated in this and the other FIGS. herein, the region comparer 442 could be implemented as a software step rather than as a hardware component.

Where more than one Region Code is attached to the scrambled program 436 in FIG. 10 the Region Codes are compared in sequence by region comparer 442 to determine if there is any match between any of the Region Codes 438 and the Region Index 440. If any match occurs, the output of the region comparer 442 serves as an enabling input to AND gate 444. The Non-geographic conditional access signal 446 (i.e., representative of the customer's account being reasonably current, the customer having elected to get a given premium channel or program, etc.) is provided using known systems and provided as a second enabling input to AND gate 444. The third input to AND gate 444 is provided by the AND gate 452 which compares the authorized coordinates 448 for the Set-Top box 37 of FIG. 2 with the GPS determined coordinates 450. When all three enabling inputs to AND gate 135 are present the program de-scrambler 454 is enabled and the Scrambled Program 436 is de-scrambled.

It will be appreciated that a latch or other storage device, not shown, might be used for the enable out of gate 444 in the case where multiple Region Code(s) are included in the program. Alternately, a given Region Code 438 may be interpreted by Region Comparer 442 as a match for several of the Region Indices 440 in which case latching of enable is not required. Likewise, in the simple case where only a single Region Code accompanies a given program, latching of an enable is not required. However, latching of an enable might also be used if the regions overlap such that a box might be in two regions at a given time and, thus, have two Region Indices that would be sequentially compared in region comparer 442 against any Region Code(s) 438.

It will be appreciated that combinations of regions may be readily structured and used for cases where different legal restrictions are in force for different program segments. As an example, one program assigned to Region A whose scrambled signal can be received by a subscriber in Region B will not be accessible to said subscriber because of a mis-match between the subscriber Region and that Region for which the program is intended. A different program, as a second example can be assigned to both Regions A and B and be potentially accessible to subscribers in both those Regions. In fact, a program can be enabled for all Regions. This becomes the situation described in the parent patent application.

A second method to achieve geographic conditional access involves a first part which is performed by the Service Provider and a second part performed by the Set-Top box. This method has similarity to the first disclosed method but also contains important additions. In this second method the Set-Top box is provided with a region coordinate set that, when interpolated, describe the geographic boundary around eligible receiving sites. The coordinate sets are available to the Set-Top box by two different means. In the first means the coordinates are communicated in a scrambled fashion to the Set-Top box via the satellite transmission. In the second means the coordinates are pre-programmed into the secure authorization card assigned to said Set-Top box, often called the Smart Card. Alternatively where such a card is not used in the Set-Top box the coordinates can be saved in a secure section of memory inside the box. With either of these coordinate access methods the Set-Top box first calculates needed interpolations and then uses the GPS to determine whether the Set-Top box is inside the boundary described by one or more region coordinate set. One particular set of coordinates is sent to all of the boxes which were pre-determined to be within the aforementioned geographic boundary by the means described for the first method of this

invention. If the box position is inside the boundary then geographic conditional access is granted. If other criteria which includes payment for the service is also satisfied then the program desired by the customer will be de-scrambled by the Set-Top box.

The geographic coordinates to be sent to each Set-Top box are those which describe a certain region. As discussed in the first method a shorthand Region Index is used to denote each particular region. In this second method one or more Region Index (Indices) is delivered to each Set-Top box consistent with the geographic address of the box. Subsequent to this operation each group of coordinates which bounds a certain Region has attached to it the appropriate Region Index. The Set-Top box then saves the set of coordinates whose Region Index matches the Region Index previously and individually provided to said box.

The Set-Top Box with the above described capability can now perform two operations using GPS. It can perform the function of determining if said box has been moved from its initial location, as before, and secondly it can now determine whether or not it is anywhere within a certain region described by the Region coordinate set, even though it may have been moved from its initial operating location. Said two operations are useful in the two different programming conditions:

1. It is desired that for some programming the Set-Top box not be removed to some commercial location from its registered residential location, and
2. It is satisfactory for some programming that the Set-Top box be usable anywhere within the allowed Region regardless of commercial or residential.

Thus programs can be additionally tagged as to which of the two situations independently is to be implemented for the program material. The Set-Top box can also be operated in a mode wherein neither geographic requirement is mandatory when a program is appropriately tagged. Finally, the Set-Top box can be operated such as to require both of said conditions simultaneously.

The details of the second method will be described relative to the first method. All of the operations shown in FIG. 7 and FIG. 8 are performed for method two as well as method one. In addition method two provides for using the region coordinates directly in the Set-Top box. In the case where these coordinates are transmitted in scrambled form to each Set-Top box, they are done so with the appropriate Region Code tagged onto each coordinate group. In this way each coordinate group may be transmitted just once rather than individually for each Set-Top box. Each Set-Top box is programmed to accept and store the coordinate set for the region whose Region Code matches the Region Index which has been individually sent to each Set-Top box. As previously mentioned, the matter of transmission of coordinate sets to the boxes can be replaced by the action of providing these coordinate sets already inside the Set-Top box at the time of purchase or lease by the subscriber. The coordinate set might be securely stored in the Smart Card, as an example although other implementations accomplish the same basic purpose.

The Set-Top box for method two operates according to FIG. 9, except that the coordinate set must additionally be received and stored by the Set-top box.

FIG. 11 shows the logic operation for the Set-Top box operating according to the second method. An Operational Code, hereafter call Op Code, is transmitted from the satellite in addition to the Region Code for each Scrambled Program 460. This Op Code has four possible values 0, 1, 2 and 3 whose meanings are shown in FIG. 11. The Set-Top

box recognizes the Op Code and provides decoding of it to generate four possible enabling lines. In FIG. 11 these enabling lines are called, respectively, Op Code 0, Op Code 1, Op Code 2 and Op Code 3. Only one of the four will be active, meaning it enables operation of the gate receiving its signal, for a particular program. OR gate 462 responds to the four possible geographic Op Codes such that if any of the inputs is satisfied its output is an enabling input to AND gate 464. The second input to AND gate 464 is the Non-Geographical Conditional Access input 466. If both inputs to AND gate 464 are active then Program De-scrambler 468 de-scrambles program 460 to provide output program 470.

Further in FIG. 11, OR gate 462 responds directly to Op Code 0 and provides an enabling output for the case where there are no geographic requirements for the current program. Op Code 1 control AND gate 472 provides an active output when the Non-movement condition (per the parent application and arrangement of FIGS. 1-6 above) is satisfied by GPS comparer 474. Op Code 2 enables AND gate 476 such that a match between Region Code and Index Code in region comparer 478 will enable the output of OR gate 462. Finally, the output of AND gate 480 is enabled for Op Code 3 when both geographic conditions (box at proper coordinates and in proper region) are met.

FIG. 11 is shown in a form to facilitate understanding and other forms of implementation could be used. First, the logic can be written down and simplified to create fewer gates. Second, the comparison of Authorized Coordinates and GPS determined coordinates is a comparison of vectors rather than two binary inputs, but is shown as a binary function for ease of illustration. Further, and as mentioned above, software implementation of various components of the invention might alternately be used.

The Region Index as input to region comparer 478 is a modified version of the Region Index as determined in method one where it was provided directly from the satellite to each Set-Top box separately. The modification is shown in FIG. 12. The Region Index provided by the Service Provider for each particular Set-Top box is 482 in FIG. 12. Gate 484 serves to pass the Region Index 482 under the condition that the box is actually located in the Region X whose coordinates set is in 486 and whose Index number is 482. Calculation device or software 488 compares the sensed GPS 490 with the coordinate set(s) 486 and outputs a "yes" or enable when the GPS shows the box is in the proper region, is the process which performs the necessary calculations to determine whether the GPS determination performed in 320 is inside Region X.

A third method provides the capability for the Set-Top box itself to learn in what Region it presently resides. This permits the flexibility for the subscriber of transporting the Set-Top box to a different Region, perhaps a vacation area, and be able to use said box with programming authorized for that Region instead of the Region where the box had been authorized. In this case the Set-Top box must not be located in an invalid Region in order to de-scramble programming for use. One example of an unauthorized region might be a foreign country. Another example is a Region which is indeed defined by a coordinate set but which is unauthorized for the subset of local programming which is generated for use only in a different Region.

In the third method coordinate sets for multiple Regions are stored in the Set-Top box. These coordinate sets can be acquired by said box by one of two means. The first means is by securely receiving the coordinate sets via the satellite transmission of them. The sets are stored inside said box in a tamper proof manner. The second means of storage is the

aforementioned Smart Card which is provided at the time of purchase or lease of said box. A variant of this is the secure storage of the coordinate sets in the box itself at the time of purchase or lease.

The coordinate sets stored in the Set-Top box are organized in a hierarchy such as to include both geographic Regions which are legally protected and larger geographic areas such as individual countries. That is, a Set-Top box may be located inside a country where the rights for programming exist, but the site of said box may be outside of any Region which is protected from receiving programming not locally licensed. Such areas would occur where programming from a terrestrial broadcast transmitter cannot be received because the distance away from said transmitter is too great to permit reception. There would not be any geographic restriction in this case where the Set-Top box is inside a permitted country but outside any Region with legal restrictions. Another way of representing it is that programming which is authorized for one local area can be legally de-scrambled in that Region corresponding to the same said Region or all areas which are not defined as Regions but which are within the boundaries of the allowed country.

In summary, a large area or Region is first defined, such as a country, within which de-scrambling of programming can be permitted, subject to geographic restrictions in localized areas but outside of which de-scrambling is not permitted. Second, if the large Region criteria is satisfied and the geographic location of the Set-Top box is not within any local Region in the larger Region then no geographic restriction shall apply to any programming which has restrictions for some regions. However, if said box is within one of the defined localized Regions then restrictions of programming can be imposed by the Service Provider for some subset of programming.

In FIG. 13, there is a flow chart showing first the large region validation and next the determination of local region(s). The GPS coordinate data is furnished to the process in 500 where the actual GPS data 501 sensed for the customer access control box is compared at box 502 to the coordinate set for the large area. The region validation flag is set to 1 in box 504 if the set-top or customer access box is in the large area, whereas box 506 sets the validation flag to 0 if it is not in the large area.

The processing of the Large Region is complete at this point in FIG. 13. Had there been multiple Large Regions rather than a single Large Region, a modified processing method would have been required, similar to the method which will next be described for the determination of one or more Region Indices.

At box 508, the region test number is initialized and control goes to 510 which calculates the boundary for a region. Next, box 512 determines by way of box 514 if the GPS coordinates from 501 are in a particular local region. Box 516 puts the region number in a Region Index list if the test is positive. Box 518 tests if the highest region number is the one under test. If not, control goes back to box 510 by way of box 520, which increments the region number. When all regions have been tested, the yes from box 518 goes back to box 500. Although not shown, if no regions are found, a No-Region flag is set to one (active).

As shown in FIG. 13, the third method provides the capability for the Set-Top box itself to learn in what Region it presently resides. This permits the flexibility for the subscriber of transporting the Set-Top box to a different Region, perhaps a vacation area, and be able to use said box with programming authorized for that Region instead of the Region where the box had been authorized. In this case the

Set-Top box must not be located in an invalid Region in order to de-scramble programming for use. One example of an unauthorized region might be a foreign country. Another example is a Region which is indeed defined by a coordinate set but which is unauthorized for the subset of local programming which is generated for use only in a different Region.

In the third method coordinate sets for multiple Regions are stored in the Set-Top box. These coordinate sets can be acquired by said box by one of two means. The first means is by securely receiving the coordinate sets via the satellite transmission of them. Said sets are stored inside said box in a tamper proof manner. The second means of storage is the aforementioned Smart Card which is provided at the time of purchase or lease of said box. A variant of this is the secure storage of the coordinate sets in the box itself at the time of purchase or lease.

The coordinate sets stored in the Set-Top box are organized in a hierarchy such as to include both geographic Regions which are legally protected and larger geographic areas such as individual countries. That is, a Set-Top box may be located inside a country where the rights for programming exist, but the site of said box may be outside of any Region which is protected from receiving programming not locally licensed. Such areas would occur where programming from a terrestrial broadcast transmitter cannot be received because the distance away from said transmitter is too great to permit reception. There would not be any geographic restriction in this case where the Set-Top box is inside a permitted country but outside any Region with legal restrictions. Another way of representing it is that programming which is authorized for one local area can be legally de-scrambled in that Region corresponding to the same said Region or all areas which are not defined as Regions but which are within the boundaries of the allowed country.

In summary, a large Region is first defined, such as a country, within which descrambling of programming can be permitted, subject to geographic restrictions in localized areas but outside of which descrambling is not permitted. Second, if the large Region criteria is satisfied and the geographic location of the Set-Top box is not within any local Region in the large Region then no geographic restriction shall apply to any programming which has restrictions for some regions. However, if said box is within one of the defined localized Regions then restrictions of programming can be imposed by the Service Provider for some subset of programming.

In method 3 the Set-Top box has stored in its memory the geographic coordinate sets for the Large Region(s) which determine the boundary for one or more countries and the sets for the multiple local Regions. A unique Region Index number is included with each coordinate set. Starting with these coordinate sets and the GPS coordinate data determined in the Set-Top Box, the functions in FIGS. 13 and 16 are implemented.

It will be appreciated that this processing is exemplary for this system and may take modified forms. One example is that the continual processing of all the localized Regions might be replaced with confirmation testing of that same Region once the Region index has been established. Testing all Regions might be initiated again only if the established Region fails to pass the confirmation test.

In FIG. 16, the determination made in FIG. 13 processing along with the initially authorized coordinates for Set-Top box and non-geographic conditional access information are used to enable descrambling if appropriate. The same Op Codes are employed as in FIG. 11 with the individual

programs. It is assumed here that the incoming coded Op Code is decoded such that only one of the Op Codes zero through 3 is active at a time. In addition, there is supplied a Large-Region-Validation-Not-Required indicator which comes with the program material. If this indicator is one, then the input by that name to OR gate 530 is high, or active.

The operation in FIG. 16 proceeds similarly to that of FIG. 11. Components that are operable in essentially the same fashion as components in FIG. 11 will be numbered in the 600 series with the same last two digits and the discussion herein will focus on differences. However, the first difference is that AND gate 664 now has three inputs instead of two. The new input comes from OR gate 530 which is active (a one) if either the GPS Large-Region-Validation-Flag is active (a one) or the Large-Region-Validation-Not-Required Flag is active (a one). These were determined in the processing of FIG. 13. The output of AND gate 664 is active and the Program Descrambler 668 enabled if all three inputs to 664 are active (all ones).

The other difference in FIG. 16 from FIG. 11 is the addition of OR gate 532. The purpose of this gate is to provide an active input (a one) to gates 676 and 680 if either of two conditions is satisfied. The first is a match found between the Region Index stored in the Region Index list and the Region Code which appears with the particular program. The second is the flag which is active if no local Region was found in the search in FIG. 13.

With reference to FIG. 14 practical aspects of the operation of the present will be illustrated by examples. The large area A includes regions R1, R2, R3, and R4 and an open area OA within A, but outside of regions R1 through R4. A customer C1 in region R1 can receive signals that are region-specific for region R1. Additionally, the customer or subscriber C1 can receive signals that are large area signals (i.e., can be accessed anywhere in area A) and are not region specific. The customer may receive other signals called region-exclusion signals, that are blacked out of one or more regions R2, R3, and R4, but are accessible in region R1. For example, if a particular network has no affiliates in region R1, an affiliate signal from one of regions R2, R3, or R4 might be made accessible in region R1 even though it is excluded from other regions having an affiliate of that network. Other signals, called location-specific signals, may be accessible only if the customer access control or set-top box 37 of FIG. 2 remains at a single fixed location as explained in the preferred arrangement given for FIGS. 1-6. Of course, any or all of those classes of signals may include non-geographic restrictions on them such as the subscriber's account being paid in a reasonable time and the customer having elected to receive any premium channels.

Customer C2 lives in a region R2, which may be associated with a different city or television broadcast market from that of region R1. Customer C2 would receive signals in similar fashion to customer C1 except that C2 receives region-specific signals for region R2 and receives region-exclusion signals provided that they are not excluded from region R2. An example of a region-exclusion signal would be when a sports premium view channel or a pay per view channel broadcasts a sports event that is contractually blacked out from region R2. The blackout region may be a region code, not shown, that could, by way of appropriate gates, disable gate 664 of FIG. 16 such that access to such program would be denied.

Customer C3 lives in a region R3 and receives signals similar to the other customers based on C3's location in region R3. Again, this customer or subscriber receives region-specific signals corresponding to region R3.

The invention allows two possibilities if the customer C3 moves with his set-top box or customer access control to location C3' in region R4. A first technique prevents usage in other regions. For example, a region determiner similar to FIG. 12 may compare the previously stored region index with the current value and block access upon a change. (The previously stored index may be a region index in the customer access control box set by a smart card or other tamper resistant programming when provided to the customer or simply the initial determined value using a region determiner like FIG. 12.) However, a second technique allows the customer to move the box or customer access control 37 from region R3 to region R4.

In order to accommodate movement from one region to another, the FIG. 12 region determination technique may simply sense that customer C3 has moved from region R3 to region R4 and grant access to region-specific signals for region R4 (but no longer give access to region-specific signals for region R3). Any location-specific signals would no longer be accessible. However, a tamper resistant technique allowing the Service Provider to reset coordinates for the new location of the customer by addressing the customer's set top box could also be provided such that the customer could receive location-specific signals at the new location.

Customer C4 is in large area A, but is in an open zone outside of the broadcast market or other regions R1 through R4. Since customer C4 is not in any of the regions R1 through R4, that customer could be allowed access to any network affiliate channels from any or all of the regions R1 through R4 depending on contractual and/or copyright considerations.

With reference to FIG. 15, customer C5 gets programming authorized for region R2, whereas customer C6 gets programming authorized for region R1. However, since regions R1 and R2 overlap and customer C7 lives in the overlap or union of the regions, customer C7 may receive signals for both regions R2 and R1.

Turning now to FIG. 17, the components are in the 700 series with the same last two digits as the corresponding component from the embodiment of FIG. 2. Thus, the customer access control 712, antenna 736, IRD 737, GPS signals 736, satellite signals 740, GPS receiver 742, receiver/decoder 744, descrambler/demultiplexer 746, conditional access system 748, GPS data processor 754, and correlation device 756 are constructed and operable like the corresponding components of FIG. 2, except as discussed below. Similarly, signals/lines 750, 752, 758, 762, and 764 function as in the corresponding signals/lines of FIG. 2.

The IRD 737 is different from IRD 37 in that the signals 740 processed by it include data signals such as Internet data signals or other data viewable or accessed by the customer (as opposed to data used to control distribution of audio or video signals). The accessing of those data signals is authorized by the same process discussed for FIG. 2. However, instead of being provided to a television set or monitor (not shown) like the video program output or to a sound system (not shown, could be integral with the television) like the audio output, the data output is provided on line 770 to the customer's computer 772. As will be readily understood, the video and audio program outputs could also be supplied to the same computer as the data program output if the computer has the capability to handle such signals.

In addition to authorizing access to data programs supplied to the customer, the key on line 752 is also supplied to an output device such as transmitter 774 for transmitting data 775 from computer 772 on antenna 776. (If the outgo-

ing transmission medium from the customer and the transmission medium supplying the customer are the same transmission medium, as is preferred, the antenna 776 is not needed as antenna 740 may both receive and transmit signals.) The transmitter 774 may be constructed in known fashion except that the key 752 may be used in a number of ways. In particular, the key may only authorize transmission when the key is valid. This may be done by testing the authenticity of the key and gating the signal for transmission through only when the key is authentic. Additionally or alternately, the key may be used in known fashion to encrypt the outgoing signal from the customer so that the outgoing signal is not understandable without the key.

The data program signals transmitted and received by the system of FIG. 17 are shown as radio frequency signals and it should be noted that the signals from antenna 776 may be supplied to a satellite for retransmission in known fashion. However, the transmission mediums for either or both outgoing and incoming signals for the customer could be received/broadcast by terrestrial systems or cable (meaning any of telephone line, cable TV line, wires, or optical fibers). Additionally, the transmission mediums used between the customer and a central access control (same functioning as in the FIG. 1 embodiment for example) could be an Internet connection between the customer and the central access control. In that case, any data programming provided may be programming not available through the internet except provided in encrypted form over the internet from the central access location to authorized customers only. Of course, the output device 774 could be a multiplexor/scrambler, instead of a transmitter depending on the transmission medium being used.

Turning now to the system of FIG. 18, components are numbered in the 800 series with the same last two digits as the corresponding component, if any, from FIG. 1 and/or FIG. 17. Thus, central access control 810 is linked via a transmission medium (cable, satellite broadcast, non-satellite broadcast, etc.) to customer access controls such as 812A and 812B (two shown, but there could be a much larger number). Connected to corresponding ones of the program outputs of customer access control 812A are computer 872, television 884, and audio system 886. (The latter components are shown for customer access control 812A only, but such components would also be connected to the control 812B and other such customer control units.)

The computer 872 is connected to control 812A via a modem 882, although the modem could be internal to the computer. The central access control 810 is connected to the internet via a central interface 888 and central computer 890. As shown in FIG. 19, central interface 888 may have a coupler 892, input buffer 894, and output buffer 896 which operate in generally known fashion. Signals (electrical or optical) from the internet to coupler 892 are provided to input buffer 894, whereas signals supplied from output buffer 896 are ported from the coupler 892 to the internet. The central access control 810 is like control 10 of FIG. 1 except that it includes a path for incoming signals from the customer to go to buffer 896 for retransmission onto the internet.

A customer interface 898 would be constructed and operable like interface 888 except that interface 898 separates out incoming and outgoing signals of the customer access control 812A may separately process the signals in the discussed manner. Although not shown, a similar interface between modem 882 and the main part of control 812A may be used.

Turning now to FIG. 20, a customer access control 937 is shown as a block and operates in similar fashion to control

737 of FIG. 17 except as discussed below. An overall explanation of FIG. 20 and situations where its features are desirable will first be presented. Then details will be given by reference to additional figures.

FIG. 20 involves a solicitation, such as for sale of merchandise and/or services, made to a single or a plurality of receivers by a transmission method such as satellite distribution, cable distribution, the Internet or some terrestrial wired or wireless distribution system. The solicitation may or may not be encrypted.

The solicitation (communication from a central office or from another location via a central office) may contain geographic filter information such that the customer access control 937 will first determine, using the GPS data 939 of the customer location, whether to present a solicitation for consideration to the customer or subscriber at the receiver unit 937.

Some examples will best illustrate geographic filtering. If the solicitation is for a regional magazine for New England, the solicitation may contain geographic filter data within it, which data indicates that the message is only to go to units 937 having GPS data 939 corresponding to New England. A regional magazine for the Southeast U.S. may contain geographic filter information such that the unit 937 only passes that solicitation to units 937 in the Southeast U.S. Newspaper solicitations might be targeted to smaller geographic areas. Solicitations for snowmobiles may be targeted to locations where snowmobiles are used and so forth.

In addition to use of geographic filtering for marketing purposes as above, geographic filtering could also be used for complying with legal restrictions. For example, if solicitations for gambling transactions are legal in some countries or states and not in others, geographic filtering can be used to direct the solicitations only to places where it is legal. Investment solicitations can be targeted or limited to states or countries where a given type of investment solicitation is approved and the geographic filtering technique blocks such investment solicitations to areas where the solicitation is not allowed or approved. Geographic filtering can provide a political poll directed only to persons in the country, state, etc. where the voters reside for the given election or political issue.

This geographic filtering technique provides a mechanism to actively include only those parties within a specific geographic area, even though the solicitation is sent through a transmission medium that normally would reach a much larger geographic area.

Note that, assuming the solicitation is not encrypted (it can be encrypted or not encrypted as desired), the geographic filtering might be defeated by a spoofing technique. However, if such a spoofing only results in a solicitation being sent to one or a few parties outside an intended area, it may be of little or no concern.

The unit 937 receives the solicitation and, assuming that it passes the geographic filtering, it is presented on a screen (not shown), a printer (not shown), or some other means such that it is understood by the customer. The customer or operator of the unit 937 may choose to respond to the solicitation by ordering the offered merchandise and/or services and initiate an order response. The order could include credit card or other payment information, quantity of the item(s), color, size, or similar appropriate information. The unit 937 may attach GPS time and location to the order information as part of the response. The solicitation can optionally require that only orders be allowed which satisfy the criteria that the GPS location of the unit 937 agrees with the authorized location of the unit 937.

Additionally, attaching the GPS information to the response can be used at the central office (i.e., location of central computer such as 890 of FIG. 18). Specifically, the central office computer can check that the address to which goods are to be shipped correspond to the GPS data on the order. In other words, and with the exception of ordering gifts to be shipped to others (in which case alternate security measures might be used), the central office computer can check to insure that the location to which the goods are to be shipped corresponds to the GPS data on the order.

The solicitation acceptance or order and attached GPS data can be part of an encrypted response. In addition to encryption, the order may use digital signature or similar authentication techniques to insure that the order has not been tampered with. The encryption key may be stored in the unit 937 or may be a part of the solicitation process. The process may include multiple transmissions between the offering party and the unit 937 (i.e., via the central office) within a prescribed time period so as to discourage breaking of the encryption keys.

As with earlier designs of the present invention, the GPS determination device should be physically connected to the customer unit 937 in such a way as to provide security against spoofing the circuitry. This may be implemented by constructing the GPS determination circuitry on the same integrated circuit as circuitry which generates the encrypted response and which appends the GPS time and location data to the response.

If credit card data is sent with the response, it should certainly be encrypted. On the other hand, there may be situations where the response need not be encrypted just as there are situations where the geographic filtering is used with unencrypted or "in the clear" solicitations. For example, a solicitation for subscribing to a newspaper can be sent unencrypted to persons in the zone of service. If the person is simply responding with a request to begin newspaper delivery, the offeror may allow the customer to pay later such that the response may be unencrypted.

With reference now to FIG. 21, the structure of unit 937 and the geographic filtering techniques are shown by components in the "1000" series with the same last two digits as the corresponding component, if any, from the FIG. 17 embodiment. It will also be understood that unit 937 is the same as unit 737 except for discussed portions. Therefore, only a few components of unit 937 are shown in FIG. 21, various other components being identical to those of unit 737. Descrambler/demultiplexer 1046, computer 1072, and transmitter 1074 work as discussed for the corresponding components of FIG. 17. The difference in operation of the system is that geographic gate or filter 1081 filters information from the descrambler/demultiplexer 1046 to the computer 1072 such that only information appropriate for a customer having the given GPS data is supplied to the computer. The filter or gate 1081 blocks the New England regional magazine from going to a customer outside the targeted area, etc. Another difference in operation of the system from the FIG. 17 arrangement is that geographic gate or filter 1083 filters information from the computer 1072 to the transmitter 1074 such that only responses appropriate for a customer having the given GPS data is supplied to the transmitter 1074 for transmission to the central office computer.

FIG. 21 shows geographic filtering or gating of data sent to the customer (i.e., operator of unit 937) and geographic filtering of data sent from the customer. If desired, geographic filtering can be done only for data going in one direction, instead of both. The design shows the gate 1081

downstream from the descrambler/demultiplexer 1046, but in some applications it could be internal, or possibly upstream, relative to descrambler/demultiplexer 1046. The design shows the gate 1083 upstream from the transmitter 1074, but in some applications it could be internal, or possibly downstream (either at the customer location and/or at the central office location), relative to transmitter 1074.

Note that FIG. 21 is based on use of the geographic filtering in combination with the conditional access techniques of FIG. 17. However, the geographic filtering can be used without the conditional access techniques in which case descrambler/demultiplexer 1046 can simply be a demultiplexer. For example, if sending a solicitation to subscribe to a newspaper, encryption and conditional access may not be required. The geographic filtering may be used simply to target an intended audience.

Turning to FIG. 22, the geographic gate 1081 will be illustrated, it being understood that gate 1083 could be constructed in like fashion. Data coming in from the left goes to register 1101 which puts the non-geographic part of the data on line 1103 and the geographic part of the data on line 1105. The geographic part is, of course, data describing the geographic characteristics of the intended recipients for the given message or solicitation. Comparer 1107 compares the geographic characteristics of the message with the GPS data at the customer's location. A match (meaning that the GPS data conforms to the intended recipients, not necessarily identical bits of data) causes AND gate 1109 to pass the non-geographic parts of the message. Thus, the message is supplied only to those having the intended geographic location(s).

Note that in the case of sending geographically limited messages or solicitations, the user authorization messages 24 of the central office location of FIG. 1 carry geographically limiting information such that the conditional access system 20 or other system impressing such geographic constraints on outgoing messages may be considered as a geographic limiter.

Although specific constructions have been presented herein, it is to be understood that these are for illustrative purposes only. Various modifications and adaptations will be apparent to those of skill in the art. For example, various gates and other hardware components are shown, but many of these components could be realized by software performing geographic filtering or other of the functions of the hardware components. In view of possible modifications, it will be appreciated that the scope of the present invention should be determined by reference to the claims appended hereto.

What is claimed is:

1. A signal access control system comprising a customer access control operable at a customer location and having:
 - a signal input to receive at least one signal from a remote source;
 - a signal processor operably connected to receive signals from the signal input;
 - a conditional accesser operably connected to the signal processor;
 - a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source; and
 - a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser, the conditional accesser authorizing access only if the GPS

signal receiver receives signals consistent with the customer access control being at an authorized location; and wherein the conditional accesser is operable to block access to at least some signals not authorized for reception at the customer location.

2. The signal access control system of claim 1 wherein the conditional accesser authorizes access only if the GPS signal receiver receives signals consistent with the customer access control being at a single fixed location authorized for service.

3. The signal access control system of claim 2 wherein conditional accesser authorizes access using criteria to test for authorization in addition to information about the location of the customer access control.

4. The signal access control system of claim 1

wherein the customer access control further includes a GPS processor operably connected to receive direct GPS information from the GPS receiver and a decoder operably connected to the signal input to provide indirect GPS signals received from a transmission medium carrying the at least one signal from a remote source; and

wherein the GPS processor uses information from the indirect GPS signals to determine which GPS sources are to be used by the customer access control and the location of the determined GPS sources.

5. The signal access control system of claim 4 further comprising a central access control remote from customers and having:

- a source of at least one signal;
- an output device for placing signals from the source onto a transmission medium for transmission to customers with the customer access control;
- a central GPS receiver operable to receive position information from remote sources and operably connected to apply data messages to the output device, the data messages corresponding to the position information and the output device supplying the position information to the transmission medium for transmission to customers.

6. The signal access control system of claim 1 wherein the signal input receives signals from a transmission medium selected from the group consisting of satellite broadcast, non-satellite broadcast, and cable and the signals received via the transmission medium selected from the groups consisting of audio signals, video signals, and data signals.

7. The signal access control system of claim 6 wherein the signals received via the transmission medium include video signals.

8. The signal access control system of claim 1 wherein the signal input receives data program signals.

9. The signal access control system of claim 8 further comprising a central access control remote from customers and having:

- a source of at least one signal;
- a central output device for placing data program signals from the source onto a transmission medium for transmission to customers with the customer access control;
- a central GPS receiver operable to receive position information from remote sources and operably connected to apply data messages to the output device, the data messages corresponding to the position information and the output device supplying the position information to the transmission medium for transmission to customers.

10. The signal access control system of claim 9 wherein the signal input receives data program signals from the central output device.

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11. The signal access control system of claim 10 wherein the signal input receives data program signals corresponding to data from the Internet and the customer access control includes a customer output device operable to place outgoing signals on the Internet.

12. The signal access control system of claim 11 wherein the central access control further includes a central Internet interface and wherein the customer output device is operable to place outgoing signals on the Internet via the central Internet interface of the central access control.

13. The signal access control system of claim 12 wherein the transmission medium used by the central output device and the transmission medium used by the customer output device are the same transmission medium.

14. The signal access control system of claim 1 wherein the signal input receives data program signals corresponding to data from the Internet.

15. The signal access control system of claim 14 wherein the customer access control includes a customer output device operable to place outgoing signals on the Internet.

16. A signal access control system comprising a customer access control operable at a customer location and having:

a signal input to receive at least one signal;

a signal processor operably connected to receive signals from the signal input;

a conditional accesser operably connected to the signal processor;

a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source; and

a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser, the conditional accesser authorizing access only if the GPS signal receiver receives signals indicating that the customer access control is at an authorized location; and wherein the conditional accesser authorizes access only if the GPS signal receiver receives signals consistent with the customer access control being at a single fixed location authorized for service; and wherein the conditional accesser is operable to block access to at least some signals not authorized for reception at the customer location.

17. The signal access control system of claim 16 wherein the signal input receives data program signals corresponding to data from the Internet.

18. The signal access control system of claim 17 wherein the customer access control includes a customer output device operable to place outgoing signals on the Internet.

19. A signal access control system comprising a customer access control operable at a customer location and having:

a signal input to receive at least one signal;

a signal processor operably connected to receive signals from the signal input;

a conditional accesser operably connected to the signal processor;

a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source; and

a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser, the conditional accesser authorizing access only if the GPS

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signal receiver receives signals indicating that the customer access control is at an authorized location; and wherein the conditional accesser uses criteria to test for authorization in addition to information about the location of the customer access control; and

wherein the conditional accesser is operable to block access to at least some signals not authorized for reception at the customer location.

20. The signal access control system of claim 19 wherein the signal input receives data program signals corresponding to data from the Internet.

21. The signal access control system of claim 20 wherein the customer access control includes a customer output device operable to place outgoing signals on the Internet.

22. A signal access control system comprising a central access control remote from customers and having:

a source of at least one signal;

an output device for placing signals from the source onto a transmission medium for transmission to customers;

a central GPS receiver operable to directly receive position information from remote GPS sources, the remote sources being remote from both the central access control and the customers, and operably connected to apply position data messages to the output device, the position data messages corresponding to the position information and the output device supplying the position information to the transmission medium for transmission to customers; the position data messages usable at customer locations to aid in determination of customer locations.

23. The signal access control system of claim 22 wherein the central access control further includes a central Internet interface operable to bi-directionally convey signals to and from the Internet based on interactive real-time actions of customers remote from the central access control.

24. A signal access control system comprising a customer access control operable at a customer location and having:

a signal input to receive at least one signal from a remote source;

a signal processor operably connected to receive signals from the signal input;

a conditional accesser operably connected to the signal processor;

a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source;

a GPS signal receiver operable at the customer location to receive position information from remote sources and operably connected to the conditional accesser, the conditional accesser authorizing access only if the GPS signal receiver receives signals consistent with the customer access control being at an authorized location; and

a region comparer to compare a region code received with the at least one signal from the remote source with a region index stored at the customer location and operable to output a region comparer output, the region code being representative of a geographic region authorized to receive a signal and the region index being representative of a geographic region of the customer access control, there being different region codes for different geographic regions; and

wherein the conditional accesser receives the region comparer output and conditions access to a given(s) of

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the signals from the remote source upon the region comparer output indicating that those given one(s) of the signals are authorized for an access region of the customer access control; and wherein the conditional accesser is operable to block access to at least some signals not authorized for reception at the customer location.

25. The signal access control system of claim 24 wherein the signal input receives data program signals corresponding to data from the Internet.

26. The signal access control system of claim 25 wherein the customer access control includes a customer output device operable to place outgoing signals on the Internet.

27. A signal system comprising:

a signal input to receive at least one signal;

a geographic filter operably connected to receive signals from the signal input and having a geographic filter output; and

a GPS signal receiver at a customer location and operable to receive position information from remote sources and operably connected to supply information to the geographic filter and wherein the geographic filter selectively passes signals from the signal input to the geographic filter output depending on the GPS signal receiver receiving signals consistent with the GPS signal receiver being at an appropriate location, thus geographically filtering signals; and

wherein the geographical filter is operable to block access to at least some signals not authorized for reception at the customer location.

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28. The signal system of claim 27 wherein the geographic filter is operable to geographically filter signals sent to the customer location from a remote source.

29. The signal system of claim 27 wherein the geographic filter is operable to geographically filter signals sent from the customer location.

30. The signal system of claim 27 wherein the GPS signal receiver and the geographic filter are part of a customer access control and the customer access control further includes:

a signal processor operably connected to receive signals from the signal input;

a conditional accesser operably connected to the signal processor; and

a signal output operably connected to the signal processor and providing a useable output signal only upon the conditional accesser authorizing access to one or more signals from the remote source.

31. The signal system of claim 27 further comprising a central access control remote from customers and having:

a source of at least one signal;

an output device for placing signals from the source onto a transmission medium for transmission to customers; and

a geographic limiter operably connected to apply geographic data messages to the output device; and

wherein the geographic filter at the customer location is operable to use the data messages to determine whether the geographic filter passes a given signal.

* * * * *



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King et al.

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(45) **Date of Patent:** **Apr. 3, 2001**

(54) **MOBILE STATION LOCATION
DETERMINATION IN A RADIO
COMMUNICATION SYSTEM**

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(73) **Assignee:** **Motorola, Inc.**, Schaumburg, IL (US)

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(52) **U.S. Cl.** 342/357.09; 342/357.1;
342/357.15

(58) **Field of Search** 342/357.06, 357.09,
342/357.1, 357.15

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,445,118	4/1984	Taylor et al.	343/357
4,797,677	1/1989	MacDoran et al.	342/352
5,119,101	6/1992	Barnard	342/357
5,430,657 *	7/1995	Kyrtos	701/226
5,731,786	3/1998	Abraham et al.	342/357
5,889,492	3/1999	Kurby et al.	342/357
5,893,044	4/1999	King et al.	701/214

OTHER PUBLICATIONS

GPS assistance in broadcast mode, P. Agashe, et al., submission to TIA committee TR45.5.2.3, Feb. 16, 1999.

Draft Location Parameters and Message Structure, S. Droste, submission to TIA committee TR45.5.2.3, Apr. 8, 1999.

Preliminary Least Squares Fit Broadcast Message, I. Lin, et al., submission to TIA committee TR45.5.2.3, Apr. 27, 1999. Point-to-Point and Broadcast Signaling Messages for GPS Capable GSM Mobile Stations, Y. Zhao, submission to TIA committee T1P1, Jul. 6, 1999.

* cited by examiner

Primary Examiner—Thomas H. Tarcza

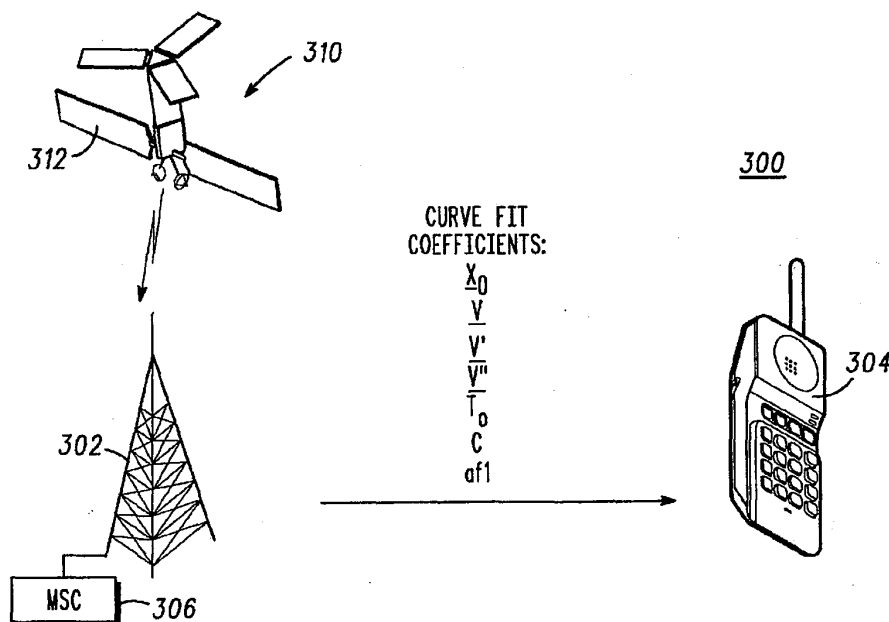
Assistant Examiner—Fred H. Mull

(74) *Attorney, Agent, or Firm*—Rennie W. Dover

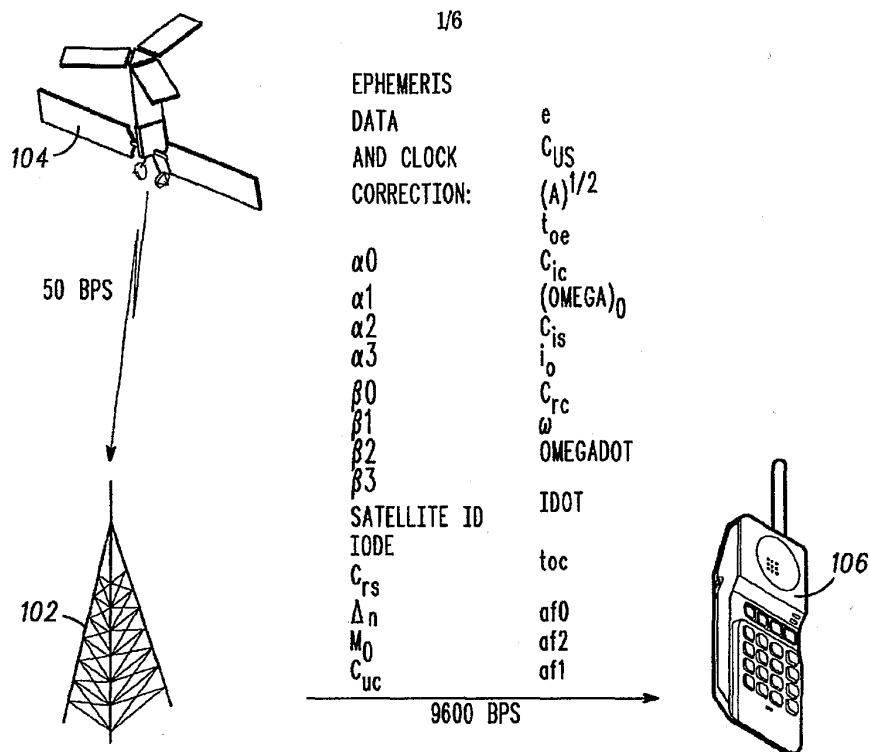
(57) **ABSTRACT**

A method and apparatus for location determination of a mobile station (304) in a fixed radiocommunication system having at least one base station (302) reduces the computational load on the mobile station. Satellite ephemeris information and clock correction information are received at a base station and periodically used to calculate satellite position data. The satellite position data are conveyed to the mobile station. At other times, the satellite ephemeris data is used to calculate curve fit data at the base station. The curve fit data is transmitted to the mobile station, reducing the amount of data conveyed over the communication link and the computation load on the mobile station.

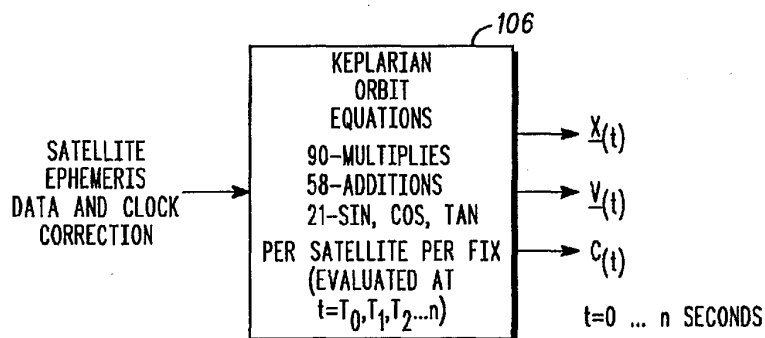
33 Claims, 6 Drawing Sheets



10/18/2001, EAST Version: 1.02.0008



-PRIOR ART-

FIG. 1

-PRIOR ART-

FIG. 2

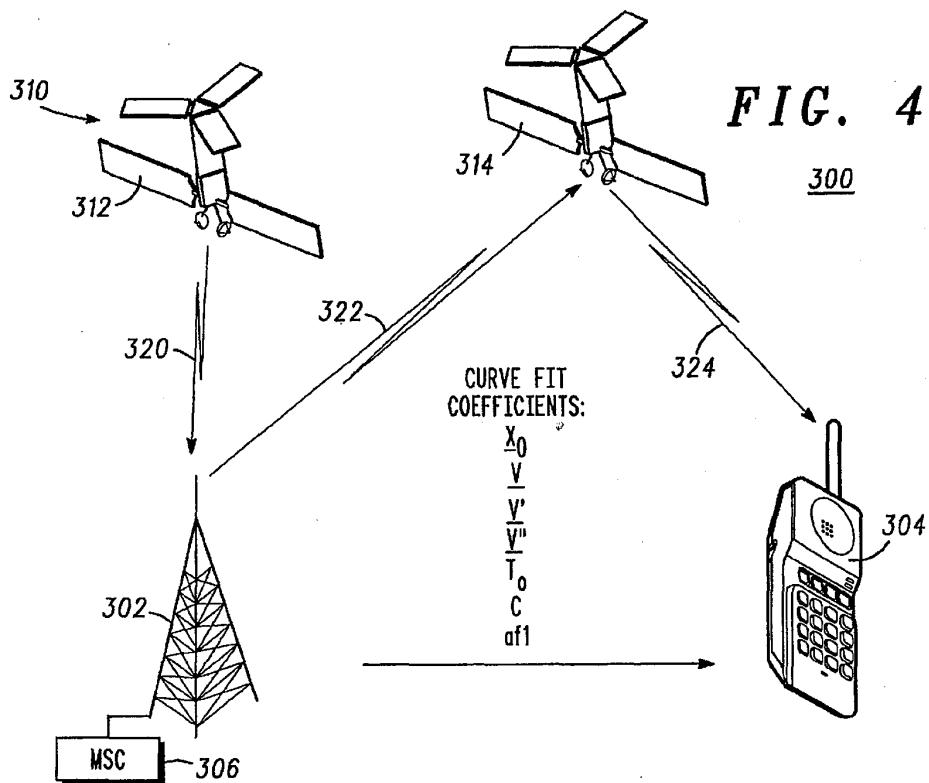
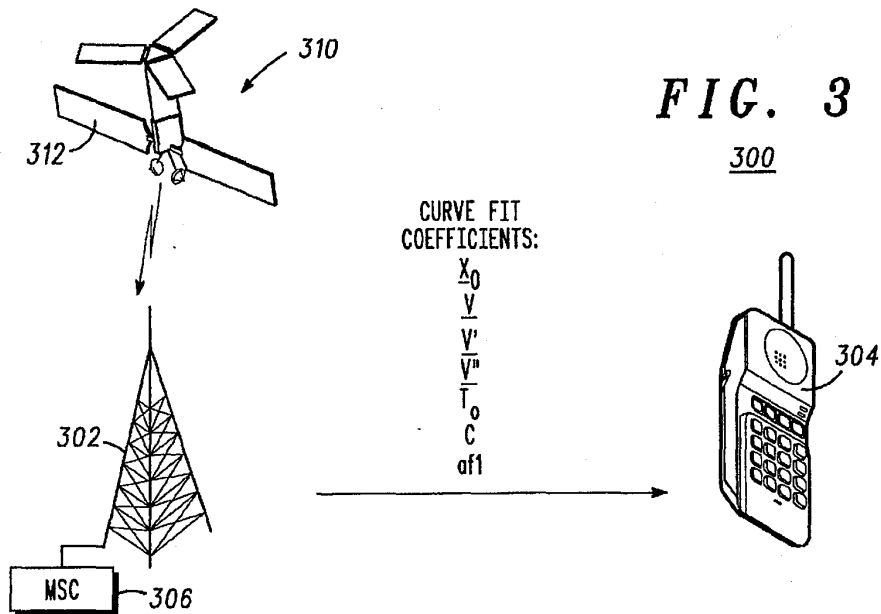


FIG. 5

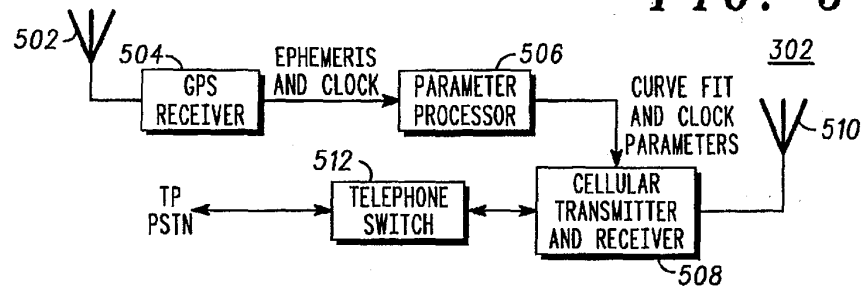


FIG. 6

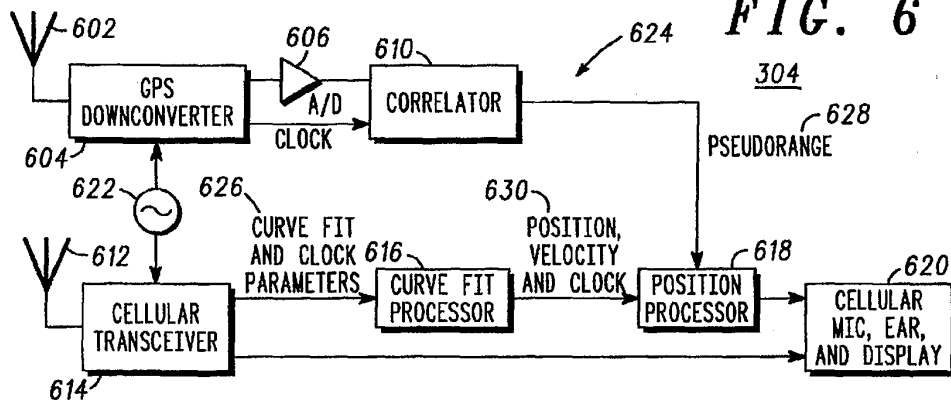
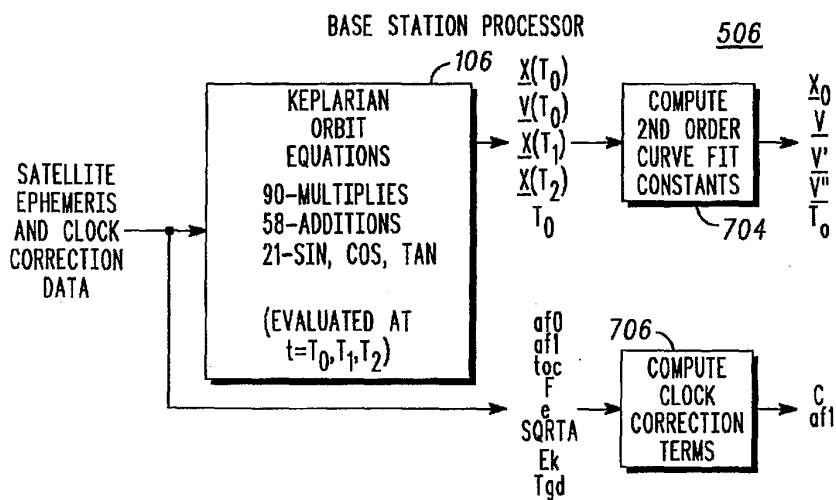


FIG. 7



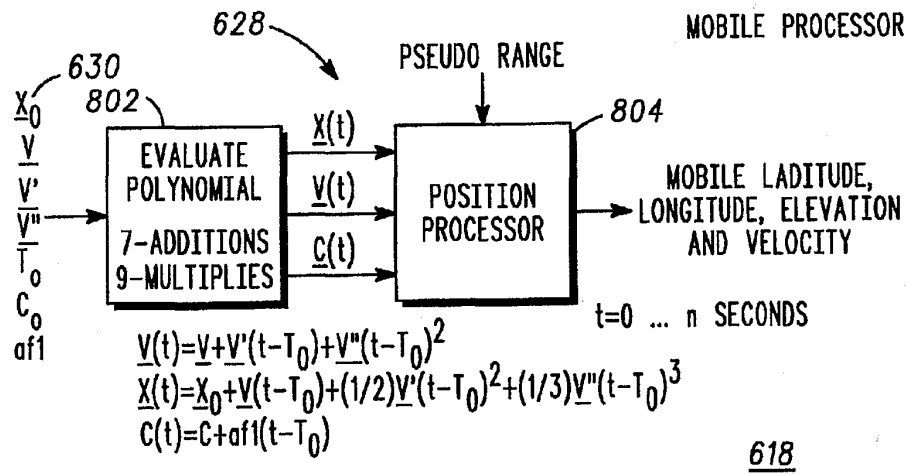


FIG. 8

ALGORITHM FOR COMPUTING 2ND ORDER CURVE FIT PARAMETERS

$$\begin{aligned} \underline{X}_0 &= \underline{X}(T_0) \\ \underline{V} &= \underline{V}(T_0) \\ \underline{V}' &= (8 * \underline{d2} - \underline{d1}) / (2 * dt^2) \\ \underline{V}'' &= 3 * (\underline{d2} - 4 * \underline{d1}) / (4 * dt^3) \\ \underline{C} &= af0 + af1(T_0 - t_{oc}) + tr + Tgd \\ \text{WHERE,} \\ dt &= T_1 - T_0 \\ \underline{d1} &= (\underline{X}(T_1) - \underline{X}(T_0)) - \underline{V}(T_0) * dt \\ \underline{d2} &= (\underline{X}(T_2) - \underline{X}(T_0)) - 2 * \underline{V}(T_0) * dt \\ tr &= r * e * SQRTA * SIN(Ek) \end{aligned}$$

FIG. 9

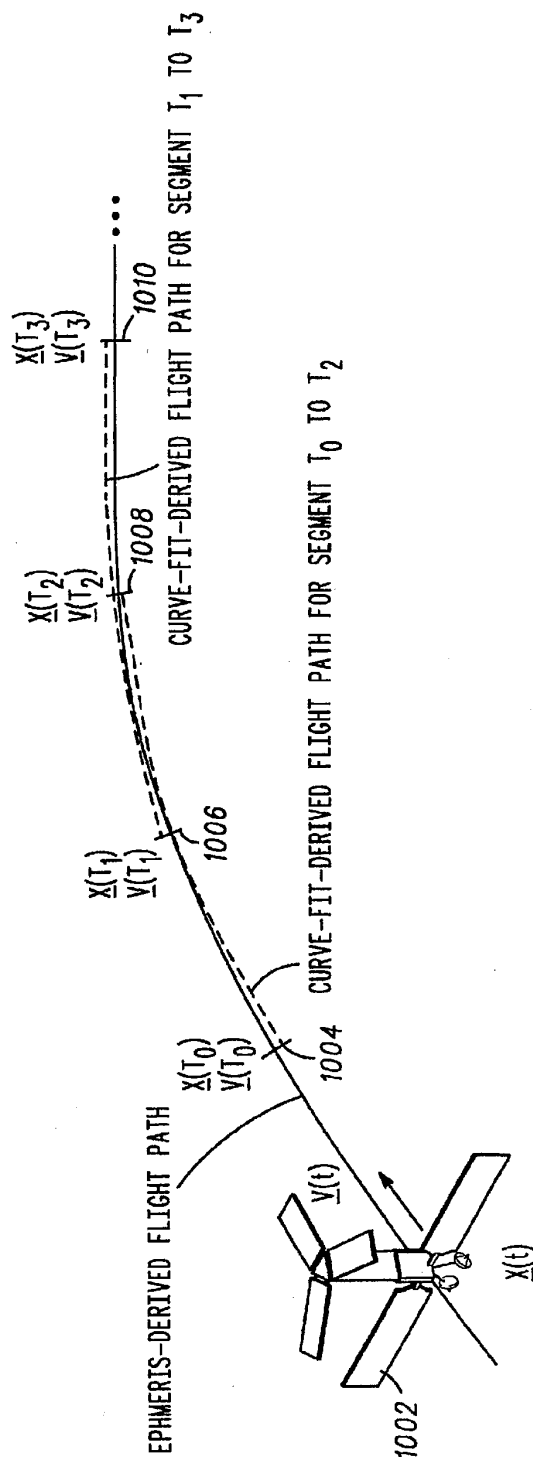


FIG. 10

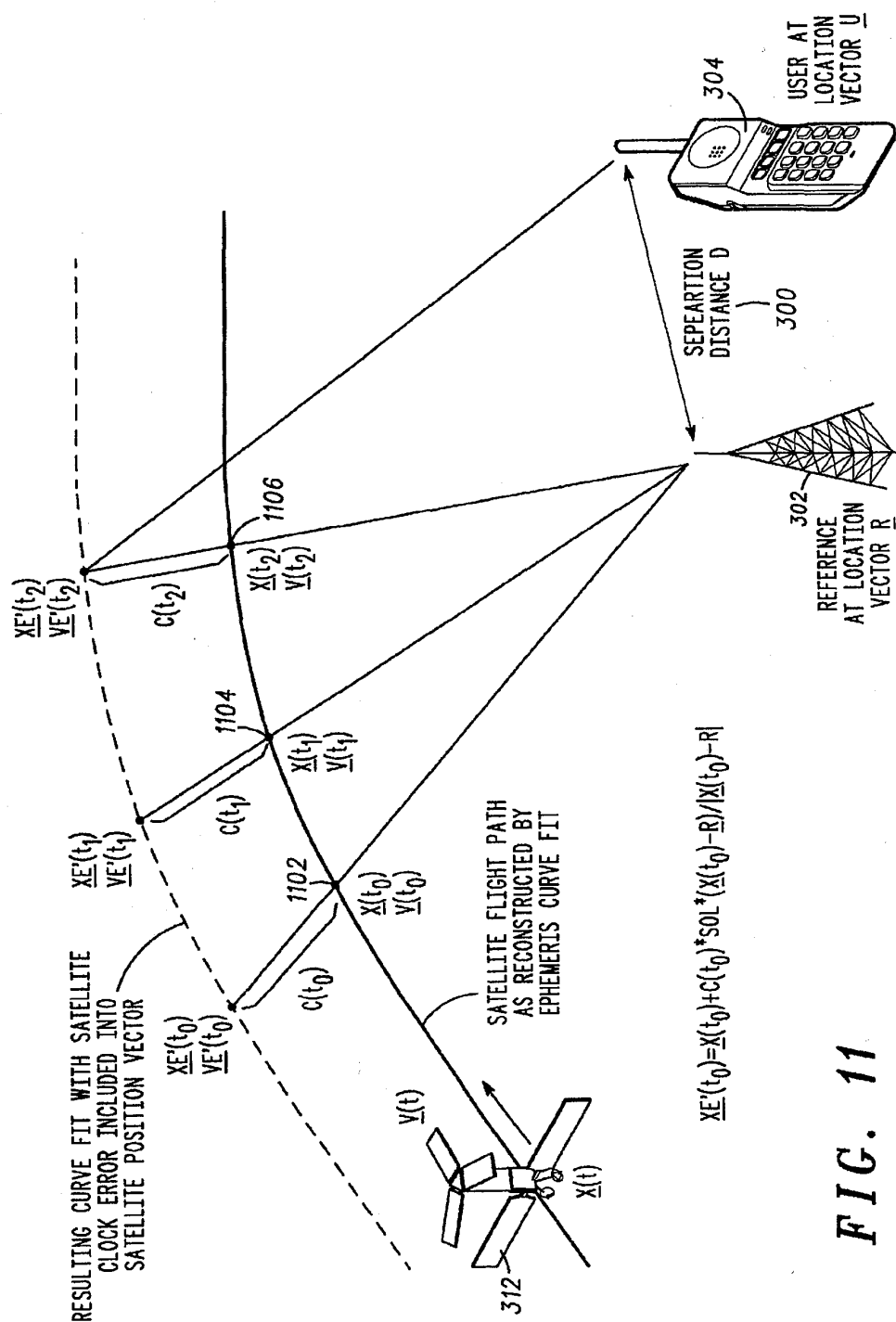


FIG. 11

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MOBILE STATION LOCATION DETERMINATION IN A RADIO COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates generally to radio communication systems. More particularly, the present invention relates to method and apparatus for mobile station location determination in such a radio communication system.

Radio communication systems generally provide two-way voice and data communication between remote locations. Examples of such systems are cellular and personal communication system (PCS) radio systems, trunked radio systems, dispatch radio networks, and global mobile personal communication systems (GMPCS) such as satellite-based systems. Communication in these systems is conducted according to a pre-defined standard. Mobile stations, also known as handsets, portables or radiotelephones, conform to the system standard to communicate with one or more fixed base stations.

It is desirable to obtain and communicate physical locations of mobile stations within the system. In the future, such location information will be required. The United States Federal Communications Commission (FCC) has required that radio systems provide physical location information for emergency ("E911") purposes. Further, with location information available for individual mobile stations, position-dependent services and messaging including advertising can be tailored to the user of the mobile station responsive to location of the mobile station.

Current generations of radio communication have only limited location determination capability. In one technique, the position of the mobile station is determined by monitoring mobile station transmissions at several base stations. From time of arrival measurements, the mobile's position can be calculated. The precision of this technique at times may not be sufficient to meet requirements, though.

In another technique, each mobile station is equipped with a receiver suitable for use with a global satellite navigation system such as the Global Positioning System (GPS). The GPS receiver detects transmissions from a constellation of GPS satellites orbiting the Earth.

Using data and timing from the transmissions, the GPS receiver calculates the positions of the satellites and from those positions, its own position. A GPS satellite in orbit moves at about 4,000 meters per second. The satellite has location data defined by a parameter $X(t)$ and velocity data defined by a parameter $V(t)$. The parameters $X(t)$ and $V(t)$ are three dimensional position and velocity vectors for this satellite and are referenced to an earth-centered-earth-fixed Cartesian coordinate system. The GPS system includes 24 satellites, several of which may be in view of the mobile station at any one time. Each satellite broadcasts data according to pre-defined standard format and timing.

Traditionally, the satellite coordinates and velocity have been computed inside the GPS receiver. The receiver obtains satellite ephemeris and clock correction data by demodulating the satellite broadcast message stream. The satellite transmission contains 576 bits of data transmitted at 50 bits per second. The constants contained in the ephemeris data coincide with Kepler orbit constants requiring many mathematical operations to turn the data into position and velocity data. In one implementation, this conversion requires 90 multiplies, 58 adds and 21 transcendental function calls (sin, cos, tan) in order to translate the ephemeris into a satellite position and velocity vector at a single point, for one

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satellite. Most of the computations require double precision, floating point processing. A receiver must perform this computation every second for every satellite, for up to twelve satellites.

Thus, the computational load for performing the traditional calculation is significant. The mobile must include a high-level processor capable of the necessary calculations. Such processors are relatively expensive and consume large amounts of power. As a portable device for consumer use, a mobile station is preferably inexpensive and operates at very low power. These design goals are inconsistent with the high computational load required for GPS processing.

Further, the slow data rate from the GPS satellites is a limitation. GPS acquisition at a receiver may take many seconds or several minutes, during which time the receiver circuit and processor of the mobile station must be continuously energized. Preferably, to maintain battery life in a portable radio, circuits are de-energized as much as possible. The long GPS acquisition time can rapidly deplete the battery of a mobile station. In any situation and particularly in emergency situations, the long GPS acquisition time is inconvenient and possibly dangerous for the user.

One proposal includes receiving the ephemeris and clock correction data at a base station of the radio communication system and transmitting this data over a conventional communication link to the mobile station. FIG. 1 shows a system incorporating this base-to-mobile communication link. A base station 102 receives the 50 bits per second (bps) transmission from a GPS satellite 104. The base station 102 acts as a repeater, gathering the data from the GPS satellite 104 and re-transmitting it at a higher data rate to a mobile station 106. The ephemeris and clock correction data are received at the mobile station and used for calculation of satellite position. From satellite position, mobile station position can in turn be determined. FIG. 2 illustrates the computational requirements for determining the position vector $X(t)$, the velocity vector $Y(t)$ and the clock correction $C(t)$ at the mobile station using the ephemeris data and clock correction data received from the base station.

The illustrated system has some advantages. A greater data rate is possible when using the base-to-mobile communication link. As illustrated in FIG. 1, a conventional cellular system allows data transmission over this link at a typical rate of 9600 bits per second. This allows the mobile receiver circuit to be turned off a greater amount of time, reducing power consumption in the mobile station. However, the high computational load associated with the raw ephemeris data remains.

Another proposed solution stores a GPS almanac at the mobile station. The almanac data are a truncated, reduced precision subset of the ephemeris data. A base station computes location and clock correction information for the almanac and transmits this correction over the communication link to the mobile station. The mobile station determines that it has the proper correction data for its almanac and, if so, computes satellite location and clock data using the almanac.

This system reduces slightly the computational load required of the mobile station. However, the mobile station receiver must still remain energized during transmission of its almanac data and subsequently during all possible transmission times to receive correction data for its almanac. Also, the almanac data must be stored at the mobile station which can increase the size and cost of the mobile station.

Accordingly, there is a need for an improved method and apparatus for location determination in a radio communication system.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF
THE DRAWINGS

FIG. 1 is a block diagram showing a prior art system communicating satellite ephemeris and clock correction data to a mobile station in a radio communication system;

FIG. 2 is a block diagram illustrating calculation of satellite position, velocity and clock correction data in the mobile station of the system of FIG. 1;

FIG. 3 is a block diagram of a radio communication system;

FIG. 4 is a block diagram of a second embodiment of the radio communication system of FIG. 3;

FIG. 5 is a block diagram of a base station of the radio communication system of FIG. 3;

FIG. 6 is a block diagram of a mobile station of the radio communication system of FIG. 3;

FIG. 7 illustrates operation of the processor of the base station of FIG. 5;

FIG. 8 illustrates operation of the processor of the mobile station of FIG. 6;

FIG. 9 illustrates calculations necessary for computing the parameters transmitted from the base station to the mobile station;

FIG. 10 illustrates estimated and actual satellite positions; and

FIG. 11 illustrates estimated and actual satellite positions.

DETAILED DESCRIPTION OF THE
PRESENTLY PREFERRED EMBODIMENTS

Referring now to FIG. 3, it shows a block diagram of a radio communication system 300. The system 300 includes one or more base stations such as base station 302, one or more mobile stations such as mobile station 304 and a mobile switching center 306. The base station 302 provides two-way radio communication of voice and data between the base station 302 and mobile stations such as the mobile station 304 located in a predetermined geographic area near the base station 302.

The mobile switching center 306 provides overall control of the system 300. In particular, the mobile switching center 306 controls handoff of communication between the mobile station 304 and two or more base stations such as the base station 302. The mobile switching center 306 is in wire line communication with each base station 304 of the system 300. The mobile switching center 306 in some applications provides connection to other communication systems, such as the public switched telephone network (PSTN).

The system 300 may be configured as any of a wide variety of known or future systems. Such systems including cellular radiotelephone systems, trunked radio systems; satellite radio systems and any other suitable radio communication system. Exemplary cellular systems include cellular systems according to standards such as the Global System for Mobile communications (GSM), code division multiple access (CDMA) systems according to interim standard IS-95, time division multiple access systems according to interim standard IS-136, advanced mobile phone systems (AMPS), and others.

Operated in proximity to the radiocommunication system 300 is a global navigation positioning system 310. The satellite system 310 is independent of the radio communication system 300. In FIG. 3, the system 310 includes at least one satellite 312 in radio communication with radio equipment on the earth. The satellites including satellite 312 are

in earth orbit. One example of a suitable global navigation positioning system is the global positioning system (GPS) operated by the United States. Another example is the global orbital navigation satellite system (GLONASS) operated by Russia. Satellites such as the satellite 312 of the system 310 transmit timing and position information for receipt by the receivers on the ground for time keeping and geolocation purposes. In the exemplary embodiment of FIG. 3, the system 310 is the GPS system and the satellite 312 periodically transmits satellite ephemeris information and clock correction information.

For location determination by the mobile station 304 in the radio communication satellite 300, the system 300 receives at the base station 302 satellite ephemeris information and clock correction information for at least one satellite such as satellite 312. Preferably, such information is received for a plurality of satellites including at least four satellites. In the illustrated embodiment, the information is received directly from the satellites themselves using a receiver such as a GPS receiver associated with the base station. However, in alternative embodiments, the information could be received remotely and transmitted to the base station 304. The information could be received at the mobile switching center 306 and communicated to each base station of the system 300.

At the base station 302, satellite position curve fit data and clock correction data are calculated in response to the satellite ephemeris information and clock correction information. Subsequently, the satellite position curve fit data and clock correction data is transmitted from the base station 302 at predetermined intervals. At the mobile station 304, the satellite position curve fit data and clock correction data are received. The mobile station 304 determines a position for the at least one satellite, satellite 312, using the received data. Preferably, the satellite position curve fit data and clock correction data is updated and transmitted every five minutes. However, other time intervals may be suitably selected. In alternative embodiments, the clock correction data may be omitted or combined into the satellite position information to further reduce the amount of data that must be transmitted to the mobile station 304.

Significantly, the mobile station 304 does not need to store satellite almanac data to compute satellite positions. The curve fit data transmitted by the base station 302 is adequate to allow rapid, reliable GPS acquisition without use of almanac data.

In this manner, the computation load imposed upon the mobile station 304 is substantially reduced. As will be described below, estimation of position of the satellite 312 using the curve fit data requires substantially less computational power at the mobile station 304. The computation of satellite position using the curve fit data is only performed periodically, such as once every five minutes. This reduces the complexity of calculations that must be performed in the mobile station 304, reduces storage requirements in the mobile station 304 and reduces power consumption in the mobile station 304.

The illustrated techniques may be extended to any GPS station, independent of operation in a two way radio system such as a cellular system. A mobile station equipped with a local receiver can receive local transmission of satellite position curve fit data transmitted from a terrestrial or local transmitter. The mobile station determines a restricted range of satellite Doppler and code phase search. Since the search range is restricted, acquisition of the satellite signal occurs more quickly. If the mobile station is further equipped with

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a GPS receiver, satellite position and, in turn, the mobile station position can be determined by a computational element such as a processor of the GPS station. Such a GPS station provides advantages of reduced GPS acquisition time over conventional GPS receivers that use satellite ephemeris or almanac information alone. The local receiver can be relatively inexpensive and low-power and should be suitable for receiving data using any modulation or encoding technique on permitted frequencies. The terrestrial transmitter can be part of another radio system, such as a two-way radio system (cellular and trunked radio systems are examples) or can be a stand-alone transmitter or series of transmitters dedicated to GPS acquisition assist.

FIG. 4 illustrates an alternative embodiment of the radio communication system 300 of FIG. 3. In FIG. 4, the radio communication system 300 includes a plurality of base stations such as base station 302 in radio communication with one or more mobile stations such as mobile station 304. The system is under control of a mobile switching center 306 which controls handoff of two-way radio communication between the mobile station 304 and two or more base stations such as base station 302.

Operated proximate the radio communication system 300 is a global navigation satellite system 310 including a satellite 312 and a satellite 314. The satellites 312, 314 transmit timing and position information for use by ground based receivers for geolocation purposes. However, the satellite system 310 is independent of the radio communication system 300.

In the embodiment of FIG. 4, the base station 302 receives a transmission 320 from a satellite 312. The transmission 320 includes satellite ephemeris information and clock correction information for at least one satellite, including the satellite 312. The transmission 320 is a conventional transmission, for example of the type provided by the GPS system. After receiving the transmission 320, the base station 302 calculates satellite position and clock correction curve fit data in a manner to be described below.

The curve fit data is subsequently transmitted in a transmission 322 to a satellite of the satellite system 310. Depending on timing, position and other factors, the transmission 322 may be directed back to the satellite 312 or to a different satellite such as satellite 314. After receiving the curve fit data, the satellite 314 transmits in a transmission 324 the curve fit data directly to the mobile station 304. This provides an alternative technique for transmitting the curve fit data from the base station 302 to the mobile station 304.

FIG. 5 is a block diagram of a base station 302 for use in the radio communication system 300 of FIG. 3. The base station 302 includes a satellite antenna 502, a satellite receiver 504, a parameter processor 506, a cellular transmitter and receiver 508, a cellular antenna 510 and a telephone switch 512.

The satellite antenna 502 detects radio frequency transmissions from earth orbiting satellites. The received transmissions are conveyed to the satellite receiver 504 which demodulates and decodes the transmitter information in a manner well known in the art. In the embodiment of FIG. 5, the satellite receiver 504 is configured to receive transmissions from a GPS satellite system. However, other satellite systems may be accommodated as well, including, for example, GLONASS, Iridium, GlobalStar and others now known or developed in the future. The GPS receiver 504 decodes satellite ephemeris information and clock correction information from the transmission detected at the satellite antenna 502. The satellite receiver 504 thus forms a

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means for receiving satellite ephemeris information and clock correction information. In alternative embodiments, this function may be performed by a receiver located remotely from the base station 302.

The satellite ephemeris information and clock correction information are conveyed to the parameter processor 506. The parameter processor 506 may be embodied as any suitable high speed, high precision data processor, such as one or more commercially available microprocessors for data processing the ephemeris information and clock correction information. The function performed by the parameter processor 506 may be performed by the same processor which controls the base station 302 or a processor which controls a cellular call at the base station 302, or the parameter processor 506 may be an independent processor dedicated to position location operations. The parameter processor 506 produces curve fit and clock correction data, as will be described below. The parameter processor 506 thus forms a processor configured to compute satellite position curve fit data in response to the satellite ephemeris information and clock correction information.

The curve fit data are provided to the cellular transmitter and receiver 508. The cellular transmitter and receiver 508 implements two-way voice and data radio communication in accordance with a cellular standard, such as GSM, IS-95, IS-136 or another. The cellular transmitter and receiver 508 formats a message according to the formatting rules of the cellular standard which controls operation of the radiotelephone system in which the base station 302 operates. In addition, the cellular transmitter and receiver 508 may detect a request from a mobile station received at the antenna 510 requesting position information for use in calculating mobile station position. In response to the request, the cellular transmitter and receiver 508 formats a message for transmission to a mobile station using the antenna 510. Thus, the cellular transmitter and receiver 508 forms a transmitter coupled to the processor 506 and configured to broadcast the satellite position curve fit data to all mobiles in the region at predetermined intervals or transmitted individually to particular mobile stations when the mobile station requests the data.

The telephone switch 512 provides two-way communication between the base station 302 and an external communication network, such as the PSTN. The telephone switch 512 may also provide connection to other base stations of the radiocommunication system in which the base station 302 operates. In alternative embodiments, the telephone switch 512 may receive the satellite ephemeris information and clock correction information from a remote location, such as a mobile switching center.

FIG. 6 is a block diagram of a mobile station 304 for operation in the radio communication system 300 of FIG. 3. The mobile station 304 includes a satellite antenna 602, a downconverter 604, and analog-to-digital converter (ADC) 606, and a correlator 610. The mobile station 304 further includes a cellular antenna 612, a cellular transceiver 614, a curve fit processor 616, a position processor 618 and a user interface 620.

The downconverter 604 is configured to receive a satellite signal from one or more satellites as detected at the satellite antenna 602. The downconverter 604 operates in response to an oscillator 622 which generates a reference frequency. The satellite receiver 604 in the illustrated embodiment is a GPS downconverter. GPS signals conventionally contain high rate repetitive signals called pseudo-random or pseudo-noise (PN) sequences. The PN codes are called C/A codes and

have a binary phase-reversal rate of 1.023 MHz and a repetition period of 1023 chips for a code period of 1 msec. Each GPS satellite broadcasts its signal with a unique code.

Following downconversion to baseband in the downconverter 604, the received signal is converted from analog to digital data by the ADC 606. The downconverter 604 further produces a clock signal which is provided to the correlator 610.

The correlator 610 multiplies the received signal by a stored replica of the appropriate code contained within its local memory and then integrates or filters the product in order to obtain an indication of the presence of the signal. By sequentially adjusting the relative timing of this stored replica relative to the received signal, and observing the correlation output, the receiver can determine the time delay between the received signal and a local clock. The initial determination of the presence of such an output is termed acquisition. Once acquisition occurs, the process enters the tracking phase in which the timing of local reference is adjusted in small amounts in order to maintain a high correlation output. The time delays measure between the receive signal from each satellite and the local clock form pseudo-ranges. The correlator 610 provides the pseudo-range data to the position processor 618. Thus, the downconverter 604, the ADC 606, and the correlator 610 in combination form a satellite receiver 624 configured to receive satellite signals from one or more satellites and produce pseudo-range data 628 in response to the satellite signals.

The cellular antenna 612 detects and transmits energy on cellular frequencies from a base station of a cellular system. The cellular transceiver 614 operates to transmit and receive voice and data information with a cellular base station of the radiocommunication system in which the mobile station 304 operates. The cellular transceiver 614 operates in response to the oscillator 622 which generates a reference frequency.

The cellular transceiver 614 is configured for two-way voice and data communication with a remote base station and to receive satellite position and clock correction curve fit data 626 transmitted from the base station. The curve fit data are provided from the transceiver 614 to the curve fit processor 616. The curve fit processor 616 may be implemented as a microprocessor or other suitable computation device within the mobile station 304. The curve fit processor 616 may also perform functions of digital signal processing and call processing in the mobile station 304. Further, the curve fit processor 616 may be implemented as a group of software instructions suitable for processing the curve fit and clock correction data received from the cellular transceiver 614. The curve fit processor 616, in a manner to be described below, calculates position and velocity vectors and clock correction data 630 in response to the curve fit and clock data 626. The position, velocity and clock information 630 are provided to the position processor 618.

The position processor 618 is coupled with the transceiver 614 and the satellite receiver 604 and configured to compute satellite positions of the one or more satellites in response to the satellite position and clock correction curve fit data 626 and the pseudo-range data 628 received from the correlator 610. The position processor 618 may be implemented as any suitable processor, such as a microprocessor or digital signal processor of the mobile station 304. Further, the position processor 618 may be implemented as a group of software instructions and associated data for processing the position velocity and clock data and the pseudo-range data.

The user interface 620 permits user control of the mobile station 304 by a user of the mobile station 304. In the

illustrated embodiment, the user interface 620 includes a microphone, an earpiece, a display and a keypad.

FIG. 7 illustrates operation of the parameter processor 506 of the base station 302 of FIG. 5 to compute satellite position curve fit data in accordance with the present invention. The procedure is illustrated in conjunction with FIG. 10.

The Keplerian equations which describe motion of earth orbiting satellites are only evaluated at discrete points in time 1004, 1006, 1008, separated by some period T_1 , say five minutes. In FIG. 10, a satellite 1002 has a position $X(t)$ and a velocity $V(t)$. At a first point 1004, at time T_0 , satellite ephemeris information and clock correction information received at the base station processor 506 are used to calculate the satellite position and velocity vectors. A group of instructions 702 operating in conjunction with the base station processor 506 implements the Keplerian orbit equations to produce the position vector $X(T_0)$, and the velocity vector $V(T_0)$. At a second time 1006, labeled T_1 in FIG. 10, the satellite ephemeris information and clock correction information received at the base station processor 506 are used to calculate the vectors $X(T_1)$ and $V(T_1)$. At a third time 1008, labeled T_2 in FIG. 10, the satellite ephemeris information and clock correction information received at the base station processor 506 are used to calculate the vectors $X(T_2)$ and $V(T_2)$. In the illustrated embodiment, T_2 is different from T_1 by five minutes and T_1 is different from T_0 by five minutes. Other time differences may be chosen and the time differences may not be uniform. The ephemeris data is evaluated at each of the three points producing position vector and velocity vector data.

This data is then entered into a process that computes the second order curve fit vector constants. A satellite in orbit around the earth is subject to both a constant acceleration and a constant velocity. The two can be used to produce a vector sum defining the position of the satellite:

$$X(t) = \frac{1}{2}At^2 + Vt + C$$

where C is an initial displacement, not necessarily zero.

This equation describes the motion of the satellite as a simple second order equation in time. Other forces such as solar wind and gravitational variations also affect the motion of the orbiting satellite. These additional forces require that the process be extended to additional terms of the polynomial equation.

In general, any continuously varying function can be modelled with an infinite order polynomial. Thus, the motion of the satellite can be described as

$$X(t) = X_0 + V_0(t - T_0) + \frac{1}{2}V_1(t - T_0)^2 + \frac{1}{6}V_2(t - T_0)^3 + \dots$$

The velocity of the satellite can be obtained directly from $X(t)$ by taking the derivative of the function with respect to time:

$$V(t) = V_0 + V_1(t - T_0) + \frac{1}{2}V_2(t - T_0)^2 + \dots$$

The error introduced by truncating the infinite order polynomials to a finite order can be predicted and computed. It has been determined that limiting the $X(t)$ polynomial to 4 terms and the $V(t)$ polynomial to 3 terms limits the error to no more than 1 meter given a time interval of applicability (i.e., the $t - T_0$ term) of 5 minutes.

The remaining process is how best to compute the four constants X_0 , V_0 , V_1 , and V_2 . A mathematical process called a curve fit optimally selects the constants so as to minimize the total error. In order to apply this process to the orbit of

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a GPS satellite, the source of the satellite orbit truth model must be obtained. This source is the individual satellite's ephemeris data. The ephemeris data is precise Kepler orbit coefficients that allow the prediction of satellite position as a function of time. By using the ephemeris data, one can create a history of satellite velocity and position data as a function of time. These data points are entered into the curve-fit equations and the constants X_0 , V_0 , V_1 , and V_2 are automatically produced.

FIG. 9 illustrates the mathematical processing required for computing the second order curve fit parameters for use by the mobile station 304 in the radio communication system of FIG. 300. The position vector and velocity vector data are provided to the process 704 (FIG. 7) to compute the second order curve fit vector constants, X_0 , V_0 , V_1 , V_2 . Further, the clock correction data received at the base station processor 506 is provided to a third group of software instructions 706. These instructions 706 compute the clock correction terms C and αf_1 .

The second order curve fit parameters are computed as follows:

$$X_0 = X(T_0)$$

$$V = V(T_0)$$

$$V' = \frac{8d_2 - d_1}{2d^2}$$

$$V'' = 3 \frac{d_2 - 4d_1}{4d^3}$$

$$C = \alpha f_0 + \alpha f_1(T_0 - t_{oc}) + tr + T_{gd}$$

where

$$dt = T_1 - T_0$$

$$d1 = (X(T_1) - X(T_0)) - V(T_0)dt$$

$$d2 = (X(T_2) - X(T_0)) - 2V(T_0)dt$$

$$tr = Fe\sqrt{A} \sin(Ek)$$

In this manner, the ephemeris data is evaluated at the base station 302 at each of the three points, T_0 , T_1 and T_2 , producing position vector and velocity vector data $X(T_0)$, $V(T_0)$, $X(T_1)$, $V(T_1)$, $X(T_2)$, and $V(T_2)$. After computing the curve fit vector constants, X_0 , V_0 , V_1 , and V_2 , the three axis resulting polynomial is evaluated to produce a quadratic equation for the position and velocity vector of the satellite over the period of time from T_0 to T_2 .

In one embodiment using the curve fit technique at 1 Hz, for 12 satellites evaluated at five minute intervals, the total multiply and add operations required of the mobile station processor is only 8 percent of the requirement for doing a traditional ephemeris evaluation at 1 Hz for 12 satellites of five minute intervals.

The curve fit parameters are updated in synchronism with the start of the next five minute interval so that the process can run continuously. The error in the curve fit solution as compared to the ephemeris computed solution can be constrained and predicted. The error can be reduced by reducing the update time below five minutes or by carrying one or two additional terms of the curve fit process (i.e., turning it into a fourth or fifth order equation). Also, the number of bits used for storing the curve fit parameters X_0 , V_0 , V_1 , and V_2 will effect the error as well. However, given a second order position curve fit and five minute update intervals, satellite position errors are constrained well below one meter.

FIG. 8 illustrates operation of the position processor 618 of the mobile station 304 of FIG. 6 to compute mobile station position in accordance with the present invention. The mobile processor receives the curve fit and clock

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parameters 630 which have been received and decoded by the cellular transceiver 614 of the mobile station 304 (FIG. 6). In FIG. 8, the position processor 618 includes a polynomial evaluation stage 802 and a position processing stage 804. The polynomial evaluation stage 802 evaluates $X(t)$, $Y(t)$ and $C(t)$ according to the following equations, using the curve fit parameters X_0 , V , V' , V'' , T_0 , C_0 and αf_1 :

$$X(t) = X_0 + V(t - T_0) + (1/2)V'(t - T_0)^2 + (1/6)V''(t - T_0)^3$$

$$V(t) = V + V'(t - T_0) + V''(t - T_0)^2$$

$$C(t) = C + \alpha f_1(t - T_0)$$

The position, velocity and clock vectors are provided to the position processing stage 804. The position processing stage 804 uses these vectors and the pseudo-range data 628 to calculate the latitude, longitude, elevation and velocity of the mobile station 304.

In one embodiment, the number of bits per satellite required to implement this design while maintaining adequate accuracy in position determination has been determined to be as follows:

Parameter	No. Bits	LSB Scale
X_0	22	2^4
V_0	17	2^{-4}
V_1	12	2^{-11}
V_2	8	2^{-19}

A total of 255 bits per satellite must be transmitted over the communication link from the base station to the mobile station to convey the satellite position curve fit data. As mentioned earlier, a total of 576 bits per satellite must be transmitted over the communication link from the base station to the mobile to convey the satellite raw ephemeris and clock correction data. Consequently, the technique of transmitting curve fit parameters for satellite position and clock correction reduces the total number of bits by 255/576, or only 44% of the total number of original bits.

The computational load at the mobile station has been substantially reduced. The computational load of the curve fit process is only 8% of that required to use the traditional ephemeris calculations to determine a string of satellite position and velocity solutions.

The satellite velocity curve fit and clock correction parameters, once they are delivered to the mobile, frees the mobile from having to predict the Doppler for all satellites in order to acquire the signals. In previous art, the GPS receiver in the mobile needed to maintain a satellite almanac or ephemeris data internally to predict which satellites are visible and the corresponding Doppler shift for each satellite in order to acquire the signal. The velocity and position curve fit parameters can be used to predict very precisely the Doppler for each visible satellite, thus eliminating the need to maintain satellite almanac or ephemeris data internally to the mobile. In addition, the satellite position curve fit and clock correction data can be used to predict the possible range of code phases over which the satellite signal will exist at the mobile station. In this way, the mobile station is freed from having to search the entire pseudo-random noise code phase space, allowing the search to be completed in less time. In this way, the satellite velocity and position curve fit parameters and the clock correction parameters act in such a way so as to form an aide in the acquisition of the satellite signals, allowing the search for such signals to occur in less time.

FIG. 11 illustrates estimated and actual satellite positions. In FIG. 11, provision is made for combining the satellite position curve fit data with the satellite clock correction parameters. This permits elimination of the clock correction parameters completely and reduces even further the number of bits to be transmitted from 254 bits to 217 bits per satellite. In order to accomplish this, the effect of the clock error must be translated into an equivalent satellite position error. This is illustrated in FIG. 11.

In FIG. 11, a satellite 312 of a global navigation positioning system such as GPS orbits above a radio communication system 300. The radio communication system 300 includes a plurality of base stations 302 in two-way radio communication with mobile stations such as mobile station 304. As was illustrated in FIG. 10, ephemeris data is received and curve fit data are calculated at successive points in time, such as point 1102, point 1104 and point 1106. The curve fit data are transmitted from the base station 302 to the mobile station 304 after predetermined intervals, such as five minutes.

Translating the effect of clock error into equivalent satellite position error requires that the satellite orbit curve fit $X(t)$ be modified by an amount corresponding to the satellite clock correction. Effective range extensions C_0 , C_1 , and C_2 are computed from the satellite clock correction as derived from the ephemeris data at time t_0 , t_1 , and t_2 multiplied by the speed of light (SOL). This magnitude can be either positive (farther away) or negative (closer to the mobile station), but typically is on the order of less than 1 ms (but can be as large as 5 ms).

The effective position $XE'(t)$ is calculated as follows:

$$XE'(t_0) = X(t_0) + C(t_0)SOL \left(\frac{X(t_0) - R}{|X(t_0) - R|} \right)$$

In order to modify the effective satellite orbit, a reference point RL is required to project the satellite orbit position along the line extending between its true position $X(t)$ and the RL. The RL can conveniently be the base station 302. Simple vector mathematics modifies the satellite orbit path $X(t)$ to the modified orbit path $X'(t)$.

Choosing each individual base station of the system 300 as the reference site allows for control of the error induced in the range measurement. It is assumed that the base station 302 is within 10 Km of the mobile station 304 (valid most of the time in cellular systems). Also, it is known that the satellite clock correction cannot be any larger than 5 ms, since this is the maximum magnitude of the parameter. The maximum error in satellite predicted range is a function of this clock error and the base station-to-mobile-station separation distance. The maximum error in the measured range based on the modified or projected satellite orbit, a 10 Km mobile to reference point distance, and 5 ms of clock correction is approximately 1 meter, which is acceptably small given other system errors such as multipath, receiver noise, ionospheric delay, and other quantization effects.

From the foregoing, it can be seen that the present invention provides an improved method and apparatus for location determination in a radio communication system. A base station of the radio communication system receives satellite transmissions including satellite ephemeris information. Periodically, the base station calculates curve fit data which is transmitted to a mobile station. In response to the curve fit data, the mobile station determines the position of the satellites in the system. In this manner, the amount of data that must be received at the mobile station is substantially reduced, as well as the computational load imposed on

the mobile station. As a result, power drain in the mobile station is reduced and the processor of the mobile station is freed up for other tasks.

In another embodiment, the curve fit process is adjusted to absorb the clock correction term ($C(t)$) into the satellite position and velocity terms $X(t)$ and $Y(t)$. By this technique, the number of bits necessary to transmit the curve fit data from the base station to the mobile station is reduced.

In another extension, any satellite station such as a GPS station can receive the curve fit data to reduce the time required to acquire the satellite system. The curve fit data reduce the range of data that must be searched to locate the satellite signals from the satellites. Thus, the computational complexity and the time required for system acquisition are reduced.

While a particular embodiment of the present invention has been shown and described, modifications may be made. For example, other types of radio systems besides two-way radio systems may be adapted to employ the principles of the present invention. It is therefore intended in the appended claims to cover such changes and modifications which follow in the true spirit and scope of the invention.

What is claimed is:

1. A method for position location by a mobile station in a radio communication system, the method comprising the steps of:

receiving at the mobile station satellite position curve fit data transmitted from a base station of the radio communication system; and

determining a position of the mobile station using the satellite position curve fit data.

2. The method of claim 1 further comprising the steps of: receiving at the mobile station from the base station clock correction curve fit data; and

determining the position of the mobile station using the clock correction curve fit data.

3. The method of claim 1 wherein receiving the satellite position curve fit data comprises the steps of:

receiving data related to position and velocity of a plurality of earth orbiting satellites.

4. The method of claim 3 wherein determining the position of the mobile station comprises the steps of:

determining positions of each satellite of the plurality of satellites using the data; and

determining the position of the mobile station using the positions of each satellite.

5. The method of claim 4 further comprising the steps of: receiving a signal at the mobile station from at least some satellites of the plurality of satellites;

in response to the signal, determining pseudo-ranges between the mobile station and the at least some satellites; and

determining the position of the mobile station using the positions of each satellite and the pseudo-ranges.

6. The method of claim 1 wherein receiving the satellite position curve fit data comprises:

receiving a broadcast transmission of the base station; and detecting the satellite position curve fit data in the broadcast transmission.

7. The method of claim 6 wherein receiving the broadcast transmission comprises the step of:

detecting a paging channel transmitted by the base station for all mobile stations in a geographic area served by the base station.

8. The method of claim 1 wherein receiving the satellite position and clock correction curve fit data comprises:

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detecting a point-to-point transmission from the base station intended for the mobile station.

9. The method of claim 8 further comprising the steps of: transmitting from the mobile station to the base station a request for position data; and

receiving the satellite position curve fit data in response to the request.

10. A method for mobile station location determination in a radio communication system which includes a plurality of base stations configured for radio communication with at least one mobile station, the method comprising the steps of:

(a) receiving at a base station of the radio communication system satellite ephemeris information and clock correction information for at least one earth orbiting satellite;

(b) transmitting from the base station at predetermined intervals satellite position curve fit data and clock correction data;

(c) at a mobile station, receiving the satellite position curve fit data and the clock correction data; and

(d) at the mobile station, determining a position for the at least one satellite using the satellite position curve fit data and clock correction data.

11. The method of claim 10 further comprising the step of:

(e) at the mobile station, determining a position of the mobile station using the position for the at least one satellite.

12. The method of claim 11 further comprising the steps of:

(f) at the mobile station, receiving next satellite position curve fit data and clock correction data after a predetermined interval; and

(g) updating the position of the mobile station in response to the next satellite position and curve fit data.

13. The method of claim 10 wherein step (a) comprises: receiving the satellite ephemeris information and clock correction information at the base station directly from the at least one earth orbiting satellite.

14. The method of claim 10 wherein step (a) comprises: receiving the satellite ephemeris information and clock correction information at the base station from another location in the radio communication system.

15. The method of claim 10 wherein step (b) comprises a step of:

broadcasting the data for reception by all mobile stations in a geographic area served by the base station.

16. The method of claim 10 wherein step (b) comprises a step of:

transmitting the data on a paging channel of the radio communication system.

17. The method of claim 10 further comprising the step of:

(e) transmitting data indicative of the position of the mobile station to a base station of the radio communication system.

18. A radiotelephone comprising:

a transceiver configured for two-way communication with a remote base station and to receive satellite position curve fit data transmitted from the base station;

a satellite receiver configured to receive satellite signals from one or more satellites and produce pseudo-range data in response to the satellite signals; and

a processor coupled with the transceiver and the satellite receiver and configured to compute satellite positions of the one or more satellites in response to the satellite position curve fit data and the pseudo-range data.

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19. The radiotelephone of claim 18 wherein the transceiver is further configured to receive data corresponding to clock correction data, the processor being responsive to the clock correction data to calculate the satellite positions.

20. The radiotelephone of claim 18 wherein the processor is further configured to update the satellite positions using the satellite position curve fit data received from a base station of the system after a predetermined interval.

21. A base station for a radio communication system, the base station comprising:

means for receiving satellite ephemeris information and clock correction information;

a processor configured to compute satellite position curve fit data in response to the satellite ephemeris data and clock correction information; and

a transmitter coupled to the processor and configured to transmit the satellite position curve fit data at predetermined intervals.

22. The base station of claim 21 wherein the means for receiving comprises a global positioning system (GPS) receiver at the base station.

23. The base station of claim 21 wherein the means for receiving comprises an input for receiving the satellite ephemeris information and clock correction information from another location in the radio communication system.

24. A method of position location by a mobile station in a radio communication system, the method comprising the steps of:

receiving raw satellite ephemeris and clock correction data for a plurality of satellites at a base station of the radio communication system;

using the raw satellite ephemeris, computing the true satellite position and velocity data points for the plurality of satellites at at least three periods of time over a predetermined interval;

using the clock correction data, computing clock corrections at the at least three periods of time over the predetermined interval;

selecting a reference point that is near the mobile station; projecting the satellite position and velocity data points away from the reference point by an amount corresponding to the propagation delay associated with the clock correction data at each of the at least three periods of time;

determining curve fit parameters for the projected satellite position and velocity data points;

transmitting the curve fit parameters to the mobile station; and

at the mobile station, using the curve fit parameters for the projected satellite position and velocity data points to compute position of the mobile station.

25. The method of claim 24 wherein the step of determining curve fit parameters comprises a step of determining a plurality of parameters related to satellite position and velocity at the at least three periods of time.

26. The method of claim 24 further comprising the steps of receiving satellite signals at the mobile station from at least some satellites of the plurality of satellites;

in response to the satellite signals, determining pseudo-ranges between the mobile station and the at least some satellites; and

determining the position of the mobile station using the positions of each satellite and the pseudo-ranges.

27. A global positioning system (GPS) station comprising: a local receiver configured to receive satellite position curve fit data for one or more satellites from a local transmitter; and

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a processor configured to determine positions of the one or more satellites using the satellite position curve fit data.

28. The GPS station of claim 27 further comprising a satellite receiver configured to receive satellite signals broadcast by the one or more satellites, the processor being further configured to determine position of the GPS station using the positions of the one or more satellites and the satellite signals.

29. The GPS station of claim 28 wherein the local receiver is further configured to receive clock correction data from the local transmitter, the processor being further configured to determine the position of the GPS station using the clock correction data.

30. A method of assisting satellite acquisition by a mobile radio, the method comprising the steps of:

receiving at the mobile radio satellite position curve fit data for one or more satellites transmitted from a local transmitter; and

at the mobile radio, determining a restricted range of satellite Doppler and code phase search to reduce acquisition time of the one or more satellites.

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31. The method of claim 30 further comprising the steps of:

receiving at the mobile radio satellite signals broadcast by the one or more satellites;

searching the restricted range of satellite Doppler and code phase; and

locating at least some of the satellite signals.

32. The method of claim 31 further comprising the step of using the satellite position curve fit data, determining positions of the one or more satellites.

33. The method of claim 32 further comprising the steps of:

receiving at the mobile radio clock correction data for the one or more satellites transmitted from the local transmitter; and

using the clock correction data and the positions of the one or more satellites, determining position of the mobile radio.

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(54) **FLEXIBLE MONITORING OF LOCATION AND MOTION**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

3,478,344	11/1969	Schwitzgebel et al.	340/312
3,518,376	6/1970	Kamen et al.	179/15
3,722,152	3/1973	Schlatter et al.	52/79

(List continued on next page.)

OTHER PUBLICATIONS

Tom Logsdon, "The Navstar Global Positioning System,"
pp. 1-91, Van Nostrand Reinhold, 1992.
"Loran-C User Handbook," U.S. Department of Transpor-
tation, U.S. Coast Guard, Commandant Publication
P16562.5, Nov. 1992.

(List continued on next page.)

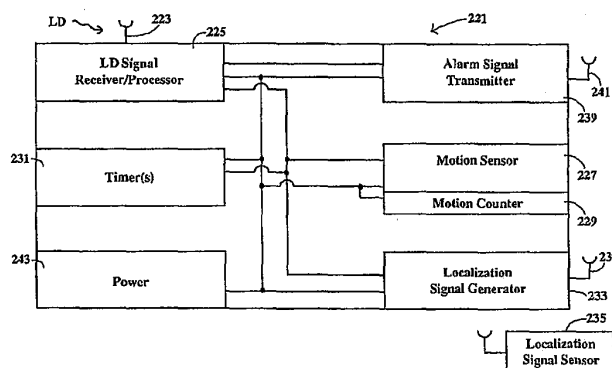
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(57) **ABSTRACT**

Method and apparatus for monitoring the present location of a person ("confinee") who is to be confined to a designated site, which site can have a diameter as small as a few meters or as large as several kilometers. The present location of the confinee is checked at selected time intervals with time periods ranging from one second to thousands of seconds, as desired. The confinee wears a location-determining ("LD") unit that receives electromagnetic signals that contain information allowing determination of the present location of the LD unit, and thus of the confinee, from three or more non-collinear outdoor LD signal sources and from three or more non-collinear indoor LD signal sources. The indoor LD signal sources may be radiowave transmitters. The outdoor LD signal sources may be transmitters for a Loran, Omega, Decca, Tacan, JTIDS ReInav or PLRS or similar ground-based system, or transmitters for a satellite positioning system, such as OPS or GLONASS. The relative phases or transmission times for the signals from each indoor LD signal source are determined and provided for the LD unit. The present location or change location of the LD unit is determined and compared with the permitted site location coordinates at a sequence of selected times to determine if the confinee is present at the site at such times. The LD unit issues an alarm signal if the confinee is not on the site and has not arranged beforehand to leave the permitted site for a selected time interval. The permitted site can be redefined, for a selected time interval, to include the first permitted site, a second permitted site and a corridor extending between the first and second permitted sites for a selected time interval, after which the permitted site can be changed again to include only the first or the second permitted site or a portion thereof. This allows the confinee to temporarily leave the original permitted site to seek medical attention or to attend to other needs, or to be moved permanently to the second site. The permitted site can be redefined at any time and for any subsequent time interval. One or more exclusion sites can be designated where the confinee is not permitted to go at any time.

28 Claims, 18 Drawing Sheets



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U.S. PATENT DOCUMENTS

3,889,264	6/1975	Fletcher et al.	343/105 R	5,121,096	6/1992	Moore et al.	340/326
4,054,880	10/1977	Dalabakis et al.	343/112 R	5,146,207	9/1992	Henry et al.	340/573
4,495,496	1/1985	Miller, III	340/825.54	5,153,584 *	10/1992	Engira	340/870.18
4,571,904	2/1986	Kessler et al.	52/205	5,170,426	12/1992	D'Alessio et al.	379/38
4,596,988	6/1986	Wanka	343/457	5,170,487	12/1992	Peek	455/45
4,646,290	2/1987	Hills	370/84	5,173,710	12/1992	Kelly et al.	342/463
4,651,156	3/1987	Martinez	342/457	5,189,395	2/1993	Mitchell	340/539
4,651,157	3/1987	Gray et al.	342/457	5,193,213	3/1993	Chon	455/45
4,660,193	4/1987	Young et al.	370/11	5,206,897	4/1993	Goudreau et al.	379/38
4,747,120	5/1988	Foley	379/38	5,218,344	6/1993	Ricketts	340/573
4,777,477	10/1988	Watson	340/573	5,255,306	10/1993	Melton et al.	379/38
4,782,531	11/1988	Karr et al.	381/14	5,266,944	11/1993	Carroll et al.	340/825.36
4,799,062	1/1989	Sanderford, Jr. et al.	342/450	5,280,295	1/1994	Kelley et al.	342/463
4,816,769	3/1989	Ma et al.	329/50	5,298,884	3/1994	Gilmore et al.	340/573
4,843,377	6/1989	Fuller et al.	340/573	5,396,215	3/1995	Hinkle	340/426
4,894,662	1/1990	Counselman	342/357	5,396,379	3/1995	Mayo	360/78.07
4,914,735	4/1990	Ichiyoshi	342/125	5,412,379	5/1995	Waraksa et al.	340/825.72
4,918,425	4/1990	Greenberg et al.	340/539	5,434,984	7/1995	Deloddere et al.	395/325
4,918,432	4/1990	Pauley et al.	340/573	5,471,197	11/1995	McCurdy et al.	340/573
4,924,211	5/1990	Davies	340/573	5,497,149	3/1996	Fast	340/988
4,952,928	8/1990	Carroll et al.	340/825.54	5,499,032	3/1996	Kelley et al.	342/357
4,973,944	11/1990	Maletta	340/568	5,568,119 *	10/1996	Schipper et al.	340/825.37
4,980,671	12/1990	McCurdy	340/568	5,724,025 *	3/1998	Tavori	340/573
4,999,613	3/1991	Williamson et al.	340/573	5,905,436 *	5/1999	Dwight et al.	340/573.1
5,023,901	6/1991	Sloan et al.	379/38	5,917,414 *	6/1999	Oppelt et al.	340/573.1
5,023,934	6/1991	Wheelless	455/45				
5,045,861	9/1991	Duffett-Smith	342/457				
5,051,741	9/1991	Wesby	340/825.49				
5,052,048	9/1991	Heinrich	455/66				
5,073,784	12/1991	Westfall	342/465				
5,075,670	12/1991	Bower et al.	340/573				
5,117,222	5/1992	McCurdy et al.	340/573				

OTHER PUBLICATIONS

"Navstar GPS Space Segment/Navigation User Interfaces,"
Interface Control Document GPS(200), No. ICD-GPS-200,
Rockwell International, Satellite Systems Division, Rev.
B-PR, IRN-200B-PR-001, Apr. 16, 1993.

* cited by examiner

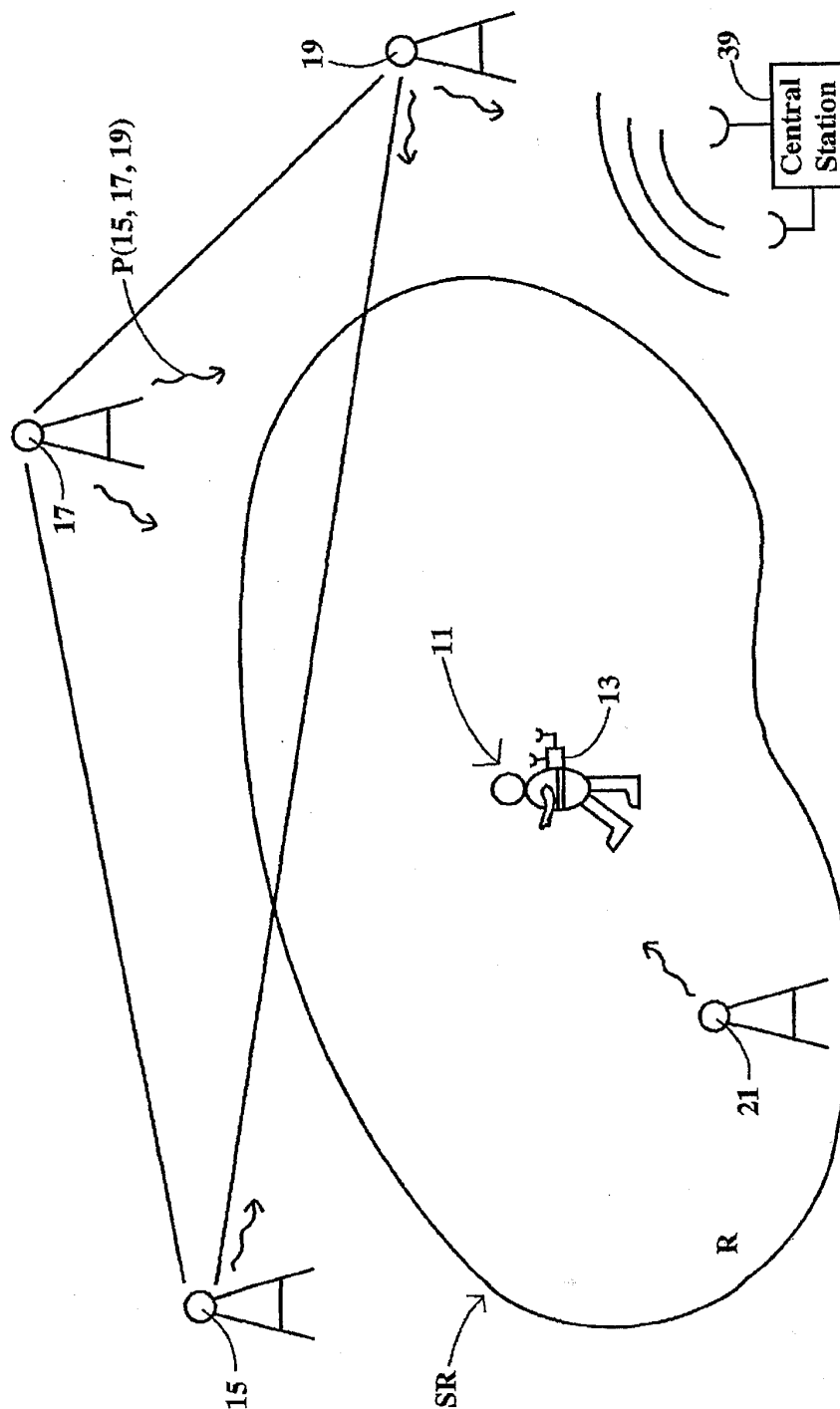
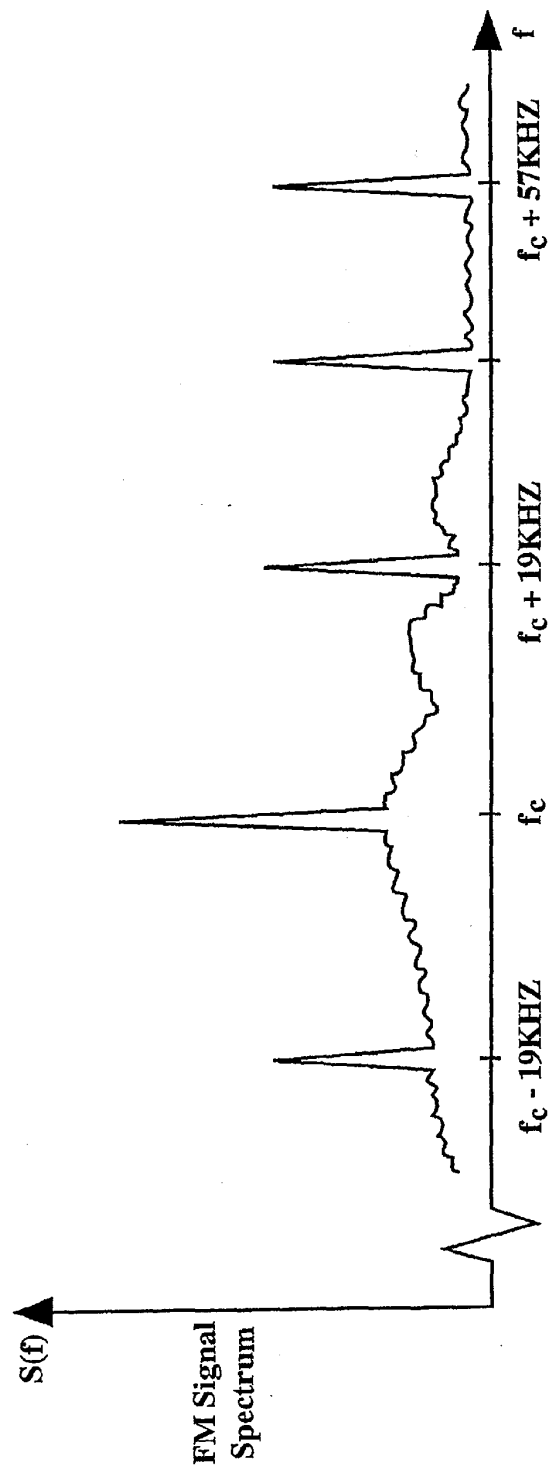


FIG. 1

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Frequency

FIG. 2

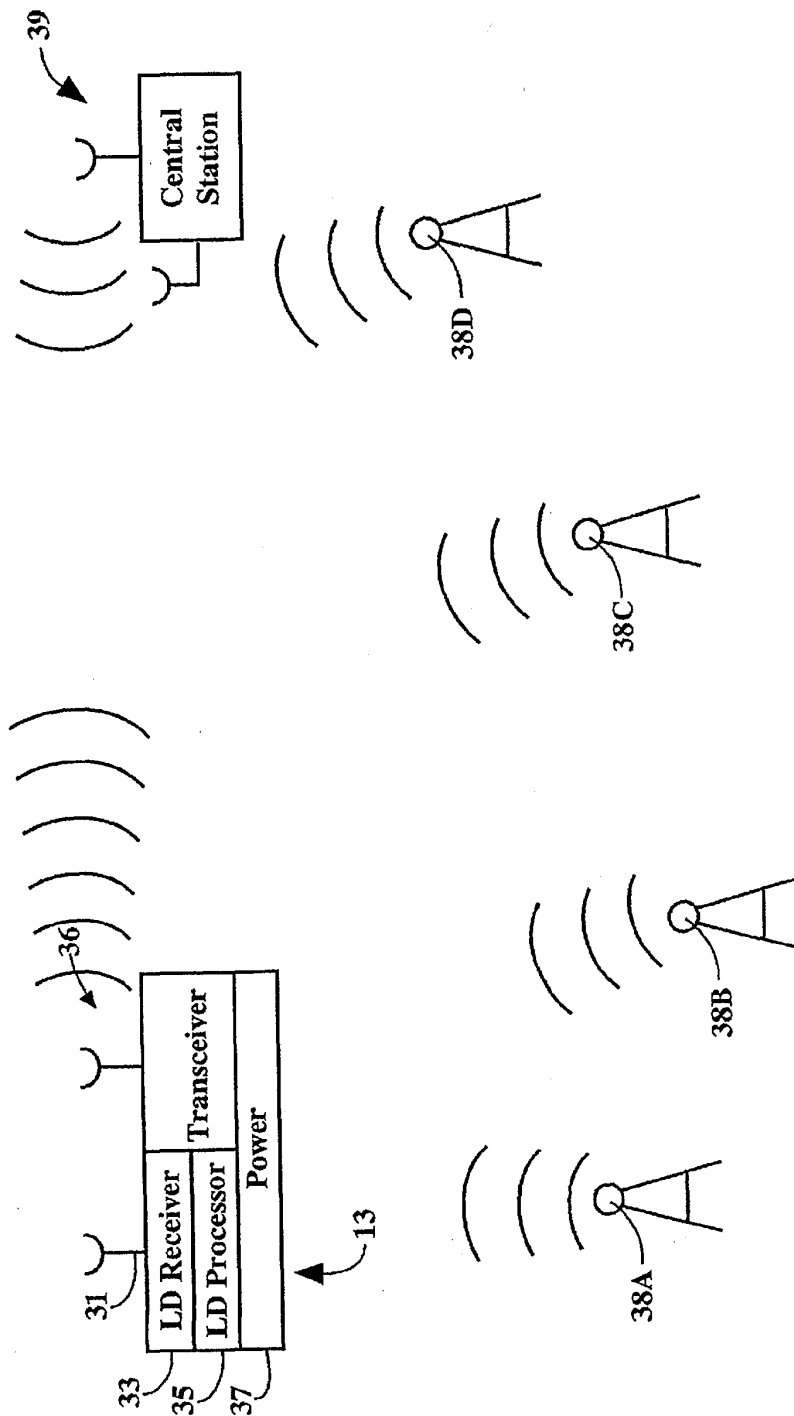


FIG. 3

10/18/2001, EAST Version: 1.02.0008

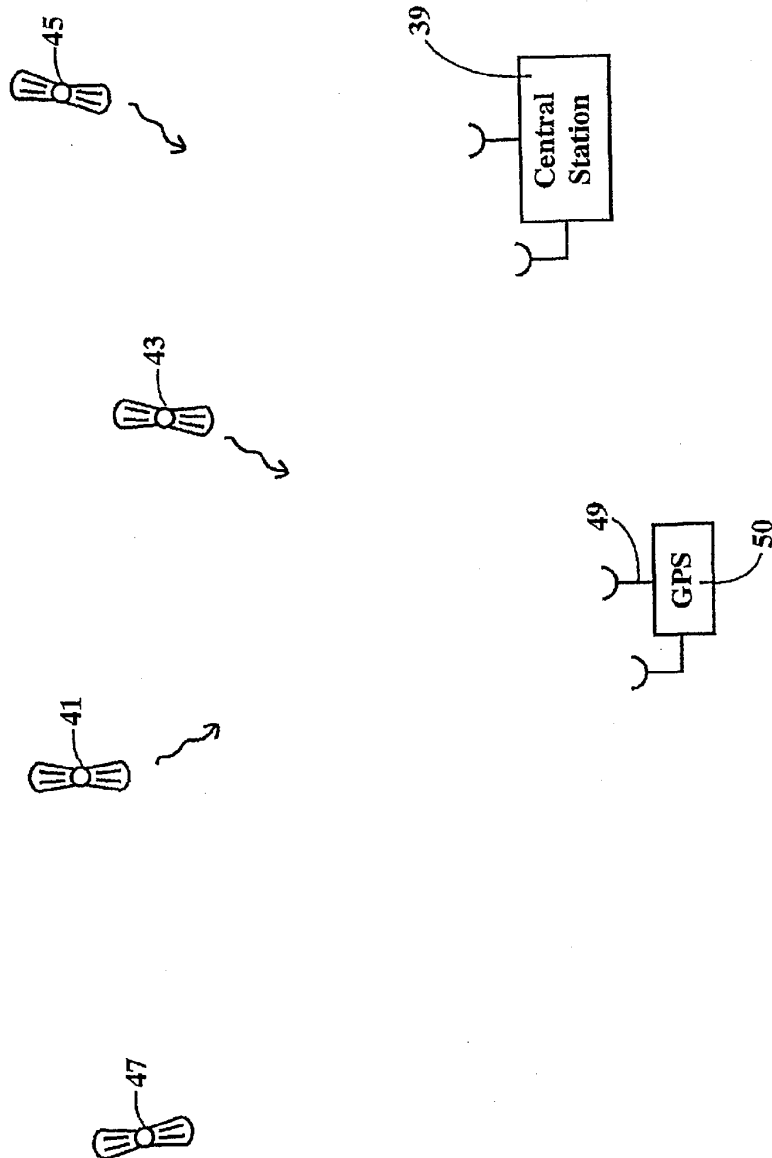
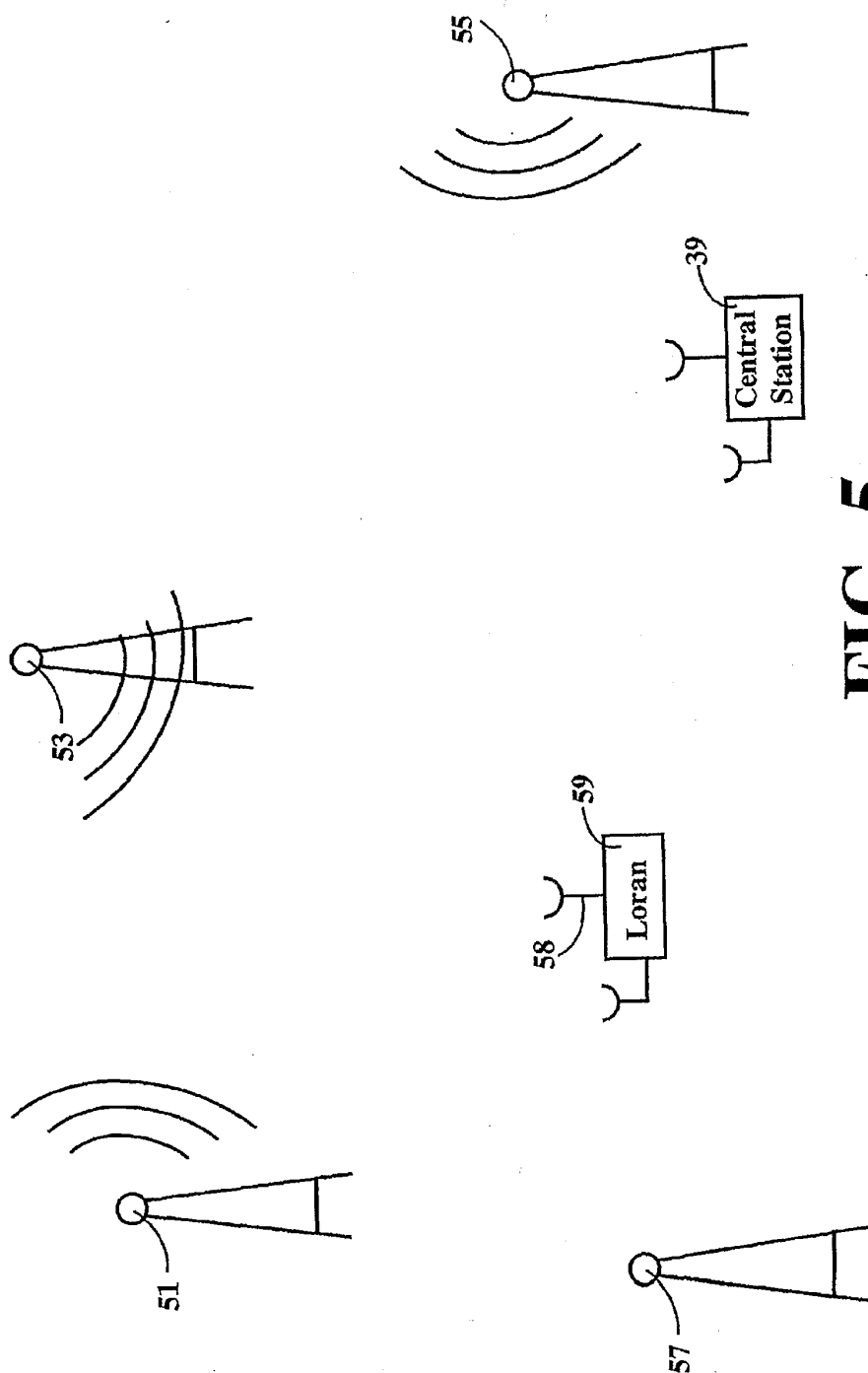
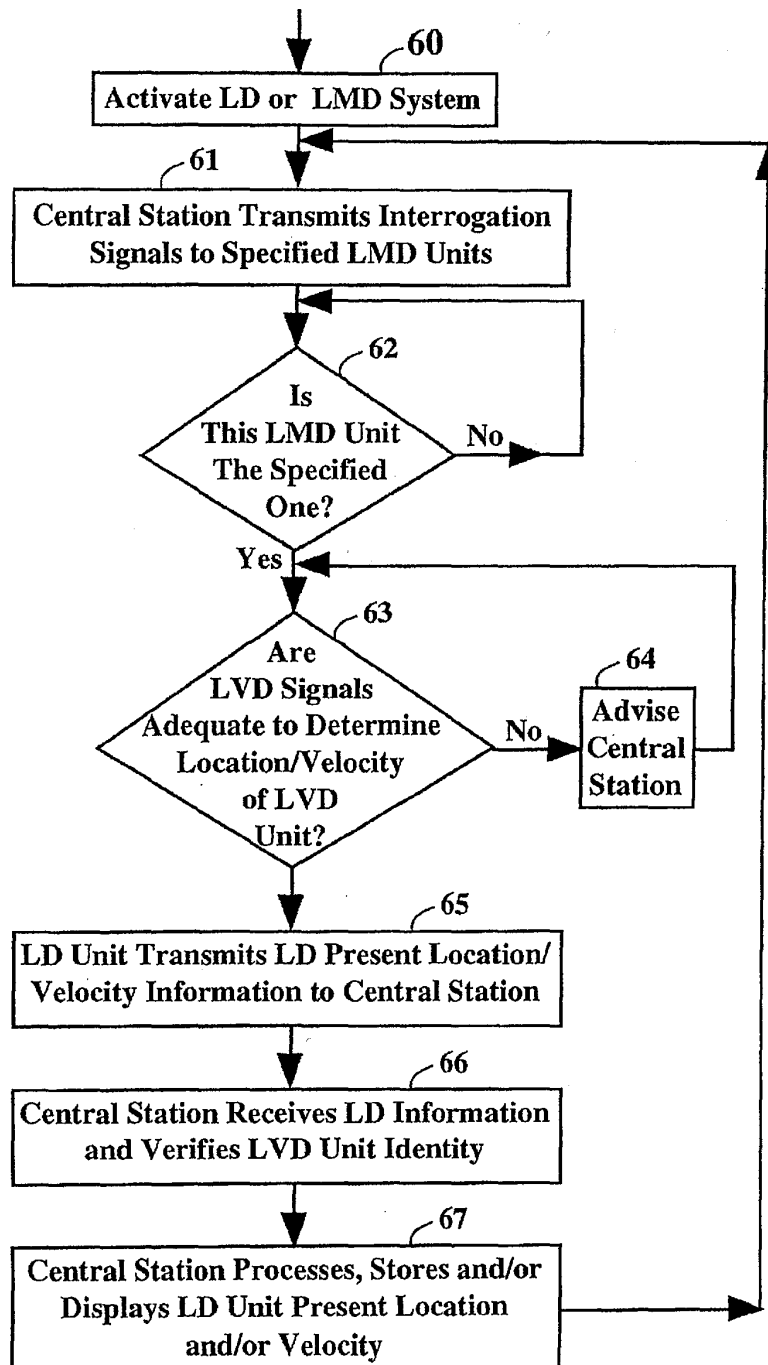
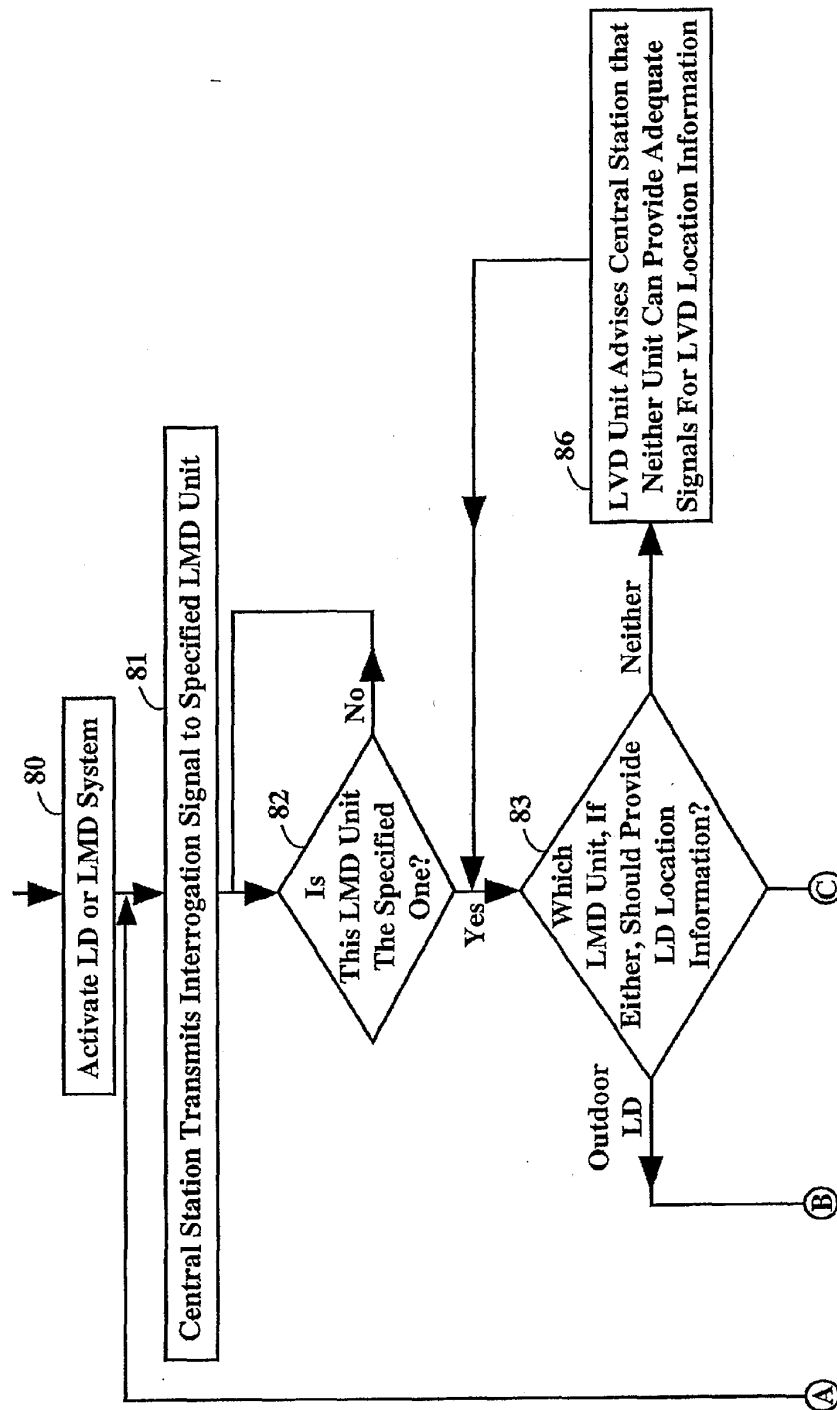


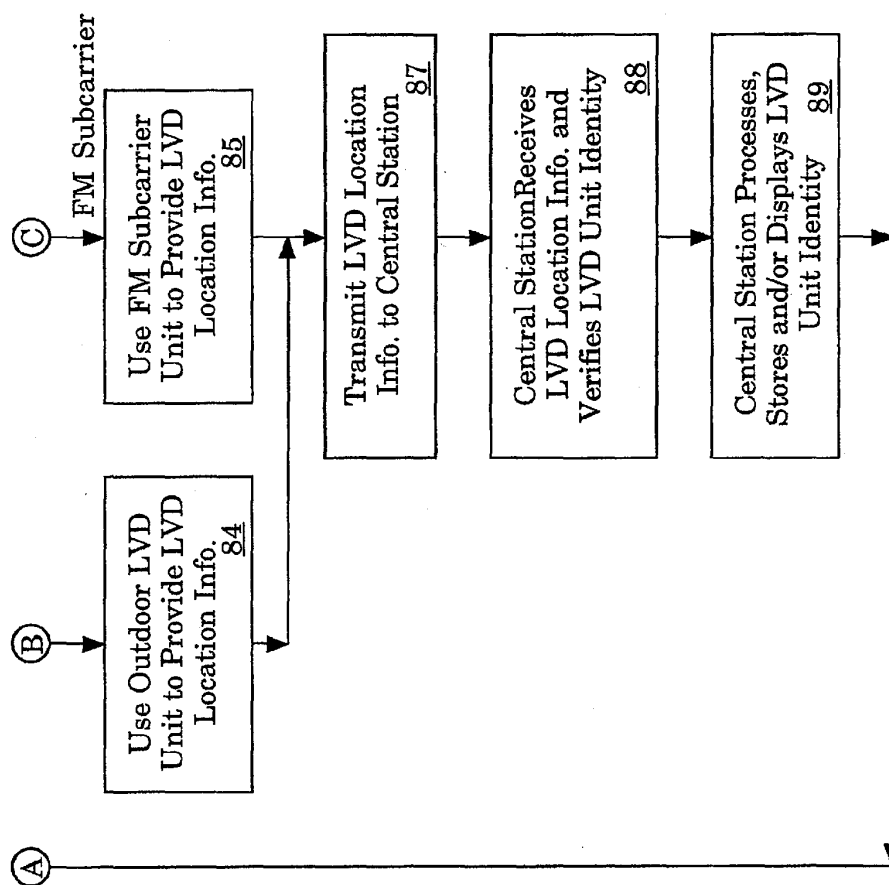
FIG. 4

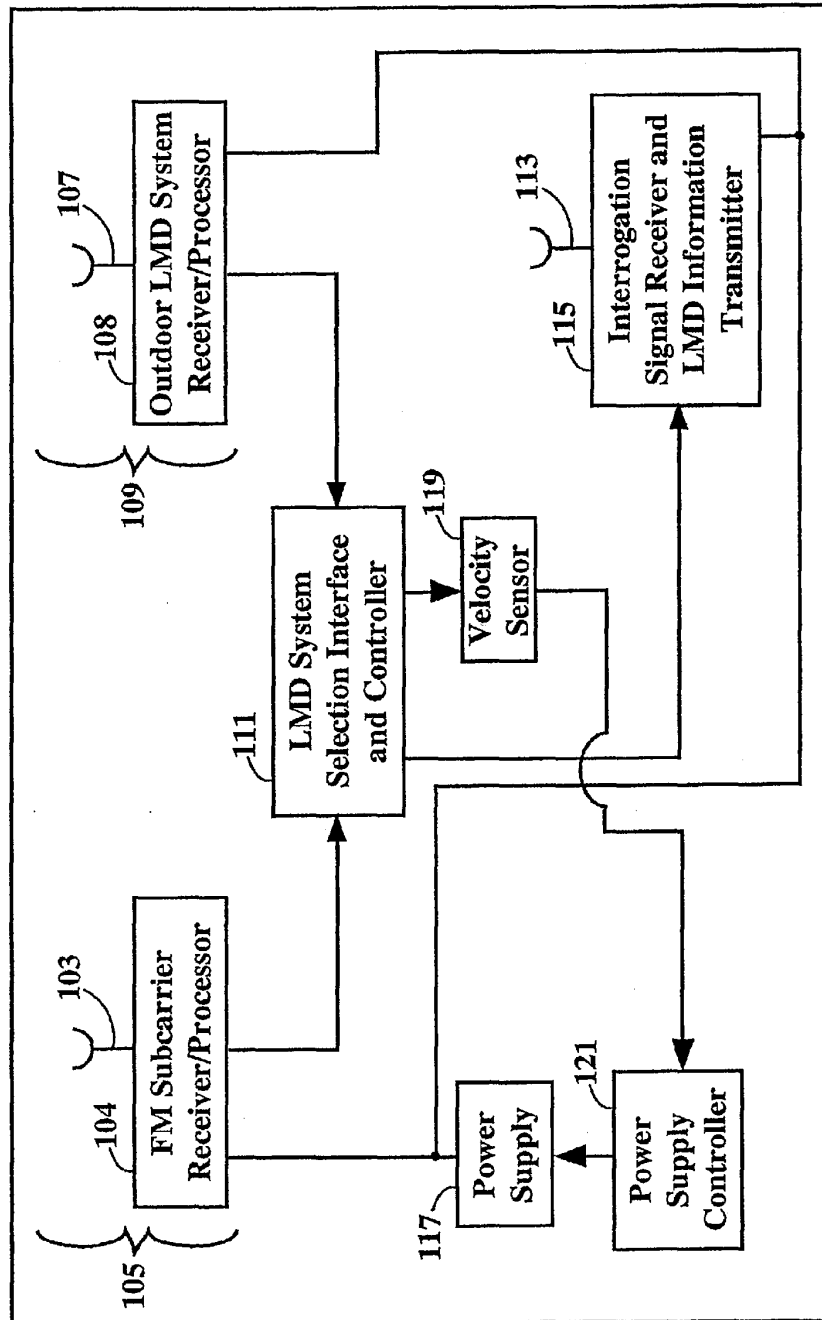


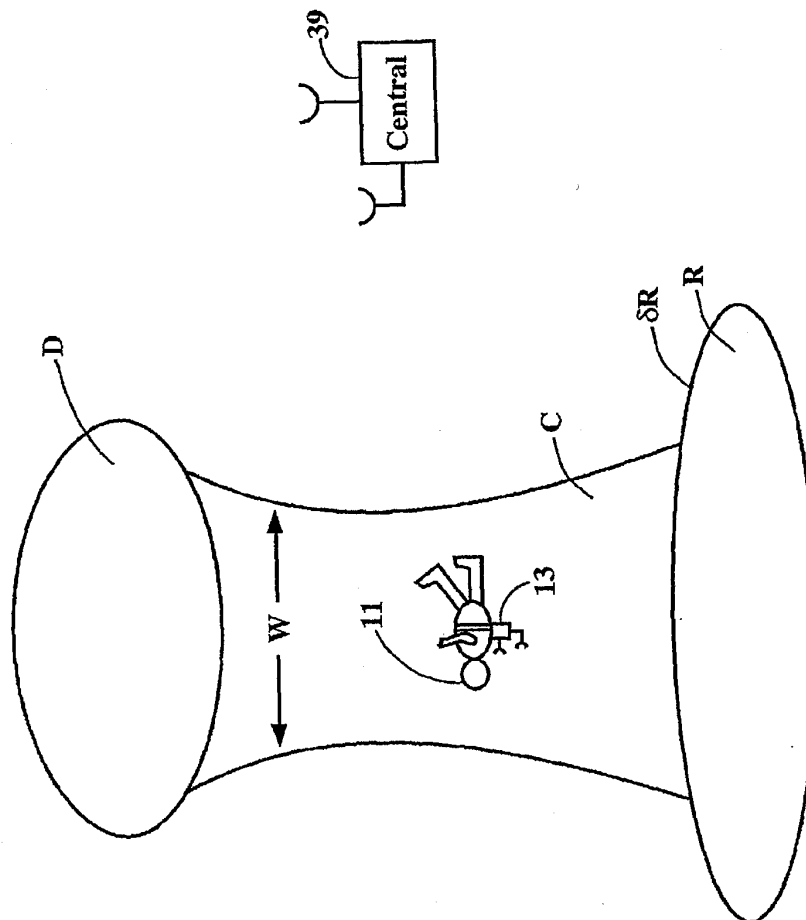
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**FIG. 6**

**FIG. 7**

**FIG. 7 Cont.**

**FIG. 8**

**FIG. 9**

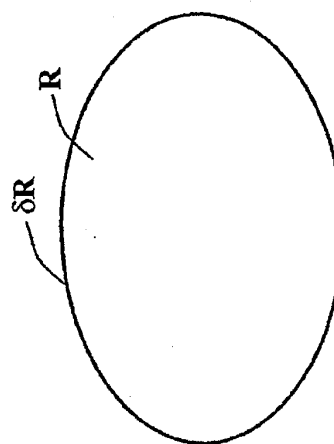
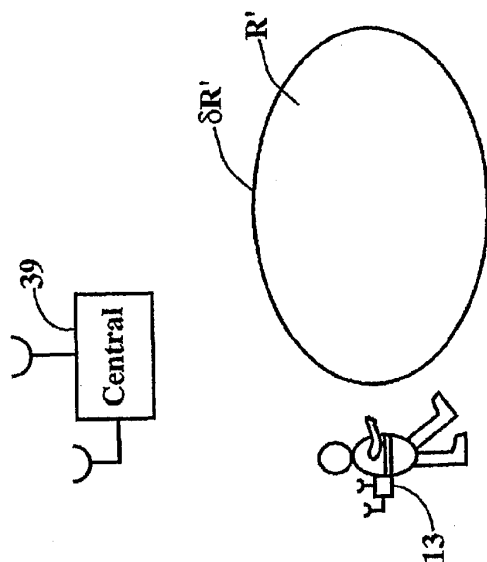
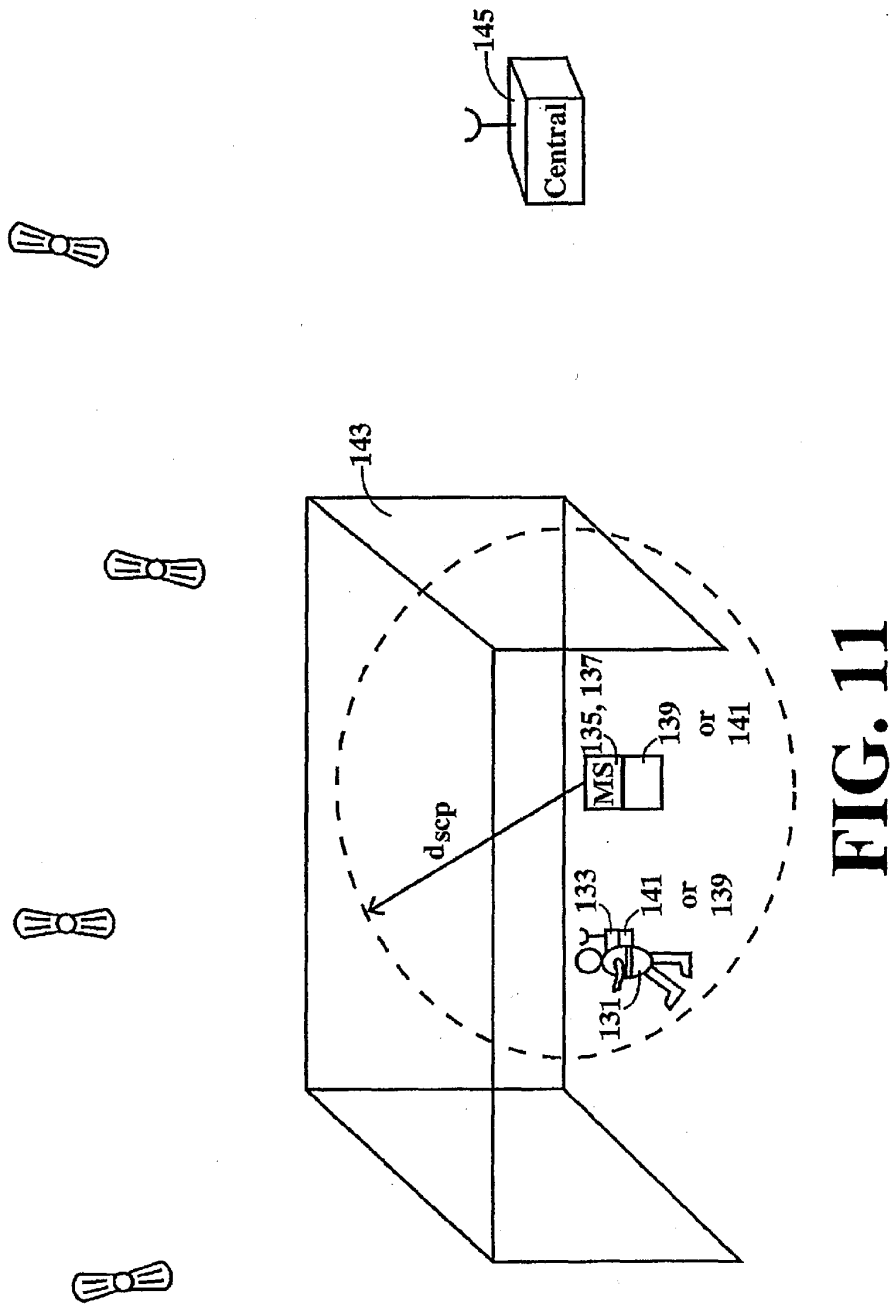


FIG. 10

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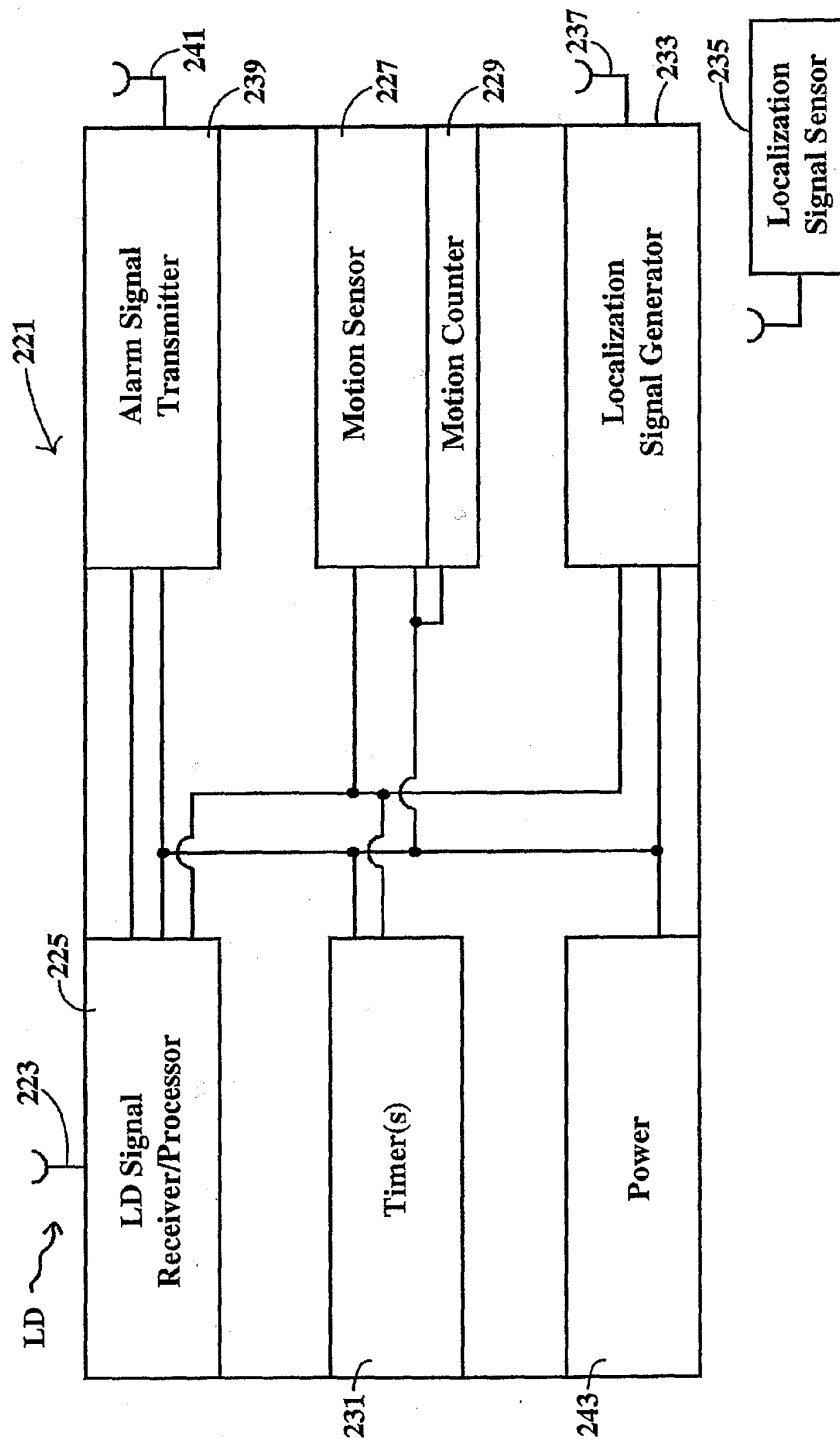
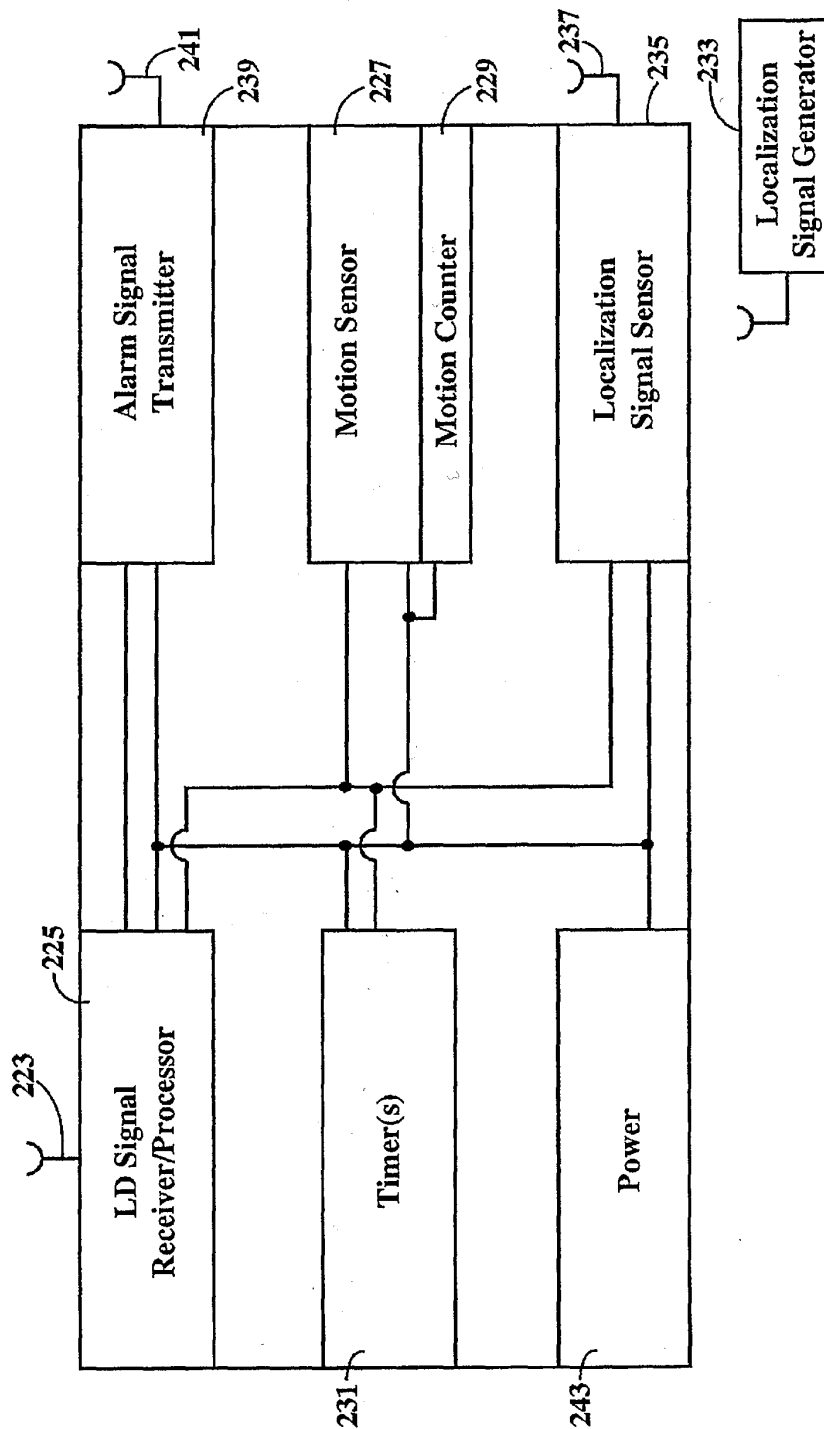
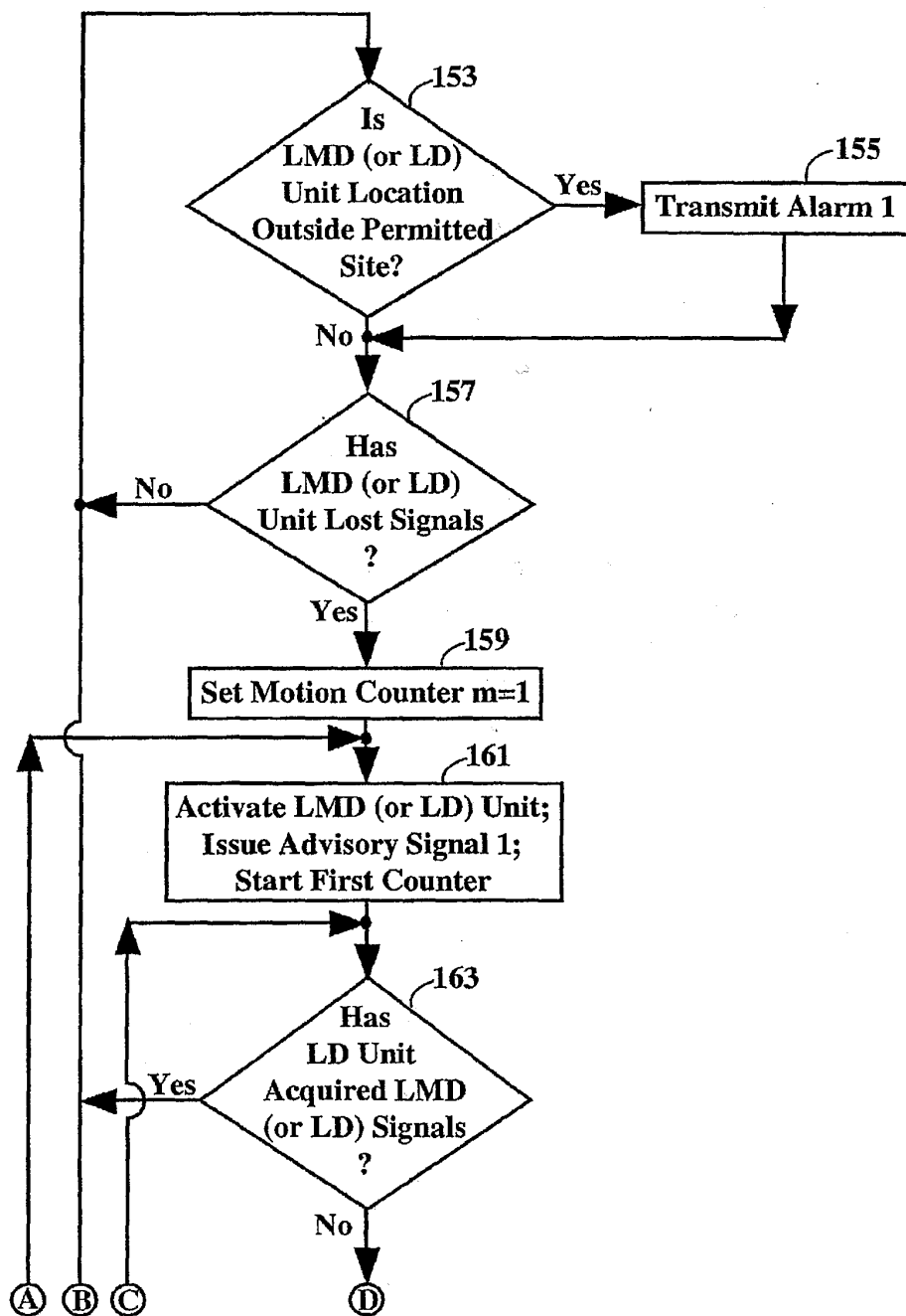


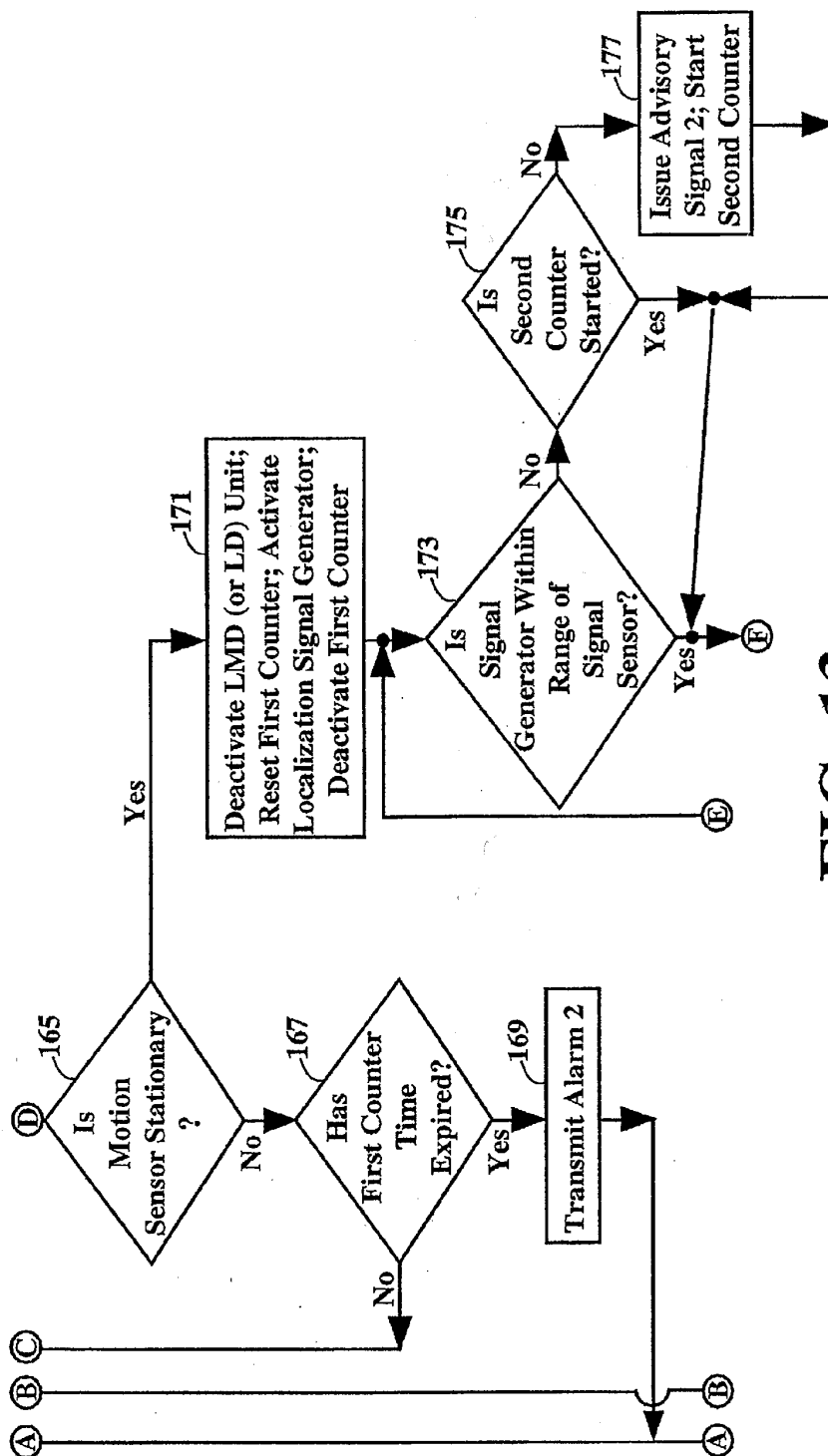
FIG. 12A

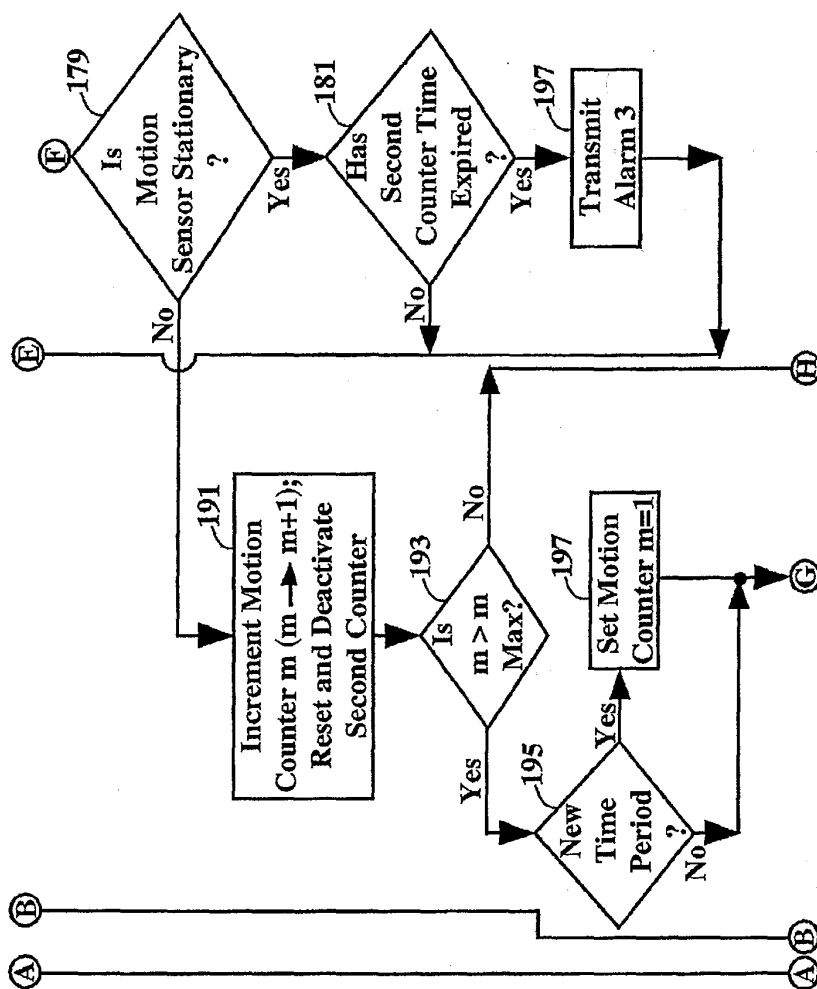
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**FIG. 12B**

**FIG. 13**

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**FIG. 13**
(Continued)

**FIG. 13**
(Continued)

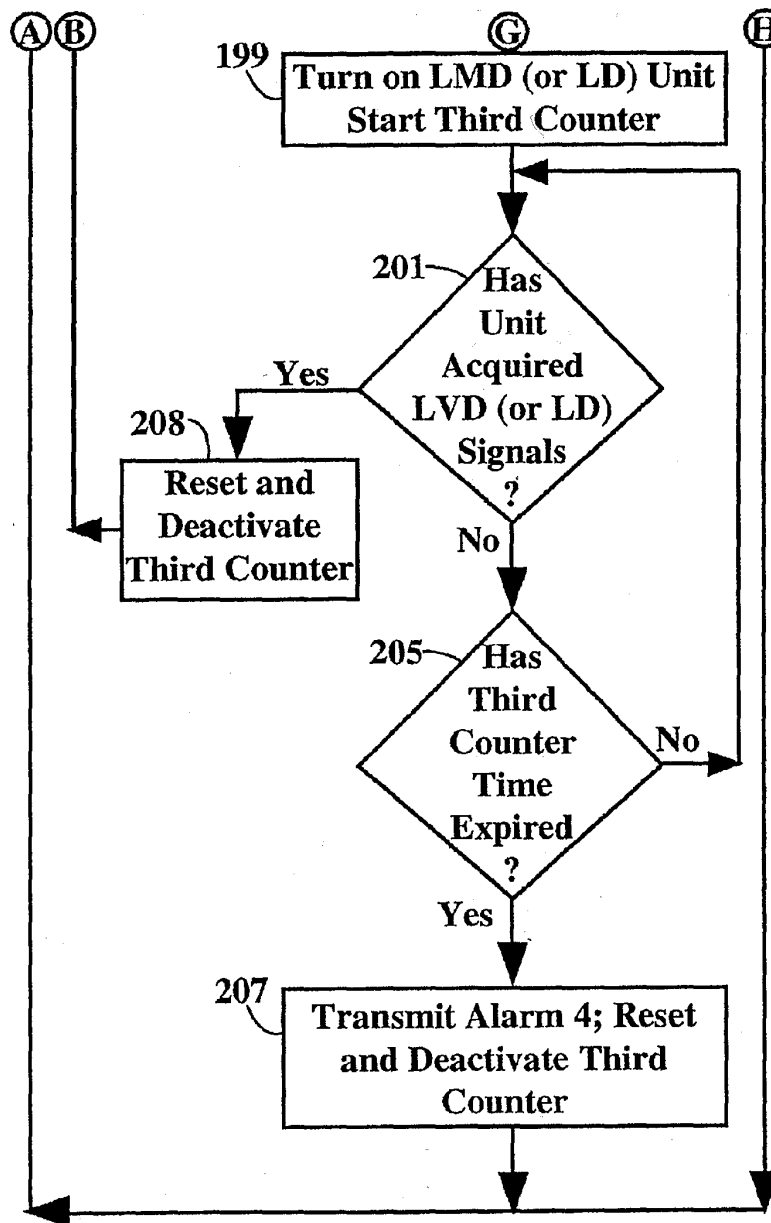


FIG. 13
(Continued)

FLEXIBLE MONITORING OF LOCATION AND MOTION

This is a continuation of application Ser. No. 08/526,989 filed on Dec. 12, 1995, now abandoned which is hereby incorporated by reference to this specification.

FIELD OF THE INVENTION

This application is a continuation in part of an earlier-filed patent application entitled "Flexible Site Arrestee Monitoring," U.S. application Ser. No. 08/171,228, now U.S. Pat. No. 5,568,119. This invention relates to monitoring the location and movement of site arrestees or confinees in an arbitrarily defined area, using radiowave communications.

BACKGROUND OF THE INVENTION

The annual growth of the population of prisoners within the state and federal prisons in the United States has averaged several percent per year for the last ten years. The total number of such prisoners exceeds 2 million. All felons convicted and sentenced for a crime are placed in one or another of these prisons, with little regard for the severity of the crime, whether the crime involved actual or threatened violence, or whether the crime was primarily directed against property. This approach has several disagreeable consequences. First, the federal and state governments cannot build prisons fast enough to accommodate the growing prison population, and some courts are treating prison overcrowding as a violation of the prisoners' constitutional rights. Second, the amount of fully-burdened money spent on new prisons, estimated to be \$80,000-100,000 per cell, is now a substantial part of the annual budget of state and federal governments. The State of California now spends more on incarceration of prisoners than on education of University of California students. Third, prisons must be built in relatively large sizes to obtain economies of scale so that siting of such prisons is often a problem. Fourth, the average cost of providing room, board, recreation and security for a prisoner is now estimated to be about \$24,000 per year, and this cost increases with inflation. Fifth, prisoners convicted of non-violent crimes are usually thrown together with, and are often preyed upon by, prisoners convicted of violent crimes. Sixth, prisoners who might still work and make a positive contribution to society are discouraged or prevented from doing so because of a lack of facilities needed for such activities.

Some workers have conceived other ways of handling some of these problems by providing portable jail or prison cells or by providing monitoring tags that must be worn by the prisoners. One early device, disclosed in U.S. Pat. No. 3,478,344, issued to Schwitzgebel et al, provides an omnidirectional transceiver carried on the waist and an encoded oscillator, uniquely identifying the wearer, that communicates with the transceiver. An inmate or other supervised person in a mental institution or a prison wears this apparatus, which receives signals transmitted from a nearby central station that interrogates the wearer's unit concerning the location of the unit. The unit responds automatically. The method used for determination of location of the wearer's unit might be triangulation, which would require provision of at least three additional stations. Miller, in U.S. Pat. No. 4,495,496, discloses a similar approach for locating miners working in different shafts in a mine. Engira, in U.S. Pat. No. 5,153,584, discloses a similar approach for monitoring the location and status of ambulatory electrocardiogram patients in a medical facility.

Schlatter et al, in U.S. Pat. No. 3,722,152, disclose a portable jail cell that can be transported as a disassembled unit and then assembled and used within a jail or other designated security area. The cell walls and floor are made of metal and concrete, and two or more such portable cells can be placed side-by-side to conserve space. A portable cell must be placed within a jail or other secured facility to provide overall security.

In U.S. Pat. No. 4,571,904, Kessler et al disclose a patient enclosure, to be placed within and form part of a hospital room, that operates similarly to the portable cell of Schlatter et al. The patient enclosure is a separate room-within-a-room that is cleared of all furniture except the patient's bed, may include padding on the walls, and is intended to be used for patients with brain damage who must be protected from further injury by their own actions.

A location determination (LD) unit for a vehicle, relying on radiowave triangulation signals provided by an Automatic Direction Finder system, is disclosed by Wanka in U.S. Pat. No. 4,596,988. The on-board unit transmits its present location when the LD unit is interrogated by receipt of a signal broadcast by a central station, which can track the locations of several vehicles simultaneously.

Gray et al disclose a vehicle security and tracking system in U.S. Pat. No. 4,651,157. An LD unit, installed in a vehicle to be tracked, receives Loran-C signals and transmits the information in these signals, unprocessed, to a central station for determination of the vehicle's present location by triangulation. The system also monitors the values of selected parameters associated with vehicle operation and transmits an advisory signal to the central station if the value of one or more of these parameters lies outside its permitted range.

A personnel monitoring system that uses the telephone for communication between the person whose location is monitored and a central station is disclosed in U.S. Pat. No. 4,747,120, issued to Foley. The monitored person wears a bracelet and is occasionally required to take some action, such as insertion of the bracelet into a decoder that transmits a coded verification signal to the central station over a dedicated phone line that is enabled only when used. The system is provided with some means that does not allow transmission of false signals to the central station.

Watson, in U.S. Pat. No. 4,777,477, discloses a location surveillance system for a designated person, such as a parolee, that detects departure of that person from a designated site, such as an enclosed building. The person wears a sensor-transmitter, a wrist band and a current-carrying loop wrapped around the body. The sensor senses when the person leaves the building and causes the transmitter to broadcast an alarm that is received by a receiver located within the building. The system senses an attempt to remove the loop from the body, using strain gauge apparatus, and transmits another alarm signal.

U.S. Pat. No. 4,918,425, issued to Greenberg et al, discloses a monitoring system for a selected object, such as a vehicle, a person, an animal or an inanimate object. The selected object carries a transponder, with a unique identification code, that receives an interrogation signal at regular intervals, specifying its ID code, from a base station, which may be portable. The transponder then transmits a coded signal that is received by the base station, indicating that the transponder is close enough to have received and understood the interrogation signal. If the base station fails to receive the coded signal responding to its own interrogation signal within a specified time interval, the base station can cause a search to be initiated for the object, which may be a child.

A similar system, which relies upon a network of stations to receive and forward the response signal to a designated base station, is disclosed in U.S. Pat. No. 5,051,741, issued to Wesby.

A house arrest monitoring system, using an identification tag that is worn near the flesh of the prisoner under house arrest, is disclosed in U.S. Pat. No. 4,918,432, issued to Pauley et al. A tag worn by a prisoner transmits a signal having a unique code portion that identifies that prisoner so that several prisoners can be sequestered at one site. A field monitoring device (FMD), connected to a telephone line, receives and analyzes these transmitted signals and determines if (1) the prisoner is present at the site and (2) the tag is being continuously worn near the flesh of the wearer. If one or the other of these conditions is not true, the FMD communicates this information to a central processing unit (CPU), using the telephone line, and personnel at this CPU respond accordingly. The intensity of the signal transmitted by the tag may be improved using a signal repeater to communicate with the FMD. One CPU is used to monitor the locations of prisoners at one or several house arrest sites. The presence of a prisoner at the site is determined primarily by receipt of a tag signal having that prisoner's code included. A prisoner, wearing a tag, could move away from the site a considerable distance before the FMD would sense this, because the location of a tag cannot be determined with much accuracy.

U.S. Pat. No. 4,952,928, issued to Carroll et al, discloses a presence monitoring and identification system, including a body condition sensor and transponder to be worn by the monitored person. In response to receipt of a radiowave request, the transponder transmits a signal to a field monitoring device (FMD), identifying the wearer and including information sensed by the body sensor, such as heart rate, skin perspiration, muscle movement, etc. The FMD is located near where the monitored person should be and periodically transmits to a central station body information on, and the location of, the monitored person. The system is intended to monitor the condition and location of a person under house arrest.

Williamson et al, in U.S. Pat. No. 4,999,613, disclose a remote confinement system in which a sequence of different, unsupervised tests are conducted on prisoners confined at a site. The tests are intended to determine the identity of a prisoner, whether a given person is present or absent at the site, and certain characteristics of the conduct of a prisoner at the site (e.g., a prisoner's sobriety). A radio transmitter, worn on the leg of each prisoner, transmits signals containing these data, which is received by an adjacent home monitoring unit, then relayed over a telephone line to a central station where these data are collected and analyzed. The present location of a prisoner cannot be accurately determined, for reasons similar to those that characterize the Pauley et al invention discussed above. U.S. Pat. No. 4,843,377, issued to Fuller et al, discloses a system that is similar to the Williamson et al patent, using breath alcohol testing and body fluid testing and verification of the prisoner identity by voice- print, graphic image matching or other means.

U.S. Pat. No. 5,052,048, issued to Heinrich for a crime deterrent system, discloses passive pursuit of a suspected perpetrator of a recent crime. Each of a plurality of citizens is provided with a short range FM or AM radio transmitter, tuned to a selected frequency for communication with a central control station. These citizens are alerted to the presence of the suspected perpetrator by a broadcast from the central station. Each such citizen that sights the sus-

pected perpetrator transmits a report to the central station, indicating the suspected perpetrator's present location and direction of movement. The central station maps the movement of the suspected perpetrator and moves to apprehend that person.

A personnel monitoring tag with tamper detection for a person under house arrest is disclosed by Bower et al in U.S. Pat. No. 5,075,670. The tag contains a small radio transmitter that intermittently broadcasts a relatively weak signal that is received by a receiver located on the assigned site. If the arrestee leaves the site, the broadcast signal will become weaker and eventually will not be received by the receiver, in which event an alarm can be given. The tag is provided with a tamper detection circuit. The tag broadcasts a normal signal when the tag has not been tampered with and broadcasts a distinguishable tamper signal when tampering is detected. This apparatus has many interesting features, but it cannot accurately determine the location of an arrestee or detect whether the arrestee stays within a boundary defining the designated site.

A tamper indicator system including a conductive strap that is placed around a limb of a house arrestee is disclosed in U.S. Pat. No. 5,117,222, issued to McCurdy et al. When the strap is put into place, electricity is conducted through a circuit and causes a pulse counter to decrement to a selected minimum number, such as zero, over an initial strap placement period. If tampering or attempted strap removal occurs during this initial strap placement period, a transmitter notifies a monitoring person of this event.

Moore et al, in U.S. Pat. No. 5,121,096, disclose a person locator system that includes an appliance to be worn by a child or by a person with impaired senses. The appliance carries its own power supply and transmits a visual signal and an audible signal (70 dB at 2500 Hz) at selected times, such as every five seconds. The audible signal can, allegedly, be heard at 300 feet. However, this only locates the person wearing the appliance within a circle of area about 283,000 square feet, and the area covered is limited by long-term tolerance for high intensity sounds (about 85 dB). Further, this requires that a another person continuously monitor the varying level of the audible sound periodically emitted by the appliance.

Henry et al, disclose an electronic house arrest system that uses optical links and infrared communications, in U.S. Pat. No. 5,146,207. A prisoner wears apparatus that serves as transmitter and as receiver, using two concealed apertures in the apparatus. This apparatus communicates with a field monitoring device (FMD) that, in turn, communicates with a central station that receives and analyzes the data collected by the FMD. Data collected and the means of communication (telephone or modem) are similar to those disclosed in the Pauley et al patent.

In U.S. Pat. No. 5,170,426, D'Alessio et al disclose a home incarceration system that incorporates voice analysis and verification over a telephone line. The voice of a prisoner who is added to this home arrest system is initially tested to establish a voice template that subsequently can be used to verify voice communication over a phone line by that prisoner. The prisoner communicates with a central office at irregular times by phone calls, and central office apparatus verifies the location and identity of the call responder (prisoner), using the voice template and other characteristics. The location of the prisoner during the time intervals between these phone calls is not determined with this system.

An electronic house arrest system disclosed by Mitchell in U.S. Pat. No. 5,189,395 allows silent calls for assistance

from a monitoring officer who makes personal and/or telephone-assisted checks of the presence and identity of prisoners at designated sites. In other respects, this system is similar to the system disclosed in the Pauley et al patent.

A telephone-based home incarceration system in which the prisoner wears a bracelet or other appliance is disclosed by Goudreau et al in U.S. Pat. No. 5,206,897. The bracelet contains an electrical circuit that has specified electrical characteristics that are monitored by an adjacent comparator circuit. If the sets of electrical characteristics do not match, indicating that the prisoner may be absent from the site of incarceration, a central station is notified by phone and appropriate action is taken. Verification of the presence and identity of the prisoner must be requested by placing a telephone call to the prisoner, who then places the bracelet in a special fixture to implement comparison of the electrical characteristics. This verification procedure probably could not be done more often than about once per hour, if the central office has many prisoners to monitor using this system.

Melton et al disclose use of a cellular interface unit for an electronic house arrest system, in U.S. Pat. No. 5,255,306. A field monitoring device (FMD) is positioned at the house arrest site and receives low power, uniquely tagged signals transmitted by a tamper-proof house arrest appliance worn by the arrestee. The FMD monitors the strength of the signals received from the appliance. When the signal strength falls below a selected threshold, the monitoring system determines that the arrestee has moved off the site, and a cellular phone network is used to alert the proper authorities at a central station. The FMD signal threshold is typically set corresponding to a separation distance of 150 feet and cannot distinguish from which direction the signals arrive.

U.S. Pat. No. 5,412,379, issued to Waraksa et al, discloses a keyless entry system, for use in automatically unlocking (or locking) a vehicle as the vehicle operator approaches (or moves away). The operator carries a portable beacon device whose beacon signal is received by a receiver in the vehicle. The beacon device includes a motion sensor that shuts down the beacon signal to conserve battery life when the beacon device is not moving.

FM subcarrier signals and AM carrier signals have been used for some types of radiowave communications. In U.S. Pat. No. 3,889,264, Fletcher discloses a vehicle location system in which the unsynchronized AM carrier signals from three or more AM radio stations form hyperbolic isophase grid lines that are used to determine location of a vehicle. The vehicle must be equipped with a three-channel, tunable receiver, and its location must be referenced to an initial known location by counting the number of isophase lines crossed after the vehicle leaves the initial location. Isophase drift is compensated for by subtraction from the count.

Dalabakis et al, in U.S. Pat. No. 4,054,880, disclose a radio navigation and vehicle location system employing three low frequency subcarrier signals received from three radio stations at a three-channel, tunable receiver located on the vehicle. Isophase lines crossed are counted after the vehicle leaves an initial known location. This system, like the Fletcher system, is a delta-position system that determines vehicle location only relative to an initially known location.

U.S. Pat. No. 4,646,290, issued to Hills, discloses use of F.C.C.-approved Subsidiary Communication Authorization (SCA) FM subcarrier signals for one way transmission. This

patent discloses transmission of a plurality of messages, which may be delivered to the transmitter at a wide range of bit rates, to be transmitted at a single bit rate that is at least as large as the highest bit rate for message delivery. This method allows for downstream insertion of additional data.

An integrated radio location and communication system for a mobile station is disclosed by Martinez in U.S. Pat. No. 4,651,156. Each mobile station carries a transceiver that issues radio signals that are received by two or more signal transceiver reference sites having fixed, known locations. The transceivers at the mobile station and the reference stations are continuously phase locked to the RF carrier signal from a nearby commercial radio station. The radio station and the mobile station each transmit a brief, distinguishable range tone at a known sequence of times, and the range tone from each station is received by each reference station. From an analysis of the differences in arrival times of the range tones received from the radio station and from the mobile station, the reference stations determine the two-dimensional location of the mobile station. The mobile station uses the beat signal between two RF subcarrier frequencies to generate its range tone signal and to distinguish that mobile station transmissions from the transmissions of any other mobile station.

Young et al, in U.S. Pat. No. 4,660,193, discloses use of two SCA FM subcarrier signals, the first being amplitude modulated and the second being phase modulated, to provide a digital data transmission system. A subcarrier signal within this system may also be modulated to carry audio signals.

A multichannel FM subcarrier broadcast system that provides a sequence of relatively closely spaced channels, using independent sidebands of suppressed carriers, is disclosed by Karr et al in U.S. Pat. No. 4,782,531. The sideband signals are generated in pairs and are phase shifted before transmission. Upon receipt of the transmitted signals, the process is reversed. An earlier patent, U.S. Pat. No. 3,518,376, issued to Caymen and Walker, discloses a similar approach without use of signal phase shifting of pairs of sideband signals.

In U.S. Pat. No. 4,799,062, Sanderford et al disclose a radio location method that uses a central processing station, a plurality of signal repeater base stations with fixed, known locations, and a mobile station with a known location at any time. The central station transmits a master grid synchronization pulse, which serves as a time reference, to the other stations at a selected sequence of times. A roving station with unknown location transmits a pulse that is received by three or more base stations and is retransmitted to the central station. The central station determines the location of the roving station using the differences in time of arrival at each base station of the pulse transmitted by the roving station. The mobile station also transmits a pulse from time to time, and its known location is compared with its computed location by the central station to determine any multipath compensation required to reconcile the known and computed locations of the mobile station. The multipath compensation for a mobile station adjacent to the roving station is applied to correct the computed location of the roving station.

Ma, in U.S. Pat. No. 4,816,769, discloses receipt of SCA FM subcarrier signals for digital data paging at a radio receiver. The system measures signal-to-noise ratio of an output amplitude of a Costas loop, used to phase lock to the FM subcarrier frequency, to determine if the signal is sufficiently strong to be processed.

A system for detection of radiowave propagation time, disclosed by Ichiyoshi in U.S. Pat. No. 4,914,735, uses detection of phase differences for transmission of the signal over M (≥ 2) different known signal paths to a target receiver. The transmitted signal includes a subcarrier signal, having a frequency that is higher than the transmitter clock frequency, modulated with a known modulation signal. The receiver has M demodulators for the signals received by the M different paths and has a phase comparator to compare the computed phases for each of these received signals. The phase differences are proportional to the signal path length differences, if compensation for transmission line distortions is included.

U.S. Pat. No. 5,023,934, issued to Wheelless, discloses a system for communication of graphic data using radio subcarrier frequencies. The data are broadcast on a subcarrier channel and received by a radio receiver that is connected to a computer. The computer receives the subcarrier signals, displays the graphic data on a computer screen, and performs other functions, such as transmission error checking and modification of the displayed graphic data. The system is intended for weather data communication and display.

Westfall, in U.S. Pat. No. 5,073,784, discloses a system for location of a transmitter ("unknown") at large distances, using a large network of pairs of spaced apart radiowave receivers whose locations are known and whose relative phases are synchronized. A signal, broadcast by the unknown transmitter at less than HF frequencies, is received at different time and space points by pairs of receivers. Simple geometrical computations allow determination of the location of the unknown transmitter by comparing times of arrival of the transmitted signal.

U.S. Pat. No. 5,170,487, issued to Peek, discloses use of FM sub-carrier signals for a pager system for mobile users. A plurality of transmitters are used, each of which transmits an FM subcarrier signal or a carrier signal modulated with a chosen message signal, slightly offset in time. Each page-receiving unit is assigned a time slot, during which the receiving unit dials through the set of frequencies corresponding to the FM subcarrier and modulated-carrier signals to determine if a page message has been sent for that mobile user.

A system that allows determination of an absolute location of a vehicle is disclosed by Kelley et al in U.S. Pat. No. 5,173,710. FM subcarrier signals are received from three radio stations with known locations but unknown relative phases by signal processors at the vehicle and at a fixed station with known location relative to the three radio stations. The fixed station processor determines the relative phases of the three radio stations FM subcarrier signals and broadcasts this relative phase information to the vehicle. The vehicle processor receives this relative phase data and determines its absolute location, using the phases of the FM signals it senses at its own location.

Chon, in U.S. Pat. No. 5,193,213, discloses an FM broadcast band system for receipt of relatively high frequency FM subcarrier signals. A tunable high pass receiver first circuit receives the carrier and a tunable low pass second circuit receives the subcarrier signal. Each signal can then be separately processed.

A navigation and tracking system using differential Loran-C or differential Decca signalling is disclosed by Duffett-Smith in U.S. Pat. No. 5,045,861. A reference station transmits a reference signal to a mobile station and to three or more local Loran-C or Decca (fixed) stations having

known locations relative to the reference station. The fixed stations retransmit the reference signal to the mobile station, where the phase received signal differences are compared to determine the location of the mobile station.

Most of these systems use a single communication system that may not work in all indoor environments or in all locations outdoors, rather than integrating two or more communication systems to provide information on the location and/or velocity of movement of a mobile user. What is needed is an integrated location determination system for automatically or discretionarily determining the present location and/or present velocity of a mobile user at a designated site, whether the user is presently outside or inside a building or other structure. Preferably, the system should include an appliance to be worn or carried by an arrestee or confinee (collectively referred to as an "monitored person" or "MP" herein) that will: (1) allow selected MPs to live on designated sites outside a conventional confinement facility for at least a portion of their confinement time; (2) detect with reasonable accuracy the present location and/or present motion of the MP at arbitrarily chosen times with time interval lengths as short as one second; (3) detect when tampering with the appliance is occurring and provide another alarm; (4) allow the MP to leave the designated site at prescribed times to seek medical attention or attend to other needs, while continuing to monitor the present location of the MP; (5) allow easy and flexible redefinition of a boundary of a designated site; and (6) provide these features with reduced use of electrical power.

SUMMARY OF THE INVENTION

These needs are met by the invention, which provides a system and associated apparatus that allows a monitored person (MP) to be confined to a designated site outside a conventional confinement facility for at least a portion of the MP's confinement time. The MP wears a location-determining and motion-sensing (LMD) unit that preferably cannot be removed, except by specially trained persons, and that provides information on the MP's present location coordinates and/or present velocity coordinates at each of a sequence of time intervals that may vary in length from a fraction of a second to hundreds or thousands of seconds, as desired. This LMD unit receives radiowave or similar signals that provide information used to determine the present location and/or sense motion of the LMD unit, and the wearer thereof. The inaccuracy of this present location information is preferably no greater than 1-5 meters and may be as small as a few centimeters.

In one embodiment, the appliance processes this information, determines this present location and/or present motion, and transmits this information to a central station that monitors the present location and/or present motion of one or many MPs, each of whom may be located at a single site or at separate sites. In another embodiment, the LMD unit does not process this information, or partly processes this information, and transmits this information to the central station for further processing to determine the present location of the MP. The central station compares the present location and/or motion of the MP with the designated site and its boundary to determine if the MP is staying on this site, or if the MP has crossed the site boundary into another region. If the MP has moved off the site without prearranged permission, or if no intelligible LMD response signal is received at the proper times, the central station promptly notifies the appropriate authorities. Alternatively, the central station can activate some portion of the appliance worn by the MP and temporarily disable the MP until the authorities arrive.

If the MP moves inside and remains within a building or other structure that interferes with receipt of LMD signals by the LMD unit, the MP may be permitted to move within an approximate sphere of a selected radius d_{sep} without requiring further location or velocity monitoring by the LMD unit. The LMD unit then enters a sleep mode. The sphere radius d_{sep} may be chosen large enough to include a portion of or all of the structure. When the MP moves beyond this sphere or moves outside the structure, the MP is required to "check in" or to otherwise re-activate or re-initiate receipt and analysis of LMD signals by the LMD unit.

Optionally, the LMD unit contains a tamper detection circuit that transmits a distinguishable alarm if tampering is detected. Optionally, the appliance transmits the present location information in an encrypted form that cannot be read or interfered with by the MP, except by making the transmitted signal unintelligible and thus triggering an alarm at the central station.

The MP is permitted, by arrangement beforehand, to travel to a specified secondary site that is beyond the boundary of the primary site of confinement, using a well-defined corridor that connects the primary and secondary sites, when the MP attends to personal needs, such as visits to a physician, a dentist, a food store or the like. In this instance, the MP is given a selected time interval $t_{depart} \leq t \leq t_{return}$ in which to travel within the corridor to the secondary site, transact appropriate business at the secondary site, and return to the primary site using the corridor.

The LMD unit carried on the MP's body or garments may receive FM subcarrier signals from a plurality of three or more subcarrier transmitters with known locations and determinable phase relationships. The phase differences of the sub-carrier signals provide information to determine the present location of the LMD unit.

The LMD unit may alternatively, or also, receive radio-wave signals from an "outdoor LMD system", including a plurality of three or more ground-based location determination signal sources, such as Loran, Omega, Decca, Tacan, JTIDS ReInav, Personal Location Reporting System (PLRS), or including a plurality of satellite-based location determination signal sources (SATPS), such as GPS or GLONASS, with known locations and determinable phase relationships, using phase analyses similar to analyses used for the FM subcarrier signals. Other sets of three or more radio-wave signals with known source locations and selected signal parameters may also be used. The FM subcarrier unit or the outdoor LMD unit may be used by itself, or these two units may be integrated in an LMD unit that receives FM subcarrier signals and outdoor LMD signals. The central station or another station can serve as a reference station and the appliance can serve as a mobile station in a differential positioning mode using the outdoor LMD system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of operation of one embodiment of the invention in a designated region or site R.

FIG. 2 is a graph illustrating a typical FM signal spectrum near the carrier frequency f_c used for that signal.

FIG. 3 is a schematic view illustrating use of an LMD unit that transmits and processes FM subcarrier signals, to determine the present location of a designated person according to the invention.

FIGS. 4 and 5 are schematic views illustrating use of outdoor location determination systems, using satellite-based signals and using ground-based signals, respectively, to determine the present location and/or present velocity of an LMD unit according to the invention.

FIG. 6 is a flow chart illustrating a suitable procedure, according to the invention, for determining the present location of an LMD unit, using only FM subcarrier signals.

FIG. 7 is a flow chart illustrating a suitable procedure, according to the invention, for determining the present location of an LMD unit, using a combination of FM subcarrier signals and signals generated by an outdoor LMD system.

FIG. 8 is a schematic view of a location determination unit that receives and processes FM subcarrier signals and signals from an outdoor LMD system.

FIG. 9 is a schematic view illustrating use of the invention to provide a corridor C from the site MP's usual confinement site R to a permitted destination D that is spaced apart from the site R.

FIG. 10 is a schematic view illustrating use of the invention to provide one or more exclusion regions R^* where the MP is not permitted to go under any circumstances.

FIG. 11 is a schematic view illustrating use of the invention within a structure that interferes with receipt of LMD signals.

FIG. 12 is a flow chart showing a suitable procedure for practicing an embodiment of the invention illustrated in FIG. 11.

FIGS. 13A and 13B are schematic views of an LMD unit that monitors the approximate location of an MP inside or outside a structure.

DESCRIPTION OF BEST MODE OF THE INVENTION

FIG. 1 illustrates practice of one embodiment of the invention. A monitored person (MP) 11 lives and works at or is confined to a designated site or region R having a boundary δR . The MP 11 wears a portable location determination and motion sensing (LMD) unit 13. The LMD unit 13 may receive FM signals from three or more FM signal sources 15, 17, 19, and 21 (optional) that have locations with known location coordinates (x_m, y_m, z_m) for FM signal source no. m ($m=15, 17, 19, 21$). The FM subcarrier signal of interest may have an associated frequency of about $f_c \pm 19$ kHz, where f_c is the FM carrier frequency that lies in the range 88–108 MHz. Alternatively, a higher order displacement from the carrier frequency (e.g., $f_c \pm 38$ kHz or $f_c \pm 57$ kHz) may be used. The sources of these FM subcarrier signals may be a plurality of FM broadcasting stations located in or near the site R. In this event, the subcarrier signals are obtained by filtering the total FM signals (carrier signal plus message signal plus subcarrier signal) to remove all but a subcarrier signal of a chosen frequency.

FIG. 2 illustrates the full FM signal spectrum and the useful portion of the signal that remains (e.g., $f_c \pm 19$ kHz) after frequency filtering. FM subcarrier signals can be used for all monitoring of the present location of the MP 11, inside and outside buildings and other structures. This approach has the advantage of simplicity: only one set of radiowaves is used for location determination. FM signals are less subject to noise and other interference than are other signals, such as AM signals. Alternatively, an FM subcarrier signal can be replaced by an AM subcarrier signal, which is obtained by filtering an AM signal at a frequency displaced from the AM carrier frequency by a relatively small amount. More generally, determination of the present location and/or present velocity of the MP 11 can be made using a portable LMD unit that receives and analyzes LMD radiowave signals transmitted from three or more LMD signal sources.

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An LMD unit 13, shown in FIG. 3, that is carried by or attached to the MP 11 includes a location determination (LD) antenna 31, an LD signal receiver 33, a motion sensor 34 that issues motion sensing signals when the sensor is motionless (or when the sensor is in motion), an LMD signal receiver/processor 35 that receives and analyzes the LD signals and the motion sensor signals, a signal transceiver 36 connected to the processor, and power supply 37, for receiving certain LD radiowave signals from one or more LD signal source 38A, 38B, 38C and/or 38D. Information from these LD signals and from the motion sensor signals may be transmitted, unprocessed, by the transceiver 36 to a central processing station 39, located at or near the site R, to allow determination of the present location coordinates and/or the present velocity coordinates of the MP 11 periodically (e.g., second-by-second, or more or less often, if desired). In a first mode of operation of the LMD unit 13, all signal processing occurs at the central station, and the LMD signal processor 35 may be deleted. Alternatively, the LD signals received by, and the motion sensing signals generated by, the LMD unit 31 may be partly or fully processed by the LMD signal processor 35 to partly or fully determine the present location and possible motion of the LMD unit. This processed information may be transmitted to the central station 39 for final determination of the present location and/or motion of the MP 11. The motion sensor 34 is optionally detachable from the remainder of the LMD unit 31.

If the MP 11 is outdoors or is within any building or other structure that is not electromagnetically isolated, the LMD signals may have any frequency, and GPS, GLONASS, Loran, Omega, Decca, Tacan, JTIDS ReInav, PLRS, FM subcarrier signals, or other radiowave signals may be used. If the MP 11 is within an electromagnetically isolating structure, FM subcarrier signals may often still be received within the structure without disabling signal attenuation or signal distortion. However, the invention does not require that LD signals be receivable within or near an electromagnetically isolating structure; outdoor LD signals can also be used with the invention.

In the embodiment illustrated in FIG. 1, the invention uses FM subcarrier signals emitted by three or more spaced apart FM signal sources 15, 17 and 19, positioned at known locations in the community, together with an FM signal monitor (and, optionally, source) 21 that is also located at a known position. If the FM signal monitor 21 also serves as a source, this source is preferably separated by a large distance from a plane P(15,17,19) passing through the locations of the other three FM station antennas. In this instance, the source 21 may be located on a very tall tower, for example, relative to the heights of the transmitting antennas of the other FM sources 15, 17 and 19.

The FM signal monitor 21: (1) receives the FM subcarrier signals transmitted by the other FM stations 15, 17 and 19; (2) determines the relative phases of these subcarrier signals at their respective sources, using the known distances of the antennas of each of the other FM stations 15, 17 and 19 from the FM monitor 21; (3) transmits a signal on another selected frequency that advises any FM subcarrier signal receiver of these relative phases; and (4) optionally transmits its own FM subcarrier signal, with a phase determined by an optional selected linear combination of the phases of the other three FM subcarrier signals, or determined independently of the other three phases. The MP 11 wears the portable LMD unit 13 and is assigned an identifying indicium that is included in any transmission by that LMD unit to the central station 39. Optionally, the central station 39 can continually or periodically advise a communications,

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command and control (C3) center of the location and/or velocity of the MP 11, or of the locations and/or velocities of several such persons.

The LMD unit 13 serves as a mobile station that receives the FM subcarrier signals and optionally transmits phase information for each of these subcarrier signals to the central station 39 for (further) processing and analysis. The central station 39 has a known location relative to each of the FM signal sources 15, 17, 19 and FM signal monitor 21 and can determine the phase of each these FM signals relative to a selected phase reference or can determine the FM signal source phases relative to each other at a selected time. One advantage of use of relatively low frequency FM signals, such as $f_c \pm 19$ kHz, is that such signals are attenuated and/or distorted less, in passing through walls, floors and ceilings of normal buildings, than are higher frequency radiowave signals, such as AM signals. In normal circumstances, the relative phases of the FM signal sources 15, 17, 19 and FM monitor 21 would not change, or would change at most a few times in any 24-hour period. However, the invention provides for the possibility that these relative phases can change often and/or quickly.

At or around a given time $t=t_0$, the FM subcarrier signals broadcast by the FM sources 15, 17, 19 and FM monitor 21 (optional) are

$$S'_m(t) = S_0 \exp[j(\omega_m t - \phi_m)] \quad (m=15, 17, 19, 21) \quad (1)$$

where ω_m and ϕ_m are the subcarrier frequency and present phase of the FM signal source number m . The subcarrier frequencies ω_m are preferably distinct from and spaced apart from one another. Optionally, the signal $S'_m(t)$ may itself be modulated with a known signal to produce a signal $S_{m,mod}(t)$ that is different for each source (m) and that allows identification of each source signal, independently of whether the subcarrier frequencies are distinct. The subcarrier signals are received at the LMD device 13 as time-varying signals of the form

$$S'_m(t) = S_0 \exp[j(\omega_m t - \phi_m - \omega_m d_m/c)] \quad (m=15, 17, 19, 21), \quad (2)$$

where c' is the average propagation velocity in the transmission medium (mostly air) and

$$d_m = [(x-x_m)^2 + (y-y_m)^2 + (z-z_m)^2]^{1/2} \quad (3)$$

is the distance from the FM signal source number m to the LMD unit 13, whose present location coordinates (x, y, z) and/or velocity coordinates (v_x, v_y, v_z) are as yet undetermined. analysis. The central station 39 has a known location relative to each of the FM signal sources 15, 17, 19 and FM signal monitor 21 and can determine the phase of each these FM signals relative to a selected phase reference or can determine the FM signal source phases relative to each other at a selected time. One advantage of use of relatively low frequency FM signals, such as $f_c \pm 19$ kHz, is that such signals are attenuated and/or distorted less, in passing through walls, floors and ceilings of normal buildings, than are higher frequency radiowave signals, such as AM signals. In normal circumstances, the relative phases of the FM signal sources 15, 17, 19 and FM monitor 21 would not change, or would change at most a few times in any 24-hour period. However, the invention provides for the possibility that these relative phases can change often and/or quickly.

At or around a given time $t=t_0$, the FM subcarrier signals broadcast by the FM sources 15, 17, 19 and FM monitor 21 (optional) are

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$$S_m(t) = S_0 \exp[j(\omega_m t - \phi_m)] (m=15, 17, 19, 21) (f^2=1), \quad (1)$$

where ω_m and ϕ_m are the subcarrier frequency and present phase of the FM signal source number m . The subcarrier frequencies ω_m are preferably distinct from and spaced apart from one another. Optionally, the signal $S_m(t)$ may itself be modulated with a known signal to produce a signal $S_{m,mod}(t)$ that is different for each source (m) and that allows identification of each source signal, independently of whether the subcarrier frequencies are distinct. The subcarrier signals are received at the LMD device 13 as time-varying signals of the form

$$S'_m(t) = S_0 \exp[j(\omega_m t - \phi_m - \omega_m d_m/c)] (m=15, 17, 19, 21), \quad (2)$$

where c is the average propagation velocity in the transmission medium (mostly air) and

$$d_m = [(x-x_m)^2 + (y-y_m)^2 + (z-z_m)^2]^{1/2} \quad (3)$$

is the distance from the FM signal source number m to the LMD unit 13, whose present location coordinates (x, y, z) and/or velocity coordinates (v_x, v_y, v_z) are as yet undetermined.

If the phases ϕ_m are known, the distances d_m can be determined from Eq. (2). From any three physically realistic three distances, such as d_{15} , d_{17} and d_{19} , two candidate location coordinate triples (x, y, z) can be found that, in principle, satisfy Eqs. (3) for measured distances d_m (or phases ϕ_m). Adding the distance d_{21} of a fourth FM subcarrier signal source, such as 21, will, in principle, allow elimination of one of these two candidate triples so that only one location coordinate triple (x, y, z) remains for the present location of the LMD unit 13. In practice, this scheme will not work well if the four FM signal sources lie approximately in a plane or in a line and the present location of the LMD device 13 also lies close to or in that plane or that line. Preferably, one of the four FM signal sources, optional FM source 21, should be spaced far apart from the plane passing through the locations of any three other FM signal sources 15, 17 and 19. This separation distance is preferably at least ten percent of the maximum distance from the FM source 21 to the other FM sources 15, 17 and 19. This formalism can be used for FM signals and for AM signals. This formalism can also be used for electromagnetic signals of any frequency emitted by a ground-based distance measuring system, such as Loran, Omega, Decca, Tacan, JTIDS Relnav or PLRS, or a Satellite Positioning System (SATPS), such as GPS or GLONASS, collectively referred to herein as an "outdoor LMD system."

In one cycle of an FM subcarrier signal of frequency $f_m = f_{c,m} \pm 19$ kHz ($m=15, 17, 19$, and optionally 21), an electromagnetic wave will move a distance equal to one wavelength $\lambda = c/\omega_m$, or about 15.8 kilometers (km) in a vacuum. Thus, the distance of the LMD device 13 from each FM signal source is known modulo 15.8 km. This distance ambiguity can be removed by initialization techniques. For example, if the designated site R has a diameter that is $\ll 15.8$, the present location of the MP 11 can be determined at one location on the site R, with one set of FM signal source phases, and can be used for all locations on or adjacent to the site R by determining phase changes for each signal relative to this initial location. That is, the phase ϕ_m is initially determined at a time $t=0$ for each FM or other location signal transmitter, using Eq. (2) or another suitable

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relation to determine the absolute or relative phases of the signals arriving from the signal source m at a known location, the initial location of the MP 11 on the site R.

Assume that FM signal source number m ($m=15, 17, 19$, and optionally 21) has known coordinates (x_m, y_m, z_m) . From the determinable phase differences of the signals arriving from each FM source at a selected location with as-yet-undetermined coordinates (x, y, z) (such as the present location of the MP 11), source number m is determined to lie at a distance d_m from the selected location. FM subcarrier signals, emitted from FM sources 15, 17, 19 and 21 (optional) with synchronized phases, would arrive at the selected location with time differences Δt_{ij} or source-to-source phase difference $\Delta \phi_{ij}$ ($i \neq j$; $i, j=15, 17, 19, 21$) that are determined by

$$\Delta \phi_{ij} = 2\pi(f - d_{ij})/c = f \Delta t_{ij}/c, \quad (4)$$

$$d_i = [(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2]^{1/2} \quad (5)$$

where c is the velocity of light propagation in the ambient medium and f is the frequency of the FM subcarrier signals. The three phase differences $\Delta \phi_{ij}$ ($i \neq j$; $i, j=15, 17, 19$) define three intersecting hyperboloids or similar quadratic surfaces, each having two sheets. In general, the common intersections of each of these three groups of sheets should define a point or segment of a curve, where the two points (or curve segments) 11 and 12 shown in FIG. 3 are mirror images of each other with respect to the plane $P(15, 17, 19)$ defined by the coordinates (x_i, y_i, z_i) of the i th transmitter of the FM subcarrier signals. A fourth FM subcarrier signal source 21 (optional), because it is displaced from and does not lie on the plane $P(15, 17, 19)$, transmits FM subcarrier signals that have two distinct phase differences at the intersection points 11 and 12. This fourth FM subcarrier signal can thus distinguish between 11 and 12 and allow determination of the correct location coordinates (x, y, z) for the selected location. This assumes that the phases of the four FM subcarrier signals are synchronized, with zero phase differences or known phase differences between any two of these signals. In practice, each of the four FM subcarrier signal sources will have a phase that may drift with time or change abruptly at particular times.

Where the four FM subcarrier signals have different phases, these source phase differences $\Delta \phi_{ij}$ must be determined and removed before Eq. (4) can be used to determine the location coordinates (x, y, z) of the selected location. The phase differences $\Delta \phi_{ij}$ can be determined by providing an FM subcarrier signal monitor station 21 that receives the other three FM subcarrier signals ($i=1, 2, 3$ in this example) and determines the phase differences $\Delta \phi_{i,21}$. The FM monitor 21 uses its knowledge of the separation distances between itself and the (other) FM subcarrier signal sources and of the measured signal phase differences at the monitor from the other three FM subcarrier signals. As noted above, the phase differences $\Delta \phi_{i,21}$ may vary with time, through drift, abrupt change, or both. The FM signal monitor station then broadcasts the phase differences $\Delta \phi_{i,21}$, preferably with a different carrier frequency than any FM subcarrier frequency, and these phase differences are received and stored and/or processed by a receiver at the LMD unit 13. This LMD unit 13 also receives the FM subcarrier signals and determines the "raw" or uncompensated phase differences $\Delta \phi_{ij}$ at its location ($i, j=15, 17, 19$). A signal processor associated with this receiver then forms the "true" or compensated phase differences

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$$\Delta\Phi_{15,21}=2\pi(d_{15}-d_{21})/c\Delta t-\Delta\Phi_{15,21} \quad (6)$$

$$\Delta\Phi_{17,21}=2\pi(d_{17}-d_{21})/c\Delta t-\Delta\Phi_{17,21} \quad (7)$$

$$\Delta\Phi_{19,21}=2\pi(d_{19}-d_{21})/c\Delta t-\Delta\Phi_{19,21} \quad (8)$$

This compensates for non-synchronization and possible drifting of the FM subcarrier signals transmitted by the four FM subcarrier signal sources. However, compensation is provided with respect to one of the four FM subcarrier signals, whose own phase may change with time.

Use of an FM signal monitor, which does not otherwise participate in determination of the selected location coordinates (x, y, z), to determine the phase differences $\Delta\Phi_{ij}$ (ij=15,17,19), is disclosed in U.S. Pat. No. 5,173,710 issued to Kelley et al, which is incorporated herein by reference. The FM source phase differences $\Delta\Phi_{ij}$ can be measured using a digital phase-locked-loop at the additional FM receiver/transmitter, as disclosed in FIGS. 4-11 and the accompanying text in the Kelley et al patent. In the subject invention, the FM signal monitor 21 used for monitoring the source-to-source phase differences optionally provides a fourth FM subcarrier signal (j=21), and the phase differences of the other three FM subcarrier signals are determined relative to the phase of the FM subcarrier signal transmitted by the FM signal monitor 21.

The FM signal monitor 21 can also serve as a reference station with accurately known location for differential position computations for determining the present location of the outdoor LMD signal antenna. Differential position techniques use the known location of the reference station to remove some of the errors contained in signals received by a mobile station, such as the MP 11, that is located within a few tens of kilometers from the reference station. GPS and differential GPS techniques are discussed in Tom Logsdon, *The NAVSTAR Global Positioning System*, Van Nostrand Reinhold, 1992, pp. 1-90, and differential Loran and differential Decca techniques are discussed in U.S. Pat. No. 5,045,861, issued to Duffet-Smith. The information from these references is incorporated by reference herein. Thus, the FM signal monitor station 21 can include an outdoor LMD signal antenna and associated outdoor LMD signal receiver/processor, to receive the outdoor LMD signals and to determine any location error values contained in these signals by comparison of the calculated location with the known location of the reference station. The FM signal monitor 21 can also include a transmitter to transmit these error values to a receiver/processor at the outdoor LMD signal unit so that the calculated present location of the outdoor LMD signal antenna can be adjusted by removal of outdoor LMD signal errors that have been determined from the signals received at the FM signal monitor station 21 (which also serves as an outdoor LMD signal reference station). Compensation for outdoor LMD signal errors can be provided at the reference station 21 or at the outdoor LMD unit.

The FM signals indicated in FIGS. 1 or 3 may be used outside as well as inside a building or other structure to allow determination of the present location of the MP 11. Alternatively, FM signals may be used for inside-the-building location reporting and may be supplemented for outside-the-building location reporting by supplemental (outdoor) LMD signal sources. One suitable outdoor LMD signal source, illustrated in FIG. 4, is a Global Positioning System (GPS) or Global Navigation Orbiting System (GLONASS) or similar satellite-based location determination system (collectively referred to as GPS herein). A GPS includes a plurality of three or more visible, Earth-orbiting,

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non-geosynchronous satellites 41, 43, 45, 47 that each transmit a continuous, distinguishable electromagnetic signal that is received by a GPS antenna 49 and associated GPS signal receiver/processor 50 on or near the Earth's surface.

The GPS receiver/processor 50 determines the present location of the GPS antenna by suitable processing of three or more GPS signals received from the GPS satellites 41, 43, 45, 47. A GPS and a GLONASS are discussed in more detail below. Global Positioning System signals are available throughout the world, whereas FM signal reception is often limited to line-of-sight reception, with a representative maximum reception distance of about 50 kilometers. A Global Positioning System is discussed in detail in Tom Logsdon, op cit.

Because the GPS signals use a high frequency carrier (above 1 GHz), these signals may be severely attenuated and/or distorted if such signals are received inside a building or other structure that is partly or fully electromagnetically isolating. For this reason, GPS or GLONASS signals would ordinarily be unsuitable for determination of the present location of an LD antenna that is positioned within such a building or similar structure. The invention avoids this difficulty by using signals issued by a motion sensor and signals issued by another signal generator when the MP is within or near an electromagnetically isolating structure.

The combined use of FM signals for location determination inside a building or similar structure (e.g., a deep shaft mine or tunnel under or through the Earth) plus GPS signals for location determination outside a building or similar structure can also provide a satisfactory LMD system in most urban and non-urban communities.

Alternatively, the GPS signals may be replaced by Loran-C signals produced by three or more Loran signal sources positioned at fixed, known locations, for outside-the-building location determination, as illustrated in FIG. 5. A Loran-C system relies upon a plurality of ground-based signal towers 51, 53, 55 and 57, preferably spaced apart 100-300 km, that transmit distinguishable electromagnetic signals that are received and processed by a Loran signal antenna 58 and Loran signal receiver/processor 59. A representative Loran-C system is discussed in *Loran-C User Handbook*, Department of Transportation, U.S. Coast Guard, Commandant Publication P16562.5, November 1992, which is incorporated by reference herein.

Loran-C signals use carrier frequencies of the order of 100 kHz and have maximum reception distances of the order of hundreds of kilometers. Loran-C signals (alone) can be used as the LD signals in the invention. The combined use of FM signals for location determination inside a building or similar structure plus Loran-C signals for location determination outside a building or similar structure can also provide a satisfactory LMD system in most urban and suburban communities.

Other ground-based radiowave signal systems that are suitable for use as part of an LMD system include Omega, Decca, Tacan, JTIDS Relnav (U.S. Air Force Joint Tactical Information Distribution System), PLRS (U.S. Army Position Location and Reporting System) and ORBCOM. Most of these systems are summarized in Logsdon, op. cit., pp. 6-7 and 35-40.

Other radiowave signals, such as emergency band signals in the frequency ranges 12.23-13.2 MHz, with suitable signal timing and a signal indicium included therein, can be used as a source of LMD signals for outdoors locations. For convenient reference, a satellite-based or ground-based location determination system, not including a system that uses FM subcarrier signals, that can be used to determine the

location of an MP 11 over relatively long distances outside a building or other structure over the region R will sometimes be referred to as an "outdoor LMD system".

FIG. 6 is a flow chart of a procedure that can be used to determine the present location of the MP 11, if an FM subcarrier system is used for all location determinations inside and outside buildings and other structures in a region R. In step 60, the LMD system is activated and made ready to determine the present location and/or present motion of an MP 11. A central station or other interrogator transmits an interrogation signal (e.g., "Where are you?") in step 61, with an identifying label, tag or indicium attached that specifies the identified MP 11, or specifies the LMD unit 13 carried by that person. In step 62, each LMD unit determines if it is the LMD unit specified by the central station's interrogation signal. If a given LMD unit is not the specified unit, that LMD unit ignores this interrogation signal and recycles until receipt of the next interrogation signal. If the LMD unit carried by the identified MP 11 is the specified unit, this unit optionally determines if the FM subcarrier signals received are adequate to determine the present location of the LMD unit, in step 63. If the FM subcarrier signals are inadequate, the LMD unit optionally advises the central station of this circumstance, in step 64.

Assuming that the FM subcarrier signals are adequate to determine the present location of the LMD unit or that steps 63 and 64 are absent in the flow chart of FIG. 6, the LMD unit responds, in step 65, by transmitting to the central station the last location fix computed by that LMD unit and any other relevant and available information on the identified arrestee's condition or circumstance. Preferably, the specified LMD unit responds by transmitting the requested information to the central station in a time slot (of length 10-200 msec) allocated for this response. Preferably, the responding LMD unit also includes a label, tag or other indicium identifying the responding LMD unit. The central station receives the response signal from the LMD unit and verifies that this signal carries the correct LMD unit indicium, in step 66. In step 67, the LMD unit processes, stores and/or visually or audibly displays information on the specified LMD unit present location and/or present velocity.

The procedure shown in FIG. 6 would be followed irrespective of whether the LMD unit 13 is presently inside or outside a building or other structure, because only one LMD system is providing the LMD information. Alternatively, the LMD unit can partly process the LD and motion sensor signals and can transmit this partly processed information to the central station 39 for further signal processing and determination of the LMD unit's present location. As a second alternative, the LMD unit can automatically retransmit, unprocessed, suitable information (timing, relative phases, etc.) that the LMD unit is receiving from each of the FM subcarrier signal sources and allow the central station to do all LMD signal processing.

FIG. 7 is a flow chart of a procedure that can be used to determine the present location of each MP 11, where a combination of FM subcarrier signals and signals provided by an outdoor LMD system are used for location determination. The LMD system is activated in step 80. The central station interrogates a specified LMD unit by transmitting an interrogation signal with a label, tag or other indicium that identifies that LMD unit, in step 81. Each LMD unit receives this interrogation signal and determines if the interrogation signal is directed to that LMD unit, in step 82. If a given LMD unit is not the one specified by the interrogation signal, that LMD unit ignores the interrogation signal and recycles until the LMD unit receives another interrogation signal.

If a given LMD unit is specified in the interrogation signal, that LMD unit automatically determines, in step 83 of FIG. 7, whether the LMD information should be provided by the outdoor LMD unit, by the FM subcarrier unit, or by neither, based upon the present location of that LMD unit and/or an indicium for each FM subcarrier signal and for each outdoor LMD signal that indicates which of the two signals is likely to provide the most accurate location under the circumstances. The indicium for each signal preferably is a measure of the signal robustness, such as signal strength, or the signal quality, such as signal-to-noise ratio. Use of such indicia is discussed in the co-pending patent applications entitled "Hybrid Location Determination System," U.S. application Ser. No. 08/171,557, and Portable Hybrid Location Determination System," U.S. application Ser. No. 08/191,984, assigned to the assignee of this application. In some circumstances, neither the FM subcarrier signals nor the outdoor LMD signals may provide acceptable signals for location determination, and the LMD unit optionally advises the central station of occurrence of this circumstance, in step 87.

If the LMD unit is located outside of and away from all buildings and structures, the LMD unit can use the outdoor LMD unit to provide LMD information on its present location and/or present velocity, as in step 84, or can use the FM subcarrier unit for this purpose. If the LMD unit is located inside a building or other structure or in another location that is inaccessible to outdoor LMD system signals, the FM subcarrier unit provides present location and/or present velocity information for the LMD unit, in step 85. If neither the FM subcarrier signals nor the outdoor LMD signals are adequate for location determination, the LMD system advises the central station of this, in step 86. In step 87, the LMD unit transmits to the central station its LMD information, unprocessed, partly processed or fully processed, to the central station, preferably including a first label, tag or other indicium that identifies the responding LMD unit and a second label, tag or other indicium indicating which, if any, of the two LMD systems has provided the LMD information. Optionally, the LMD unit can transmit the requested information to the central station in an allocated time slot (of length 10-200 msec) for this response. In step 88, the central station receives the information transmitted by the LMD unit, verifies the identity of the responding LMD unit, and determines which signal processing route to use, based in part on which LMD system has provided the LMD information. The central station processes, stores and/or visually or audibly displays the present location of the specified LMD unit, in step 89.

FIG. 8 is a schematic view of a portable location determination unit 101 that may be used to practice the invention, where a combination of FM subcarrier signal system and an outdoor LMD system are used to determine location of an LMD unit in the region R. The LMD unit 101 includes an FM subcarrier LMD module 105, including an FM signal antenna 103 and receiver/processor 104, and an outdoor LMD module 109, including an outdoor LMD signal antenna 107 and receiver/processor 109. Each of the receiver/processors 104 and 108 is connected to an LMD unit interface and LMD unit controller 111. The controller 111 receives location signals or other indicator signals from each of the receiver/processors 104 and 108 and determines whether the FM subcarrier signal system or the outdoor LMD system, if any, will be selected to respond to receipt of an interrogation signal requesting location and/or velocity information from the LMD unit 101 or to determine the present location and/or present velocity of the LMD unit.

This selection can be based upon the present location and/or present velocity of the LMD unit 101, or upon one or more signal conditions associated with the signals received and/or processed by each of the receiver/processors 104 and 108. The output signal (the selected location and/or velocity information signal) of the controller 111 is received by an LMD signal transmitter and antenna 113 and 115 and is transmitted to the central station that issued the interrogation signal. The LMD signal antenna and transmitter 113 and 115 can also serve as the antenna and receiver, respectively, that receive the interrogation signal transmitted by the central station. A power supply 117 supplies electrical power for at least one of the other components in the LMD unit 101. If the LMD unit 101 is not required to process any of the LMD signals received by either of the antennas 103 and 107, the two receiver/processors 104 and 108 can be deleted or simplified in the LMD unit. If only the FM subcarrier signals, or only the outdoor LMD signals, are used to determine the location of the LMD unit 101, the unused LMD antenna (103 or 107) and LMD receiver/processor (104 or 108) and part or all of the controller 111 can be deleted in the LMD unit 101.

The location coordinates (x, y, z) of the LMD unit 101 carried by the MP 11 in FIG. 1 are now known. The location coordinates (x, y, z) of the LMD unit 101 are compared with the range of location coordinates of the region R and its boundary 6R, or with the range of location coordinates for any other region and its boundary in which the MP 11 is presently permitted to be. If the location coordinates (x, y, z) of the LMD unit 101 are within the site R bounded by the boundary 6R, the receiver/processor 104 or 108 need take no action. If the location coordinates (x, y, z) lie elsewhere, the receiver/processor 104 or 108 transmits a silent radiowave alarm to the central station, indicating that the MP 11 has moved beyond the permitted region or site R and indicating the present location coordinates of the MP 11. The MP's movement within and outside the arrestee site R can thus be tracked by the central station.

Alternatively, the present location information for the MP 11 can be transmitted, unprocessed or partly processed or fully processed, to the central station. The central station then completes any signal processing needed and determines whether the MP location coordinates (x, y, z) lie within the permitted site R or beyond the boundary 6R. If these location coordinates lie beyond the permitted site boundary, or if the central station does not receive K consecutive LMD response signals from the LM unit 13 worn by the MP 11 (K a selected positive integer), the central station can transmit an alarm or otherwise alert the proper authorities to apprehend the MP.

From time to time, the MP 11 may need to leave the site R for legitimate personal needs, such as a visit to his/her physician or dentist, a visit to a hospital for emergency or elective medical treatment, or to purchase food or other necessary personal items. In such instance, the site R can be expanded, temporarily, by prearrangement with the central station 39 to include a corridor C connecting the region R to the physician's office or other legitimate destination D for the MP, as indicated in FIG. 9. When the MP 11 returns to the original site R after the prearranged visit, the corridor C and destination D are deleted and the permitted site again becomes the original site R. Alternatively, the MP 11 can be moved from the first permitted site R to a destination site D, and the first-permitted site R and the corridor C can be deleted after the MP arrives at the new permitted site D. The width W of the corridor C may be as little as 30-40 feet, which is the width of an average residential street.

Alternatively, the width W may be much greater to allow for use of any of two or more alternative paths connecting the original site R to the destination D within the corridor C. The width W may vary along the corridor C. The movements of the MP 11 in the corridor C may be timed, and the MP may be required to move according to a selected time schedule, with time tolerances optionally included to compensate for reasonable but unexpected time delays in movement between the permitted site R and the destination site D.

The MP 11 may be under court order or other constraint to avoid certain exclusion regions R*, such as the homes and/or offices of persons also involved in crimes or other activities or the residences and work places of persons whom the MP might harass or injure. This could also include the home and/or office of an estranged spouse, victim or witness to commission of a crime in which the MP 11 was involved. In this instance, the permitted region R would be supplemented at the central station 39 by an exclusion region R*, surrounding and including each home, office and/or other facility that the MP must avoid at all times, as illustrated in FIG. 10. If the MP 11 leaves the site R and crosses a designated boundary 6R* of the exclusion region R*, the receiver/processor 104 or 108 in the LMD unit 101 (FIG. 8) attached to the MP notifies the central station 39 of this development by another silent radiowave alarm, and police can be dispatched to intercept the arrestee. Optionally, the receiver/processor 104 or 108 in the LMD unit 101 could cause the MP to become disabled, for example by rendering the MP unconscious, using trans-dermal application across the MP's skin of a strong sedative or depressant. Trans-dermal application devices are available from Alza Corp., Palo Alto, Calif., and from other manufacturers in this field.

FIG. 11 illustrates a low-power-consumption embodiment of the invention, in which an MP 131 carries an LMD unit 133, which includes an FM subcarrier signal module or an outdoor LD module 134, in combination a timer 135, an optionally detachable motion sensor 137, an optionally detachable localization signal generator 139 and an optionally detachable signal attribute sensor 141. When the MP 131 moves to within a building or other structure 143, the MP has a time interval of selected length Δt_{mot} to move to some location within the structure and to settle down or position the motion sensor, using elapsed time as measured by the timer 135. The timer need not be very accurate. The time interval length Δt_{mot} may be chosen in the range 5-120 sec, preferably in the range 30-60 sec. When the MP 131 "settles down," the MP positions the motion sensor 137 adjacent to the location where the MP has settled down, and this motion sensor quickly determines that it is not moving. After this motion sensor senses absence of motion within the time interval of length Δt_{mot} , the motion sensor 137 causes the LMD unit 133 to notify a central station 145 that the MP's motion has (temporarily) ceased. The LMD unit (except the motion sensor 137) then optionally enters a sleep mode, in which many but not all of its operations are temporarily curtailed and the power consumption is correspondingly reduced. At this time, the local signal generator 139 begins to continuously transmit a distinguishable localization signal having a selected frequency or combination of frequencies f_{loc} , and the signal sensor 141 begins to receive this localization signal and to measure a localization signal attribute A. The localization signal attribute value A is an approximate measure of the distance between the localization signal generator 139 and the signal sensor 141. The frequency or frequencies f_{loc} are chosen to be low enough that the localization signal suffers only modest attenuation in passing through or around the walls and other obstructions within the structure 143.

The localization signal attribute A varies approximately inversely with the distance from the localization signal generator 139 to the signal sensor 141. Either the localization signal generator 139 or the signal sensor 141, but not both, is carried by the MP; the other of these two devices remains at a selected (preferably fixed) central location within or near the structure 143. When the signal sensor 141 senses that the localization signal intensity I, as received by this sensor 141, has dropped below a selected threshold A_{thr} (or has increased above this threshold), corresponding to a selected approximate distance of separation d_{sep} between the localization signal generator 139 and the signal sensor 141, the MP receives a second advisory signal and has a time interval of a selected length Δt_{rev} to move to a location (preferably outside or away from the structure 143) where the MP's location can again be determined by the LMD unit 131. This embodiment allows the MP 131 to move around within the structure 143 after settling down, within an approximate sphere of radius approximately d_{sep} centered at the present location of the motion sensor 137, without requiring the MP to "check in" with the monitoring authorities or to re-locate himself or herself using the LMD unit 133. If the MP fails to properly respond to the second advisory signal within the time interval of length Δt_{rev} , the LMD unit 133 advises the central station 145 of this breach, and the central station responds accordingly.

The localization signal sensor 139 and signal sensor 141 (only one is present here) and the timer 135 are shown, together with other LMD unit apparatus components that are necessary for practice of this embodiment, in FIG. 12. Most other components shown in FIG. 12 perform as in FIG. 8. The controller 111 may be used to coordinate the procedures carried out by the timer 135, motion/velocity sensor 137, localization signal generator 139 and signal sensor 141.

In the embodiment illustrated in FIG. 11, no LD signals, such as FM subcarrier signals, that can be received inside an electromagnetically isolating structure need be transmitted, received or analyzed. Use of LD signals is discussed in the patent application entitled "Flexible Site Arrestee Monitoring," U.S. application Ser. No. 08/171,228, for which this application forms a continuation in part. Alternatively, an LMD unit that receives and analyzes LMD signals may be used in the embodiment shown in FIG. 11.

The LMD (or LD) signals in this situation may consist solely of outdoor LMD signals transmitted by satellite-based signal sources, such as GPS, GLONASS, GOES, Iridium and Orbcom, or by ground-based signal sources, such as Loran, Omega, Decca, Tacan, JTIDS ReInav and the Personal Location Reporting System (PLRS), or may consist solely of FM subcarrier signals. Location and motion by the MP is accurately monitored outside any building or structure 143 that might interfere with receipt of outdoor LD signals. Within a building or structure 143 that would interfere with receipt of outdoor LD signals, the MP has a motion sensor 137 that senses motion but that is not required to determine the MP's location. The MP is assigned an approximate sphere of radius d_{sep} within the structure 143, within which the MP can move without accounting for the MP's movements or activities. The LMD unit 133 (except the motion sensor 137) optionally enters a sleep mode, with substantially reduced electrical power requirements, while the MP moves within this sphere. When the MP moves beyond this sphere, or outside or beyond the building or structure 143, the MP must take specified actions, within a selected time interval, such as 10-30 sec: (1) the MP must "check in" or re-activate or re-initiate the LMD unit 131 and facilitate continued monitoring of the MP's location and/or motion;

and/or (2) the MP must move to a location such that the localization signal attribute A, as sensed by the signal attribute sensor 141, is again at least equal to the threshold attribute value A_{thr} .

If the outdoor LD or LMD signals can be recognizably received within the structure 143 and analyzed, these outdoor LMD signals are optionally used to monitor the present location and/or motion of the MP within that structure or outside that structure.

FIG. 12 is a flow chart showing a suitable procedure for practice of the invention illustrated in FIG. 11. In step 151, the MP obtains one or more location fixes from an outdoor LD or LMD unit, from a location that is outside, or at least not shielded by, a building or other structure. In step 153, the LD unit determines whether its own location is outside the permitted site. If the answer in step 153 is "yes," the LD unit causes an alarm signal number 1 to be transmitted, in step 155, and proceeds to step 157. If the answer in step 153 is "no," the LD unit proceeds to step 157, where the LD unit determines whether it has lost LD signals. The LD unit can lose LD signals because the LD unit is inside or shielded by an electromagnetically isolating structure, such as a building, a large sign, a large tree or group of trees, or other similar obstacles to receipt of LD signals. If the answer in step 157 is "no," the system returns to step 151.

The LMD unit includes a (preferably detachable) motion sensor that senses whether or not the LMD unit is substantially motionless. When the motion sensor senses that the LMD unit is substantially motionless for at least a selected initial time interval Δt_{mot} (usually a few tens or hundreds of milliseconds), the motion sensor begins issuing a stationarity signal, which signal continues only as long as the motion sensor remains substantially motionless.

If the answer in step 157 is "yes," the system sets a motion counter value (m) for the motion sensor equal to an initial value, such as in =1, m in step 159. In step 161, the LD unit is activated (upon loss of receipt of the LD signals in step 157), a first time counter is activated and begins to accumulate a first time Δt_1 , and the LD unit issues a first advisory signal, indicating that the MP has a selected (fixed) maximum accumulated time $\Delta t_{1,max}$ (preferably =5-30 sec) in which to set down the motion sensor so that the motion sensor begins to issue its stationarity signal. In step 163, the LD unit determines if it has acquired (or reacquired) the LD signals so that the LD unit can again provide location fixes for itself. If the answer in step 163 is "yes," the system returns to step 151.

If the answer in step 163 is "no," the system determines whether the motion sensor has begun to issue the stationarity signal, in step 165. If the answer in step 165 is "no," the system determines whether the first countdown time interval has expired, equivalent to $\Delta t_1 \geq \Delta t_{1,max}$, in step 167. If the answer in step 167 is "no," the system returns to step 163. If the answer in step 167 is "yes," the system transmits an alarm signal number 2, in step 169, and returns to step 161.

If the answer in step 165 is "yes," the system proceeds to step 171, where the LD unit is deactivated, the first counter is reset to $\Delta t_1 = 0$ and deactivated, and a localization signal generator is activated and begins to transmit a distinguishable signal. This distinguishable signal may be a very low frequency signal (<10 kHz) so that this signal can readily pass through building walls and most similar structures. This distinguishable signal is received by a localization signal sensor, and a signal attribute having a signal attribute value A is determined by the sensor from the received distinguishable signal. The signal attribute value A may be measured signal intensity or some other value that is an approximate

measure of the distance between the signal generator and the signal sensor. The signal generator or the signal sensor, but not both, is attached to the MP's body. Whichever of the signal generator and the signal sensor that is not attached to the MP's body is located at a selected location, preferably close to or within the structure that has caused loss of the LD signals in step 157. Thus, one of the signal generator and the signal sensor is mobile and moves with the MP within or near the structure. The LD sensor compares the signal attribute value A with a selected threshold value A_{thr} . If $A \geq A_{thr}$ (or, alternatively, $A \leq A_{thr}$), an approximate distance d between the signal generator and the signal sensor (approximately) satisfies the relation $d \leq d_{thr}$, where $d_{thr} (>0)$ is a selected threshold distance, preferably in the range 20–200 feet. If $A < A_{thr}$ (or, alternatively, $A > A_{thr}$), the approximate distance d between the signal generator and the signal sensor (approximately) satisfies the relation $d > d_{thr}$. If $d \leq d_{thr}$, the signal generator and the signal sensor are said to be "within range" of each other.

In step 173, the system determine if the signal generator and the signal sensor are within range of each other. If the answer in step 173 is "no," the system determines, in step 175, whether a second time counter has begun to count through a second countdown interval from $\Delta t_2=0$ to a selected maximum accumulated second time $\Delta t_2=\Delta t_{2,max}$. If the answer in step 175 is "no," the second time counter is activated and the system issues a second advisory signal, in step 177, and the system proceeds to step 179. If the answer in step 175 is "yes," the system proceeds to step 179.

If the answer in step 173 is "yes," the system proceeds to step 179 and inquires whether the motion sensor is (still) issuing a stationarity signal. If the answer in step 179 is "yes," the system determines whether the second countdown time has expired, in step 181; that is, whether $\Delta t_2 > \Delta t_{2,max}$? If the answer in step 179 and 181 are "yes" and "no," respectively, the system returns to step 173. If the answer in step 179 is "yes" and the answer in step 181 is "yes," the system transmits alarm signal number 3 and returns to 173.

If the answer in step 179 is "no," the system proceeds to step 191, where the second counter is reset to $\Delta t_2=0$ and deactivated and the motion counter is incremented by replacing the motion counter value m by $m+1$. In step 193, the system determines whether $m > m_{max}$. If $m \leq m_{max}$, the system returns to step 161.

If $m > m_{max}$, the system determines whether a new monitoring time period has begun, in step 195. A monitoring time period has a selectable value, such as 24 hours, at the end of which the various counters (m , Δt_1 , Δt_2) are reset to initial values. If the answer in step 195 is "yes," the system resets the motion counter value to its initial value, in step 197, and proceeds to step 199. If the answer in step 195 is "no," the system proceeds to step 199.

Incrementing of the motion counter m in step 191, plus steps 159, 193, 195 and 197, can be optionally deleted from the procedures shown in FIG. 12. In this embodiment, if the motion sensor is determined to be non-stationary in step 179, the system resets and deactivates the second time counter in step 191 and proceeds to step 199. Here, no motion counter is used.

In step 199, the LD unit is activated and a third time counter begins to count through a third countdown interval from $\Delta t_3=0$ to a selected maximum accumulated second time $\Delta t_3=\Delta t_{3,max}$. In step 201, the system determines whether the LD unit has acquired (or reacquired) the LD signals. If the answer in step 201 is "yes," the third time counter is reset to $\Delta t_3=0$ and deactivated, in step 203, and the system returns to step 151. If the answer in step 201 is "no," the system

proceeds to step 205 and inquires whether the third countdown time has expired ($\Delta t_3 > \Delta t_{3,max}$)? If the answer in step 205 is "no," the system returns to step 201. If the answer in step 205 is "yes," the third counter is reset to $\Delta t_3=0$ and is deactivated and an alarm signal 4 is transmitted, in step 207, and the system returns to step 161.

As noted above, the LMD unit includes either the localization signal generator or the signal intensity sensor, but not both. The other of these two devices is positioned in some central location within or near the structure that interferes with receipt of the LD signals. Preferably, whichever of these two devices is not part of the LD unit is positioned at a permanent and immovable location within or near the structure. In step 171, the LD unit optionally enters a sleep mode (LMD unit deactivated) with reduced power consumption, if the motion sensor remains stationary.

In another embodiment, any or all of the steps involving (1) the first time counter and alarm signal number 2, (2) the second time counter and the alarm signal number 3, and/or (3) the third time counter and the alarm signal number 4 can be deleted in the flow chart in FIG. 12.

FIGS. 13A and 13B are schematic views of an LMD unit 221A and 221B that is suitable for practicing the embodiment(s) illustrated in the flow chart in FIG. 12. LD signals (GPS, GLONASS, Loran, FM subcarrier, etc.) are received at an LD signal antenna 223 and passed to an LD signal receiver/processor 225 for processing and determination of the present location of the LD signal antenna. The LMD unit 221A or 221B includes a motion sensor 227 and associated (optional) motion counter 229 that determines whether the LMD unit 221B or 221B is in motion and the number of times the motion sensor has been moved within a specified motion monitoring period, such as 24 hours. The LMD unit 221A or 221B also includes a timer unit 231 that contains first, second and third timers, which are (optionally) used in steps 167, 181, 205, respectively, in FIG. 12.

The LMD unit 221A or 221B further includes a localization signal generator 233 (221A in FIG. 13A) or a localization signal strength sensor 235 (221B in FIG. 13B) and an associated localization signal antenna 237, for transmitting or receiving the localization signal used in the embodiment illustrated in FIG. 12. As noted above, one of the localization signal generator 233 and localization signal sensor 235 is part of the LMD unit 221A or 221B, and the other of these devices is attached to and carried by the user 131 in FIG. 11.

The LMD unit 221A or 221B also includes an alarm signal transmitter 239 and associated antenna 241, for transmitting the first, second, third and/or fourth alarm signal as generated in the embodiment illustrated in FIG. 12. The components of the LMD unit 221A or 221B are powered by an electrical power source 243.

A Satellite Positioning System (SATPS) is a system of satellite signal transmitters, with receivers located on the Earth's surface or adjacent to the Earth's surface, that transmits information from which an observer's present location and/or the time of observation can be determined. Two operational systems, each of which qualifies as an SATPS, are the Global Positioning System and the Global Orbiting Navigational System.

An SATPS antenna receives SATPS signals from a plurality (preferably four or more) of SATPS satellites and passes these signals to an SATPS signal receiver/processor, which (1) identifies the SATPS satellite source for each SATPS signal, (2) determines the time at which each identified SATPS signal arrives at the antenna, and (3) determines the present location of the SATPS antenna from this

information and from information on the ephemeris for each identified SATPS satellite. The SATPS signal antenna and signal receiver/processor are part of the user segment of a particular SATPS, the Global Positioning System, as discussed in Logsdon, op. cit.

The Global Positioning System (GPS) is part of a satellite-based navigation system developed by the United States Defense Department under its NAVSTAR satellite program. A fully operational GPS includes up to 24 satellites approximately uniformly dispersed around six circular orbits with four satellites each, the orbits being inclined at an angle of 55° relative to the equator and being separated from each other by multiples of 60° longitude. The orbits have radii of 26,560 kilometers and are approximately circular. The orbits are non-geosynchronous, with 0.5 sidereal day (11.967 hours) orbital time intervals, so that the satellites move with time relative to the Earth below. Theoretically, three or more GPS satellites will be visible from most points on the Earth's surface, and visual access to two or more such satellites can be used to determine an observer's position anywhere on the Earth's surface, 24 hours per day. Each satellite carries a cesium or rubidium atomic clock to provide timing information for the signals transmitted by the satellites. Internal clock correction is provided for each satellite clock.

Each GPS satellite transmits two spread spectrum, L-band carrier signals: an L1 signal having a frequency $f_1=1575.42$ MHz and an L2 signal having a frequency $f_2=1227.6$ MHz. These two frequencies are integral multiples $f_1=154 f_0$ and $f_2=120 f_0$ of a base frequency $f_0=10.23$ MHz. The L1 signal from each satellite is binary phase shift key (BPSK) modulated by two pseudo-random noise (PRN) codes in phase quadrature, designated as the C/A-code and P-code. The L2 signal from each satellite is BPSK modulated by only the P-code. The nature of these PRN codes is described below.

One motivation for use of two carrier signals L1 and L2 is to allow partial compensation for propagation delay of such a signal through the ionosphere, which delay varies approximately as the inverse square of signal frequency f (delay $\propto f^{-2}$). This phenomenon is discussed by MacDoran in U.S. Pat. No. 4,463,357, which discussion is incorporated by reference herein. When transit time delay through the ionosphere is determined, a phase delay associated with a given carrier signal can be determined.

Use of the PRN codes allows use of a plurality of GPS satellite signals for determining an observer's position and for providing navigation information. A signal transmitted by a particular GPS signal is selected by generating and matching, or correlating, the PRN code for that particular satellite. All PRN codes are known and are generated or stored in GPS satellite signal receivers carried by ground observers. A first PRN code for each GPS satellite, sometimes referred to as a precision code or P-code, is a relatively long, fine-grained code having an associated clock or chip rate of $f_0=10.23$ MHz. A second PRN code for each GPS satellite, sometimes referred to as a clear/acquisition code or C/A-code, is intended to facilitate rapid satellite signal acquisition and hand-over to the P-code and is a relatively short, coarser-grained code having a clock or chip rate of 0.1 $f_0=1.023$ MHz. The C/A-code for any GPS satellite has a length of 1023 chips or time increments before this code repeats. The full P-code has a length of 259 days, with each satellite transmitting a unique portion of the full P-code. The portion of P-code used for a given GPS satellite has a length of precisely one week (7,000 days) before this code portion repeats. Accepted methods for generating the C/A-code and P-code are set forth in the document GPS Interface Control

Document ICD-GPS-200, published for the U.S. Government by Rockwell International Corporation, Satellite Systems Division, Revision B, Jul. 3, 1991, which is incorporated by reference herein.

The GPS satellite bit stream includes navigational information on the ephemeris of the transmitting GPS satellite and an almanac for all GPS satellites, with parameters providing corrections for ionospheric signal propagation delays suitable for single frequency receivers and for an offset time between satellite clock time and true GPS time. The navigational information is transmitted at a rate of 50 Baud. A useful discussion of the GPS and techniques for obtaining position information from the satellite signals is found in Tom Logsdon, op. cit.

A second configuration for global positioning is the Global Orbiting Navigation Satellite System (GLONASS), placed in orbit by the former Soviet Union and now maintained by the Russian Republic. GLONASS also uses 24 satellites, distributed approximately uniformly in three orbital planes of eight satellites each. Each orbital plane has a nominal inclination of 64.8° relative to the equator, and the three orbital planes are separated from each other by multiples of 120° longitude. The GLONASS circular orbits have smaller radii, about 25,510 kilometers, and a satellite period of revolution of $\frac{1}{7}$ of a sidereal day (11.26 hours). A GLONASS satellite and a GPS satellite will thus complete 17 and 16 revolutions, respectively, around the Earth every 8 days. The GLONASS system uses two carrier signals L1 and L2 with frequencies of $f_1=(1.602+9k/16)$ GHz and $f_2=(1.246+7k/16)$ GHz, where $k=(0, 1, 2, \dots, 23)$ is the channel or satellite number. These frequencies lie in two bands at 1.597–1.617 GHz (L1) and 1,240–1,260 GHz (L2). The L1' code is modulated by a C/A-code (chip rate=0.511 MHz) and by a P-code (chip rate=5.11 MHz). The L2' code is presently modulated only by the P-code. The GLONASS satellites also transmit navigational data at a rate of 50 Baud. Because the channel frequencies are distinguishable from each other, the P-code is the same, and the C/A-code is the same, for each satellite. The methods for receiving and analyzing the GLONASS signals are similar to the methods used for the GPS signals.

Reference to a Satellite Positioning System or SATPS herein refers to a Global Positioning System, to a Global Orbiting Navigation System, and to any other compatible satellite-based system that provides information by which an observer's position and the time of observation can be determined, all of which meet the requirements of the present invention.

A Satellite Positioning System (SATPS), such as the Global Positioning System (GPS), the Global Orbiting Navigation Satellite System (GLONASS) or ORBCOM, uses transmission of coded radio signals, with the structure described above, from a plurality of Earth-orbiting satellites. A single passive receiver of such signals is capable of determining receiver absolute position in an Earth-centered, Earth-fixed coordinate reference system utilized by the SATPS.

A configuration of two or more receivers can be used to accurately determine the relative positions between the receivers or stations. This method, known as differential positioning, is far more accurate than absolute positioning, provided that the distances between these stations are substantially less than the distances from these stations to the satellites, which is the usual case. Differential positioning can be used for survey or construction work in the field, providing location coordinates and distances that are accurate to within a few centimeters.

In differential position determination, many of the errors in the SATPS that compromise the accuracy of absolute position determination are similar in magnitude for stations that are physically close. The effect of these errors on the accuracy of differential position determination is therefore substantially reduced by a process of partial error cancellation.

What is claimed is:

1. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:

- (1) designating a site, having a connected and closed curve or surface of arbitrary shape as a site boundary, as a permitted site;
- (2) permitting an MP to move on the permitted site;
- (3) receiving location determination (LD) signals at an LD unit attached to the MP that allow determination of the present location of the MP;
- (4) determining the present location of the MP, using the LD unit;
- (5) when the MP is not on the permitted site at one or more of the location determination times, transmitting an alarm signal number 1;
- (6) providing a signal generator that is attached to the MP's body and that, when activated, transmits a distinguishable electromagnetic signal;
- (7) providing the MP with a motion sensor that, when the sensor is substantially motionless, issues a stationarity signal;
- (8) when the MP is on the permitted site:
 - (8A) determining whether the LD unit is receiving LD signals;
 - (8B) when the LD unit is receiving LD signals, returning to step (4), and when the LD unit is not receiving LD signals, proceeding to step (8C);
 - (8C) issuing an advisory signal number 1 and causing a first timer to begin a countdown from an initial time $\Delta t1 = \Delta t1, \max$;
 - (8D) determining whether the motion sensor is issuing a stationarity signal;
 - (8E) when the first timer reaches the maximum accumulated time $\Delta t1 = \Delta t1, \max$ and the motion sensor has not yet begun issuing a stationarity signal, transmitting an alarm signal number 2 and returning to step (8A);
 - (8F) when the motion sensor begins issuing a stationarity signal before the first timer reaches the maximum accumulated time $\Delta t1 = \Delta t1, \max$ deactivating the LD unit, deactivating the first timer, resetting the first timer accumulated time to $\Delta t1 = 0$, activating the signal generator and causing the signal generator to transmit a distinguishable signal;
 - (8G) providing a signal sensor, positioned at a selected location, that receives the distinguishable signal from the activated signal generator and that assigns a range attribute value A, having a real number value, to the received signal that is an approximate measure of the distance between the signal generator and the signal sensor;
 - (8H) determining whether the range attribute value A for the distinguishable signal, received from the signal generator, is less than a selected range attribute threshold value A_{thr} , at a sequence of at least two times;
 - (8I) when $A \geq A_{thr}$, continuing to compare the range attribute value A with the threshold value A_{thr} and

- (8J) when $A < A_{thr}$,
 - (8J-1) transmitting an advisory signal number 2 and causing a second timer to begin a second countdown from a time $\Delta t2 = 0$ to a second selected maximum accumulated countdown time of $\Delta t2 = \Delta t2, \max$;
 - (8J-2) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ continuing to compare the range attribute value A with the threshold value A_{thr} ;
 - (8J-3) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ transmitting an alarm signal number 3, returning to step (8H);
 - (8J-4) when the second countdown has begun and the motion sensor is not issuing a stationarity signal, deactivating the second timer and resetting the second timer accumulated time to $\Delta t2 = 0$;
 - (8J-5) when the second countdown has begun and the motion sensor is not issuing a stationarity signal, activating the LD unit and causing a third timer to begin a countdown from an initial time $\Delta t3 = 0$ to a third selected maximum accumulated countdown time $\Delta t3 = \Delta t3, \max$;
 - (8J-6) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$ determining if the LD unit has acquired LD signals;
 - (8J-7) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$ and the LD unit has acquired LD signals, initializing and deactivating the third timer and returning to step (8A);
 - (8J-8) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$, and the LD unit has not acquired LD signals, returning to step (8J-6); and
 - (8J-9) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$ and the LD unit has not acquired LD signals, deactivating and initializing the third time counter, transmitting an alarm signal number 4 and returning to step (8A).
2. The method of claim 1, further comprising the step of providing locking means for locking at least one of said LD unit and said signal generator to the body of said MP so that at least one of said LD unit and said signal generator cannot be removed or disabled except by a special means for removal of at least one of said LD unit and of said signal generator.
3. The method of claim 1, further comprising the step of choosing LD signal sources from the class of sources consisting of Global Positioning System (GPS), Global Navigational Satellite System (GLONASS), ORBCOM, Loran, Omega, Decca, Tacan, JTIDS ReInav and Personal Location Reporting System (PLRS).
4. The method of claim 1, further comprising the steps of:
 - selecting an exclusion site, spaced apart from said permitted site, onto which said MP is not permitted to go; and
 - when said MP is on the exclusion site at one or more of the location determination times, transmitting an alarm signal number 5.
5. The method of claim 4, further comprising the step of causing said LD unit to deliver to said MP's body a chemical that temporarily disables said MP, when said present location of said LD unit is determined to be within said exclusion site.

6. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:

- (1) designating a site, having a connected and closed curve or surface of arbitrary shape as a site boundary, as a permitted site;
- (2) permitting an MP to move on the permitted site;
- (3) receiving location determination (LD) signals at an LD signal receiver unit attached to the MP that allow determination of the present location of the MP;
- (4) determining the present location of the MP, using the LD unit;
- (5) when the MP is not on the permitted site at one or more of the location determination times, transmitting an alarm signal number 1;
- (6) providing a signal generator that is attached to the MP's body and that, when activated, transmits a distinguishable electromagnetic signal;
- (7) providing the MP with a motion sensor that, when the sensor is substantially motionless, issues a stationarity signal;
- (8) when the MP is on the permitted site:
 - (8A) determining whether the LD unit is receiving LD signals;
 - (8B) when the LD unit is receiving LD signals, returning to step (4), and when the LD unit is not receiving LD signals, proceeding to step (8C);
 - (8C) issuing an advisory signal number 1 and causing a first timer to begin a countdown from an initial time $\Delta t1 = \Delta t1, \max$;
 - (8D) determining whether the motion sensor is issuing a stationarity signal;
 - (8E) when the first timer reaches the maximum accumulated time $\Delta t1 = \Delta t1, \max$ and the motion sensor has not yet begun issuing a stationarity signal, transmitting an alarm signal number 2 and returning to step (8A);
 - (8F) when the motion sensor begins issuing a stationarity signal before the first timer reaches the maximum accumulated time $\Delta t1 = \Delta t1, \max$ deactivating the LD unit, deactivating the first timer, resetting the first timer accumulated time to $\Delta t1 = 0$, activating the signal generator and causing the signal generator to transmit a distinguishable signal;
 - (8G) providing a signal sensor, positioned at a selected location, that receives the distinguishable signal from the activated signal generator and that assigns a range attribute value A, having a real number value, to the received signal that is an approximate measure of the distance between the signal generator and the signal sensor;
 - (8H) determining whether the range attribute value A for the distinguishable signal, received from the signal generator, is less than a selected range attribute threshold value A_{thr} , at a sequence of at least two times;
 - (8I) when $A \geq A_{thr}$, continuing to compare the range attribute value A with the threshold value A_{thr} ; and
 - (8J) when $A < A_{thr}$:
 - (8J-1) transmitting an advisory signal number 2 and causing a second timer to begin a second countdown from a time $\Delta t2 = 0$ to a second selected maximum accumulated countdown time of $\Delta t2 = \Delta t2, \max$;
 - (8J-2) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and

$\Delta t2 < \Delta t2, \max$ continuing to compare the range attribute value A with the threshold value A_{thr} ;

- (8J-3) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ transmitting an alarm number 3, returning to step (8H);
- (8J-4) when the second countdown has begun and the motion sensor is not issuing a stationarity signal, deactivating the second timer and resetting the second timer accumulated time to $\Delta t2 = 0$;
- (8J-5) when the second countdown has begun and the motion sensor is not issuing a stationarity signal, activating the LD unit and causing a third timer to begin a countdown from an initial time $\Delta t3 = 0$ to a third selected maximum accumulated countdown time $\Delta t3 = \Delta t3, \max$;
- (8J-6) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$ determining if the LD unit has acquired LD signals;
- (8J-7) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$, and the LD unit has acquired LD signals, initializing and deactivating the third timer and returning to step (8A);
- (8J-8) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$, and the LD unit has not acquired LD signals, returning to step (8J-6); and
- (8J-9) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $\Delta t3 \leq \Delta t3, \max$ and the LD unit has not acquired LD signals, deactivating and initializing the third time counter, transmitting an alarm signal 4 and returning to step (8A).

7. The method of claim 6, further comprising the step of providing locking means for locking at least one of said LD unit and said signal sensor to the body of said MP so that at least one of said LD unit and said signal sensor cannot be removed or disabled except by a special means for removal of at least one of said LD unit and of said signal sensor.

8. The method of claim 6, further comprising the step of choosing LD signal sources from the class of sources consisting of Global Positioning System (GPS), Global Navigational Satellite System (GLONASS), ORBCOM, Loran, Omega, Decca, Tacan, JTIDS Relnav and Personal Location Reporting System (PLRS).

9. The method of claim 6, further comprising the steps of: selecting an exclusion site, spaced apart from said permitted site, onto which said MP is not permitted to go; and

when said MP is on the exclusion site at one or more of the location determination times, transmitting an alarm signal number 5.

10. The method of claim 9, further comprising the step of causing said LD unit to deliver to said MP's body a chemical that temporarily disables said MP, when said present location of said LD unit is determined to be within said exclusion site.

11. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:

- (1) designating a site, having a connected and closed curve or surface of arbitrary shape as a site boundary, as a permitted site;
- (2) permitting an MP to move on the permitted site;
- (3) receiving location determination (LD) signals at an LD unit attached to the MP that allow determination of the present location of the MP;

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- (4) determining the present location of the MP, using the LD unit;
- (5) when the MP is not on the permitted site at one or more of the location determination times, transmitting an alarm signal number 1;
- (6) providing a signal generator that is attached to the MP's body and that, when activated, transmits a distinguishable electromagnetic signal;
- (7) providing the MP with a motion sensor that, when the sensor is substantially motionless, issues a stationarity signal;
- (8) providing the motion sensor with a motion counter having an initial value $m=1$ and having a selected maximum value $m=m_{max} \geq 1$;
- (9) setting the motion counter value $m=1$; and
- (10) when the MP is on the permitted site:
 - (10A) determining whether the LD unit is receiving LD signals;
 - (10B) when the LD unit is receiving LD signals, returning to step (3), and when the LD unit is not receiving LD signals, proceeding to step (10C);
 - (10C) issuing an advisory signal number 1 and causing a first timer to begin a countdown from an initial time $\Delta t1=\Delta t1, \max$;
 - (10D) determining whether the motion sensor is issuing a stationarity signal;
 - (10E) when the first timer reaches the maximum accumulated time $\Delta t1=\Delta t1, \max$ and the motion sensor has not yet begun issuing a stationarity signal, transmitting an alarm signal number 2 and returning to step (8A);
 - (10F) when the motion sensor begins issuing a stationarity signal before the first timer reaches the maximum accumulated time $\Delta t1=\Delta t1, \max$, deactivating the LD unit, deactivating the first timer, resetting the first timer accumulated time to $\Delta t1=0$, activating the signal generator and causing the signal generator to transmit a distinguishable signal;
 - (10G) providing a signal sensor, positioned at a selected location, that receives the distinguishable signal from the activated signal generator and that assigns a range attribute value A, having a real number value, to the received signal that is an approximate measure of the distance between the signal generator and the signal sensor;
 - (10H) determining whether the range attribute value A for the distinguishable signal, received from the signal generator, is less than a selected range attribute threshold value A_{thr} at a sequence of at least two times;
 - (10I) when $A \geq A_{thr}$, continuing to compare the range attribute value A with the threshold value A_{thr} ; and
 - (10J) when $A < A_{thr}$:
 - (10J-1) transmitting an advisory signal number 2 and causing a second timer to begin a second countdown from a time $\Delta t2=0$ to a second selected maximum accumulated countdown time of $\Delta t2=\Delta t2, \max$;
 - (10J-2) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ continuing to compare the range attribute value A with the threshold value A_{thr} ;
 - (10J-3) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ transmitting an alarm signal number 3, returning to step (10H);

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- (10J-4) when the second countdown has begun and the motion sensor is not issuing a stationarity signal, deactivating the second timer, resetting the second timer accumulated time to $\Delta t2=0$, replacing the motion counter value m by an incremented value $m+1$ and determining if the incremented value satisfies $m > m_{max}$;
 - (10J-5) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $m \leq m_{max}$; returning to step (10A);
 - (10J-6) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $m > m_{max}$, determining if a new monitoring interval has begun;
 - (10J-7) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$ and a new monitoring interval has begun, resetting the motion counter to $m=1$, and proceeding to step (10J-9);
 - (10J-8) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$ and a new monitoring interval has not begun, proceeding to step (10J-9);
 - (10J-9) activating the LD unit and causing a third timer to begin a countdown from an initial time $\Delta t3=0$ to a third selected maximum accumulated countdown time $\Delta t3=\Delta t3, \max$;
 - (10J-10) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun and $\Delta t3 \leq \Delta t3, \max$ determining if the LD unit has acquired LD signals;
 - (10J-11) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, $\Delta t3 \leq \Delta t3, \max$ and the LD unit has acquired LD signals, initializing and deactivating the third timer and returning to step (10A);
 - (10J-12) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, $\Delta t3 \leq \Delta t3, \max$ and the LD unit has not acquired LD signals, returning to step (10J-10); and
 - (10J-13) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, $\Delta t3 \leq \Delta t3, \max$ and the LD unit has not acquired LD signals, deactivating and initializing the third time counter, transmitting an alarm signal number 4 and returning to step (10A).
12. The method of claim 11, further comprising the step of providing locking means for locking at least one of said LD unit and said signal generator to the body of said MP so that at least one of said LD unit and said signal generator cannot be removed or disabled except by a special means for removal of at least one of said LD unit and of said signal generator.
 13. The method of claim 11, further comprising the step of choosing LD signal sources from the class of sources consisting of Global Positioning System (GPS), Global Navigational Satellite System (GLONASS), ORBCOM, Loran, Omega, Decca, Tacan, JTIDS ReInav and Personal Location Reporting System (PLRS).
 14. The method of claim 11, further comprising the steps of:
 - selecting an exclusion site, spaced apart from said permitted site, onto which said MP is not permitted to go; and

when said MP is on the exclusion site at one or more of the location determination times, transmitting an alarm signal number 5.

15. The method of claim 14, further comprising the step of causing said LD unit to deliver to said MP's body a chemical that temporarily disables said MP, when said present location of said LD unit is determined to be within said exclusion site.

16. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:

- (1) designating a site, having a connected and closed curve or surface of arbitrary shape as a site boundary, as a permitted site;
- (2) permitting an MP to move on the permitted site;
- (3) receiving location determination (LD) signals at an LD unit attached to the MP that allow determination of the present location of the MP;
- (4) determining the present location of the MP, using the LD unit;
- (5) when the MP is not on the permitted site at one or more of the location determination times, transmitting an alarm signal number 1;
- (6) providing a signal generator that is attached to the MP's body and that, when activated, transmits a distinguishable electromagnetic signal;
- (7) providing the MP with a motion sensor that, when the sensor is substantially motionless, issues a stationarity signal;
- (8) providing the motion sensor with a motion counter having an initial value $m=1$ and having a selected maximum value $m=m_{max} \leq 1$;
- (9) setting the motion counter value $m=1$; and
- (10) when the MP is on the permitted site:
 - (10A) determining whether the LD unit is receiving LD signals;
 - (10B) when the LD unit is receiving LD signals, returning to step (3), and when the LD unit is not receiving LD signals, proceeding to step (10C);
 - (10C) issuing an advisory signal number 1 and causing a first timer to begin a countdown from an initial time $\Delta t1=\Delta t1, \max$;
 - (10D) determining whether the motion sensor is issuing a stationarity signal;
 - (10E) when the first timer reaches the maximum accumulated time $\Delta t1=\Delta t1, \max$ and the motion sensor has not yet begun issuing a stationarity signal, transmitting an alarm signal number 2 and returning to step (10A);
 - (10F) when the motion sensor begins issuing a stationarity signal before the first timer reaches the maximum accumulated time $\Delta t1=\Delta t1, \max$ deactivating the LD unit, deactivating the first timer, resetting the first timer accumulated time to $\Delta t1=0$, and activating the signal generator and causing the signal generator to transmit a distinguishable signal;
 - (10G) providing a signal sensor, attached to the MP's body, that receives the distinguishable signal from the activated signal generator and that assigns a range attribute value A , having a real number value, to the received signal that is an approximate measure of the distance between the signal generator and the signal sensor;
 - (10H) determining whether the range attribute value A for the distinguishable signal, received from the

signal generator, is less than a selected range attribute threshold value A_{thr} at a sequence of at least two times;

(10I) when $A \geq A_{thr}$, continuing to compare the range attribute value A with the threshold value A_{thr} ; and

(10J) when $A < A_{thr}$:

(10J-1) transmitting an advisory signal number 2 and causing a second timer to begin a second countdown from a time $\Delta t2=0$ to a second selected maximum accumulated countdown time of $\Delta t2=\Delta t2, \max$;

(10J-2) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ continuing to compare the range attribute value A with the threshold value A_{thr} ;

(10J-3) when the second countdown has begun, the motion sensor is issuing a stationarity signal, and $\Delta t2 < \Delta t2, \max$ transmitting an alarm signal number 3, returning to step (10H);

(10J-4) when the second countdown has begun and the motion sensor is not issuing a stationarity signal, deactivating the second timer, resetting the second timer accumulated time to $\Delta t2=0$, replacing the motion counter value m by an incremented value $m+1$ and determining if the incremented value satisfies $m > m_{max}$;

(10J-5) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $m \leq m_{max}$; returning to step (10A);

(10J-6) when the second countdown has begun, the motion sensor is not issuing a stationarity signal and $m > m_{max}$, determining if a new monitoring interval has begun;

(10J-7) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$ and a new monitoring interval has begun, resetting the motion counter to $m=1$, and proceeding to step (10J-9);

(10J-8) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$ and a new monitoring interval has not begun, proceeding to step (10J-9);

(10J-9) activating the LD unit and causing a third timer to begin a countdown from an initial time $\Delta t3=0$ to a third selected maximum accumulated countdown time $\Delta t3=\Delta t3, \max$;

(10J-10) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, and $\Delta t3 \leq \Delta t3, \max$ determining if the LD unit has acquired LD signals;

(10J-11) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, $\Delta t3 \leq \Delta t3, \max$ and the LD unit has acquired LD signals, initializing and deactivating the third timer and returning to step (10A);

(10J-12) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, $\Delta t3 \leq \Delta t3, \max$ and the LD unit has not acquired LD signals, returning to step (10J-10); and

(10J-13) when the second countdown has begun, the motion sensor is not issuing a stationarity signal, $m > m_{max}$, a new monitoring interval has not begun, $\Delta t3 \leq \Delta t3, \max$ and the LD unit has not acquired LD signals, deactivating and initializing the third

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time counter, transmitting an alarm signal number 4 and returning to step (10A).

17. The method of claim 16, further comprising the step of providing locking means for locking at least one of said LD unit and said signal sensor to the body of said MP so that at least one of said LD unit and said signal sensor cannot be removed or disabled except by a special means for removal of at least one of said LD unit and of said signal sensor.

18. The method of claim 16, further comprising the step of choosing LD signal sources from the class of sources consisting of Global Positioning System (GPS), Global Navigational Satellite System (GLONASS), ORBCOM, Loran, Omega, Decca, Tacan, JTIDS ReInav and Personal Location Reporting System (PLRS).

19. The method of claim 16, further comprising the steps of:

selecting an exclusion site, spaced apart from said permitted site, onto which said MP is not permitted to go; and

when said MP is on the exclusion site at one or more of the location determination times, transmitting an alarm signal number 5.

20. The method of claim 19, further comprising the step of causing said LD unit to deliver to said MP's body a chemical that temporarily disables said MP, when said present location of said LD unit is determined to be within said exclusion site.

21. The method of claim 1, further comprising the steps of:

(9) designating a second site, having a connected and closed curve or surface of arbitrary shape as a site boundary and being spaced apart from said first permitted site, as a second permitted site;

(10) selecting a corridor that extends between and is connected to the first site and the second site, where the combined region consisting of said first permitted site, the second permitted site and the corridor has a closed continuous curve of arbitrary shape as a combined region boundary;

(11) redefining, for a first selected time interval, the permitted site to include said first permitted site, the second permitted site and the corridor; and

redefining, for a second selected time interval the permitted site to include at least one of said first permitted site and the second permitted site.

22. The method of claim 6, further comprising the steps of:

(9) designating a second site, having a connected and closed curve or surface of arbitrary shape as a site boundary and being spaced apart from said first permitted site, as a second permitted site;

(10) selecting a corridor that extends between and is connected to the first site and the second site, where the combined region consisting of said first permitted site, the second permitted site and the corridor has a closed continuous curve of arbitrary shape as a combined region boundary;

(11) redefining, for a first selected time interval, the permitted site to include said first permitted site, the second permitted site and the corridor; and

redefining, for a second selected time interval the permitted site to include at least one of said first permitted site and the second permitted site.

23. The method of claim 11, further comprising the steps of:

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(11) designating a second site, having a connected and closed curve or surface of arbitrary shape as a site boundary and being spaced apart from said first permitted site, as a second permitted site;

(12) selecting a corridor that extends between and is connected to the first site and the second site, where the combined region consisting of said first permitted site, the second permitted site and the corridor has a closed continuous curve of arbitrary shape as a combined region boundary;

(13) redefining, for a first selected time interval, the permitted site to include said first permitted site, the second permitted site and the corridor; and

redefining, for a second selected time interval the permitted site to include at least one of said first permitted site and the second permitted site.

24. The method of claim 16, further comprising the steps of:

(11) designating a second site, having a connected and closed curve or surface of arbitrary shape as a site boundary and being spaced apart from said first permitted site, as a second permitted site;

(12) selecting a corridor that extends between and is connected to the first site and the second site, where the combined region consisting of said first permitted site, the second permitted site and the corridor has a closed continuous curve of arbitrary shape as a combined region boundary;

(13) redefining, for a first selected time interval, the permitted site to include said first permitted site, the second permitted site and the corridor; and

redefining, for a second selected time interval the permitted site to include at least one of said first permitted site and the second permitted site.

25. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:

(1) receiving location determination (LD) signals at an LD unit attached to an MP who moves on a selected permitted site, and determining the present location of the MP, using the LD unit, at one or more selected LD times;

(2) when the MP's location is not on the permitted site at each of a selected number N of consecutive LD times, transmitting a first alarm signal;

(3) attaching to the MP's body a motion sensor that senses when the sensor is in motion;

(4) when the MP's last location was on the permitted site and the LD unit does not receive LD signals adequate for determining the MP's present location, determining whether the motion sensor senses motion; and

(5) when (i) the motion sensor senses motion and (ii) the LD unit does not receive LD signals, determining a first accumulated time during which the two conditions (i) and (ii) both occur, and issuing a second alarm signal when the first accumulated time reaches a selected maximum accumulated time $\Delta t1_{max}$;

(6) when said motion sensor becomes substantially motionless before said first accumulated time reaches said time $\Delta t1_{max}$, resetting said first accumulated time to a selected initial value and causing a signal generator, attached to the MP's body to transmit a distinguishable signal;

(7) receiving the distinguishable signal at a signal sensor, positioned at a selected location, and comparing an attribute for this signal with a selected attribute threshold value;

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- (8) when the signal attribute is not greater than the threshold value, returning to step (7);
- (9) when the signal attribute is at least equal to the threshold value determining a second accumulated time during which the signal attribute is at least equal to the threshold value;
- (10) When the second accumulated time reaches a second selected maximum accumulated time $\Delta t_{2, \max}$, max issuing a third alarm signal; and
- (11) when said attribute value becomes less than said attribute threshold value before said second accumulated time reaches said time $\Delta t_{2, \max}$, max resetting said second accumulated time to zero.
26. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:
- (1) receiving location determination (LD) signals at an LD unit attached to an MP who moves on a selected permitted site, and determining the present location of the MP, using the LD unit;
 - (2) when the MP is not on the permitted site at one or more of the location determination times, transmitting a first alarm signal;
 - (3) providing the MP with a motion sensor that senses when the sensor is in motion and when the sensor is substantially motionless;
 - (4) when the MP is on the permitted site and the LD unit does not receive LD signals adequate for determining the MP's present location, determining whether the motion sensor senses motion;
 - (5) when (i) the motion sensor senses motion and (ii) the LD unit does not receive LD signals, determining a first accumulated time during which the two conditions (i) and (ii) both occur, and when the first accumulated time $\Delta t_{1, \max}$ issuing a second alarm signal;
 - (6) when the motion sensor becomes substantially motionless before the first accumulated time reaches the $\Delta t_{1, \max}$, resetting the first accumulated time to a selected initial value and causing a signal generator, attached to the MP's body to transmit a distinguishable signal;
 - (7) receiving the distinguishable signal at a signal sensor, positioned at a selected location, and estimating a distance between the signal generator and the signal sensor;
 - (8) when the estimated distance is no greater than a selected distance threshold value, returning to step (7);
 - (9) when the estimated distance is greater than the distance threshold value, determining a second accumulated time during which the estimated distance is greater than the distance threshold value;
 - (10) when the second accumulated time reaches a second selected maximum accumulated time $\Delta t_{1, \max}$, issuing a third alarm signal; and
 - (11) when the estimated distance becomes less than the distance threshold value before the second accumulated time reaches the time $\Delta t_{1, \max}$, resetting the second accumulated time to zero.
27. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:
- (1) receiving location determination (LD) signals at an LD unit attached to an MP that moves on a selected permitted site, and determining the present location of the MP, using the LD unit;

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- (2) when the MP is not on the permitted site at one or more of the location determination times, transmitting a first alarm signal;
 - (3) providing the MP with a motion sensor that senses when the sensor is in motion and when the sensor is substantially motionless;
 - (4) when the MP is on the permitted site and the LD unit does not receive LD signals for determining the MP's present location, determining whether the motion sensor senses motion;
 - (5) when (i) the motion sensor senses motion and (ii) the LD unit does not receive LD signals, determining a first accumulated time during which the conditions (i) and (ii) both occur, and when the first accumulated reaches a first selected maximum accumulated time $\Delta t_{1, \max}$ issuing a second alarm signal;
 - (6) when the motion sensor becomes substantially motionless before the first accumulated time reaches the $\Delta t_{1, \max}$, resetting the first accumulated time to a selected initial value and causing a signal generator, positioned at a selected location, to transmit a distinguishable signal;
 - (7) receiving the distinguishable signal at a signal sensor, attached to the MP's body, and estimating a distance between the signal generator and the signal sensor;
 - (8) when the estimated distance is no greater than a selected distance threshold value, returning to step (7);
 - (9) when the estimated distance is greater than the distance threshold value, determining a second accumulated time during which the estimated distance is greater than the distance threshold value;
 - (10) when the second accumulated time reaches a second selected maximum accumulated time $\Delta t_{2, \max}$, issuing a third alarm signal; and
 - (11) when the estimated distance becomes less than the distance threshold value before the second accumulated time reaches the time $\Delta t_{2, \max}$, resetting the second accumulated time to zero.
28. A method for monitoring the location of a monitored person (MP) with reference to a permitted site, the method comprising the steps of:
- (1) receiving location determination (LD) signals at an LD unit attached to an MP who moves on a selected permitted site, and determining the present location of the MP, using the LD unit, at one or more selected LD times;
 - (2) when the MP's location is not on the permitted site at each of a selected number N of consecutive LD times, transmitting a first alarm signal;
 - (3) attaching to the MP's body a motion sensor that senses when the sensor is in motion;
 - (4) when the MP's last location was on the permitted site and the LD unit does not receive LD signals adequate for determining the MP's present location, determining whether the motion sensor senses motion; and
 - (5) when (i) the motion sensor senses motion and (ii) the LD unit does not receive LD signals, determining a first accumulated time during which the two conditions (i) and (ii) both occur, and issuing a second alarm signal when the first accumulated time reaches a selected maximum accumulated time $\Delta t_{1, \max}$;
 - (6) when said motion sensor becomes substantially motionless before said first accumulated time reaches said time $\Delta t_{1, \max}$ resetting said first accumulated time

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to a selected initial value and causing a signal generator, positioned at a selected location, to transmit a distinguishable signal;

- (7) receiving the distinguishable signal at a signal sensor, positioned at a selected location, and comparing an attribute for this signal with a selected attribute threshold value;
- (8) when the signal attribute is not greater than the threshold value, returning to step (7);
- (9) when the signal attribute is at least equal to the threshold value, determining a second accumulated

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time during which the signal attribute is at least equal to the threshold value; and

- (10) When the second accumulated time reaches a second selected maximum accumulated time Δt_2 , max issuing a third alarm signal; and
- (11) when said attribute value becomes less than said attribute threshold value before said second accumulated time reaches said time Δt_2 , max resetting said second accumulated time to zero.

* * * * *



United States Patent [19]

Linguist et al.

[11] Patent Number: 5,517,690

[45] **Date of Patent:** May 14, 1996

- [54] ADAPTIVE CELLULAR PAGING SYSTEM
-
- WITH SELECTIVELY ACTIVATED CELLS

91/07022 5/1991 WIPO

OTHER PUBLICATIONS

- [75] Inventors: **Roger D. Linquist; Malcolm M. Lorang**, both of Dallas, Tex.

- [73] Assignee: Motorola, Inc., Schaumburg, Ill.

- [21] Appl. No.: 250,637

- [22] Filed: May 27, 1994

Related U.S. Application Data

- [63] Continuation of Ser. No. 661,078, Feb. 26, 1991, abandoned.

- [51] Int. Cl.⁶ H04B 7/26; H04Q 7/22;
H04Q 7/36

- [52] U.S. Cl. ~~455/33.1; 455/13.1; 455/33.4;~~
~~455/51.2; 455/56.1; 379/59~~

- [58] **Field of Search** 455/12.1, 13.1,
455/33.1, 33.4, 51.1, 51.2, 53.1, 54.1, 54.2,
56.1; 379/59, 63; 340/311.1, 825.44; 375/107,
356; 370/100.1, 104.1, 108

[56] **References Cited**

U.S. PATENT DOCUMENTS

H610	3/1989	Focarile et al .	
3,995,111	11/1976	Tsuiji et al .	
4,398,192	8/1983	Moore et al .	
4,745,599	5/1988	Raychaudhuri .	
4,747,120	5/1988	Foley .	
4,747,122	5/1988	Bhagat et al .	
4,829,554	5/1989	Barnes et al .	
4,918,437	4/1990	Jasinski et al .	
4,943,803	7/1990	Vrijkorte .	
4,968,966	11/1990	Jasinski et al .	
5,047,763	9/1991	Kuznicki et al .	
5,239,671	8/1993	Linquist et al .	455/51.2
5,263,177	11/1993	Schieve et al .	455/51.2
5,287,550	2/1994	Fennell et al .	455/51.2

FOREIGN PATENT DOCUMENTS

0167458	1/1986	European Pat. Off. .
0281150	9/1988	European Pat. Off. .
2438457A1	2/1976	Germany .
87/00994	2/1987	WIPO .

- Steven Ritter and J. McCoy, "Automatic Vehicle Location—An Overview," *IEEE Trans. on Veh. Tech.*, vol. VT-26, No. 1, Feb. 1977, pp. 7-9.

- M. Kihara, "Performance Aspects of Reference Clock Distribution for Evolving Digital Networks," *IEEE Communications Magazine*, Apr. 1989.

- "Unwanted Calls? Turn on Pager Phone," *USA Today*, Dec. 28, 1990, p. 8B.

- W. A. Gardner and C. K. Chen, "Interference-Tolerant Time-Difference of Arrival Estimation for Modulated Signals," *IEEE Trans. on Acous., Speech and Sig. Proc.*, vol. 36, No. 9, Sep. 1988, pp. 1385-1395.

- C. Cox, "Universal Digital Portable Radio Communications," *Proc. of IEEE*, vol. 75, No. 4, Apr. 1987, pp. 436-477.

- Telocator Bulletin, News and Analysis for the Mobile Communications Industry*, vol. 91, No. 3, Jun. 25, 1991.

- M. Kihira, "Performance Aspects of Reference Clock Distribution for Evolving Digital Networks," *IEEE Comm. Magazine*, Apr. 1989, pp. 24-34.

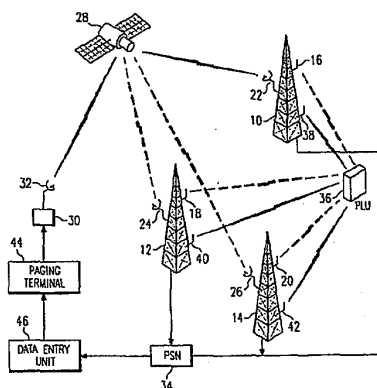
Primary Examiner—Chi H. Pham

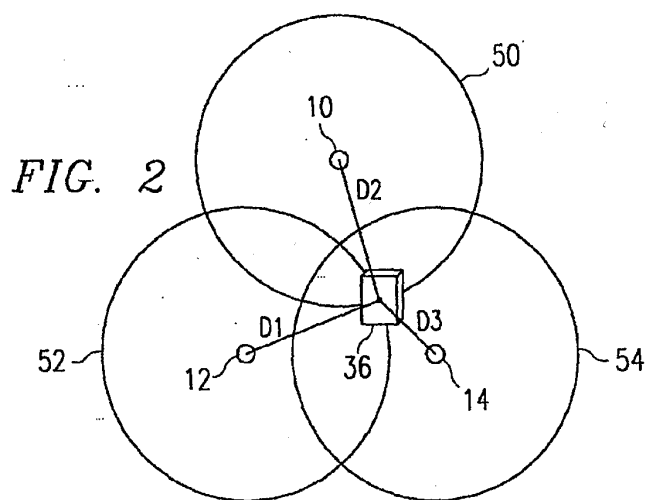
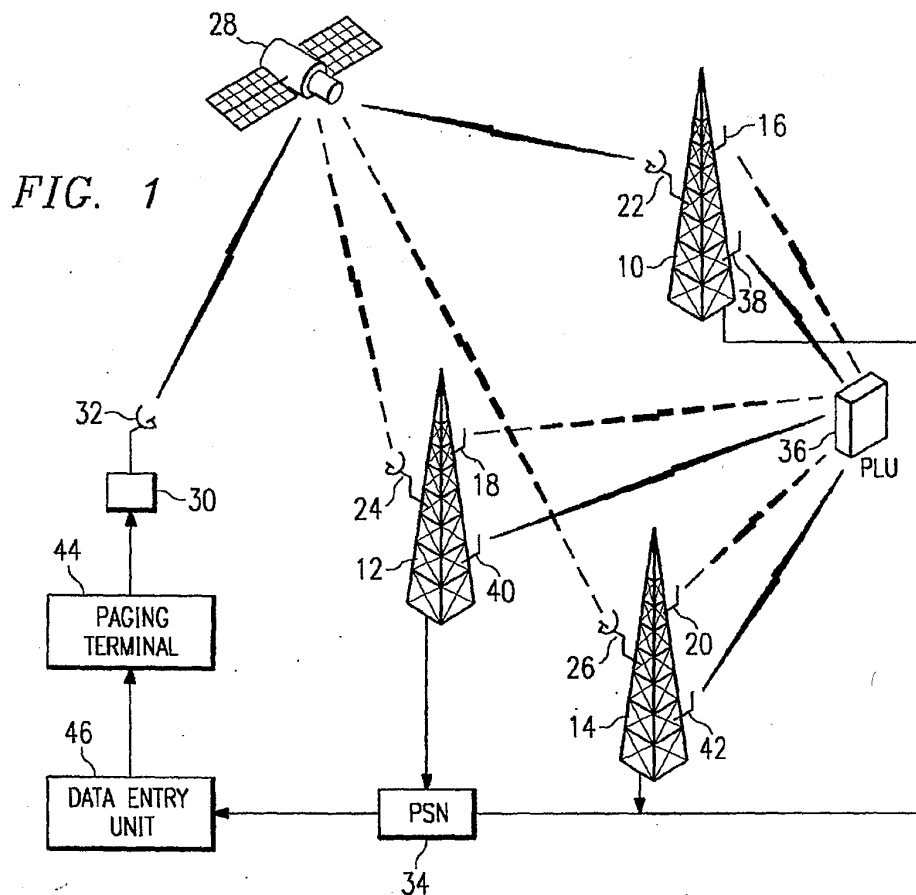
Attorney, Agent, or Firm—Pablo Meles

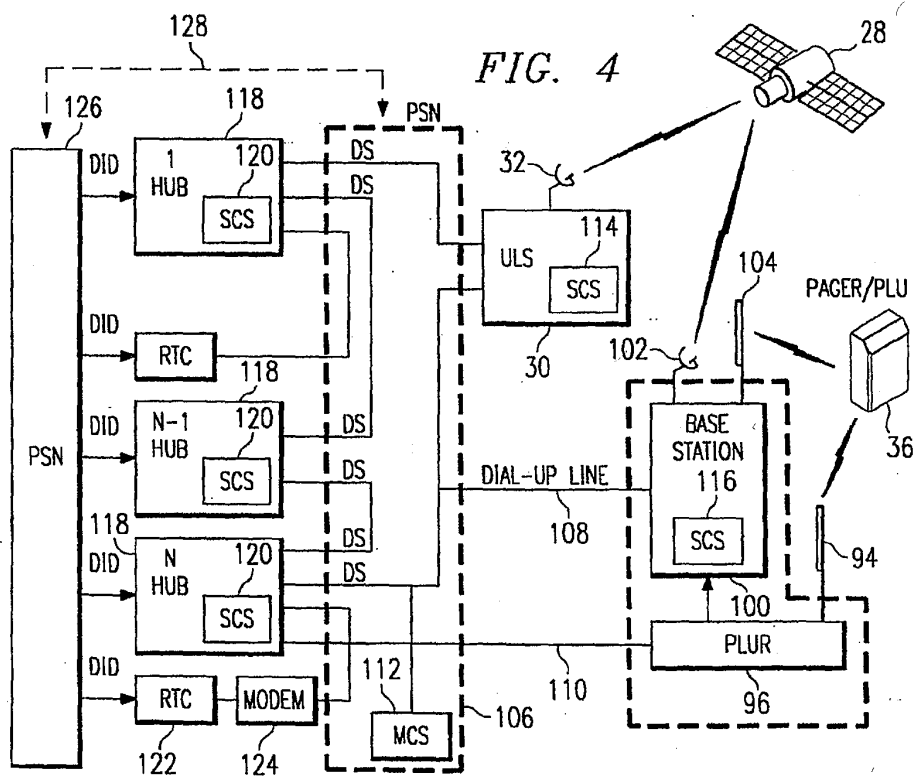
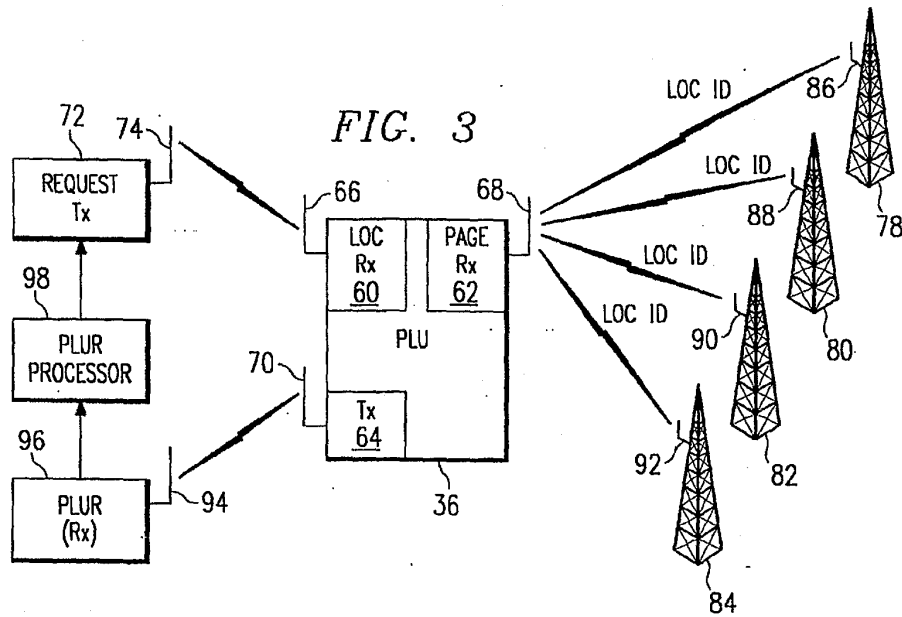
[57] **ABSTRACT**

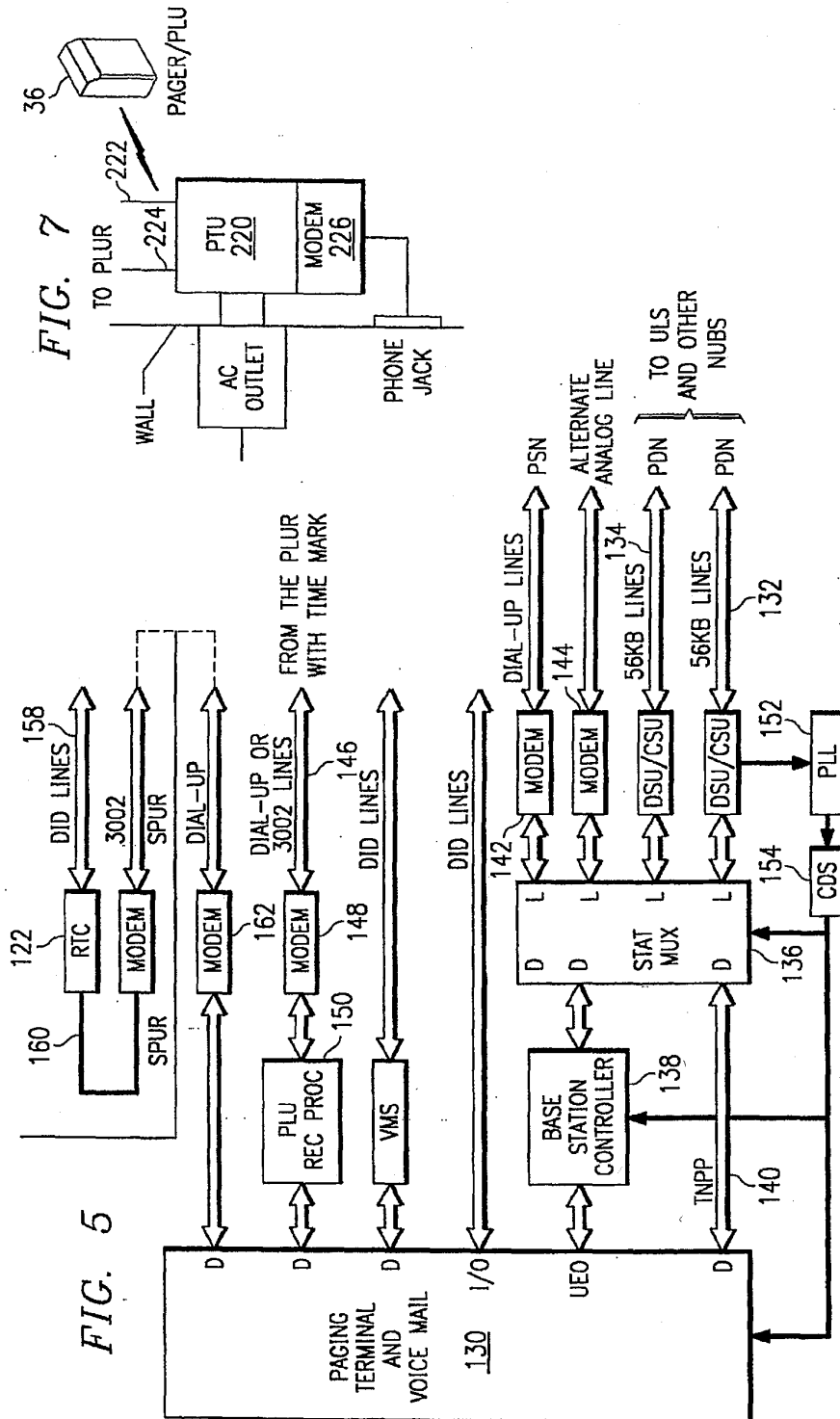
An adaptive paging system includes a paging terminal that is operable to receive paging signals and transmit them up to a satellite (28) and down through a downlink (312) to stick locations (314), (316), (318), (320) and (322). Each of the sticks (314)-(322) is associated with a given locale (324), (326), (328), (330) and (332). The sticks are operable in a simulcast mode and also in a cellular mode. In the cellular mode, each of the sticks (314)-(322) is operable to receive a separate message that is distinct from the other cells. Pagers (36), having a known location at any of the locales (324)-(332) can then be selectively addressed and data transferred thereto. To prevent interference between adjacent RF locales, adjacent cells are not turned on during transmission to select cells in the cellular mode. These can be turned on at a different time. Orthogonal coding can be utilized such that adjacent cells can be turned on, thus increasing throughput.

9 Claims, 9 Drawing Sheets









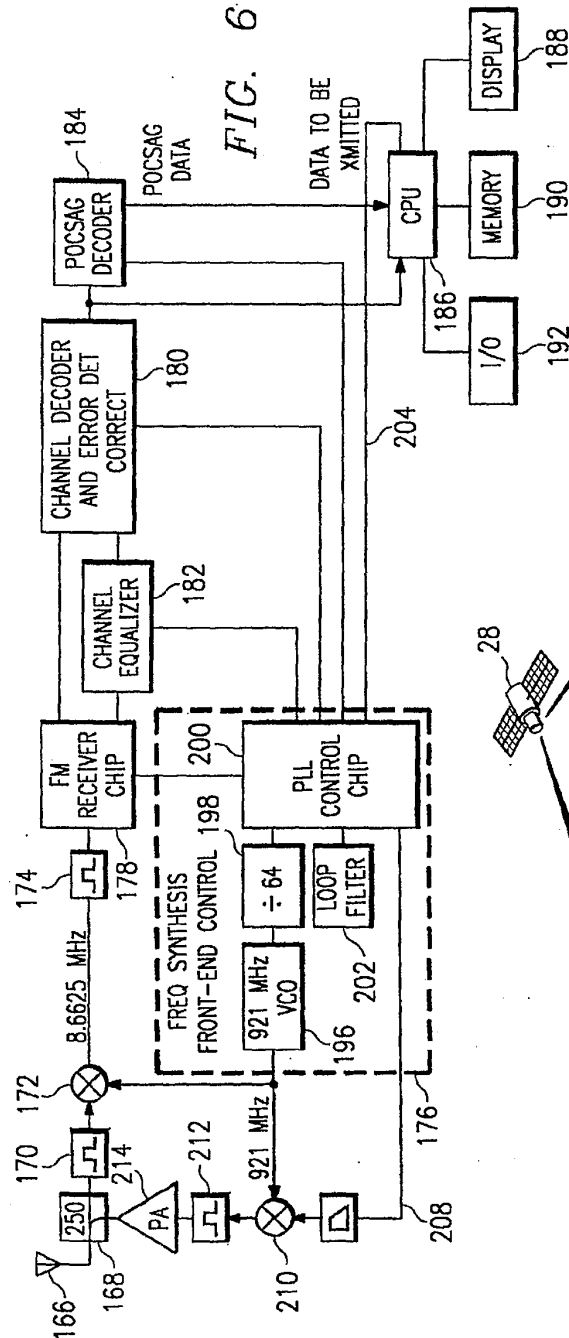


FIG. 6

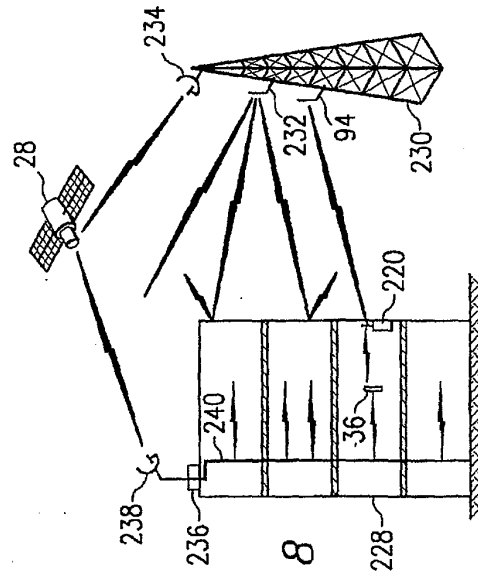


FIG. 8

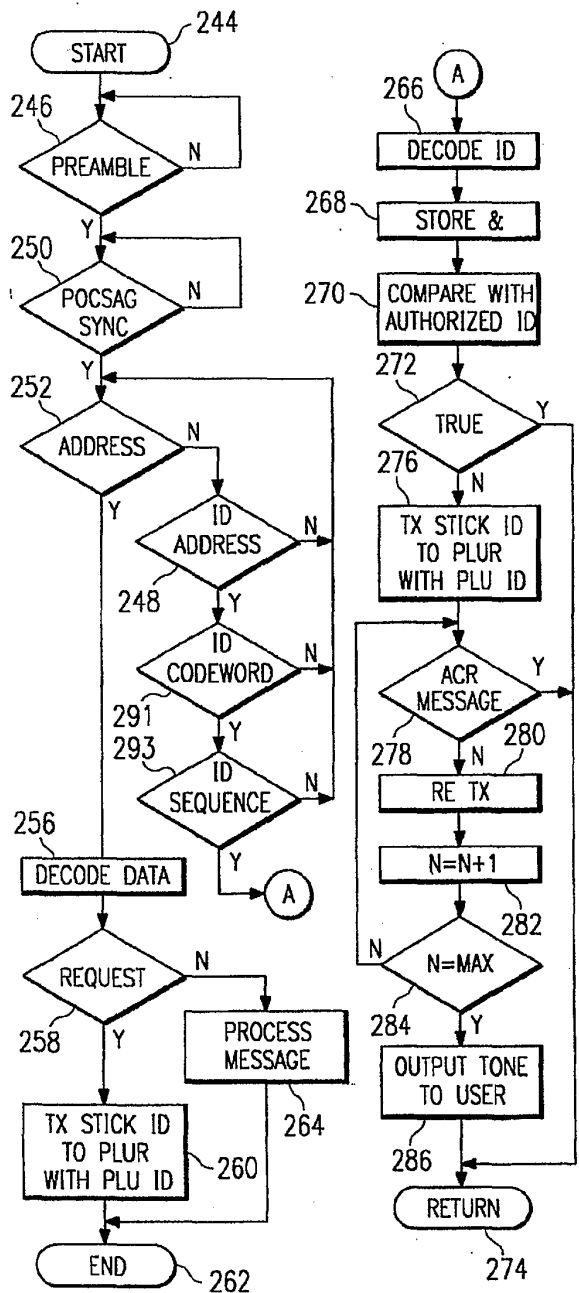


FIG. 9
PLU FLOW CHART

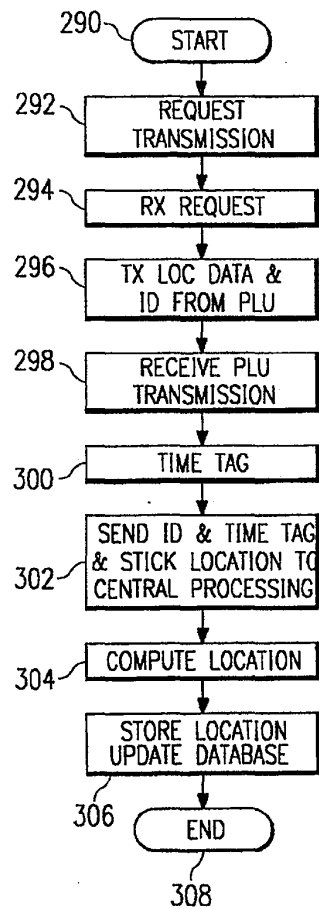
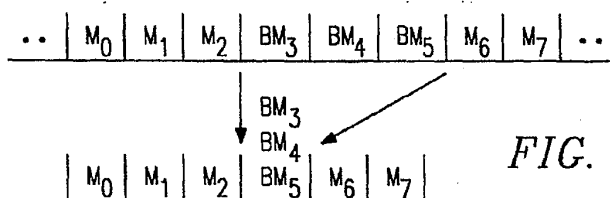
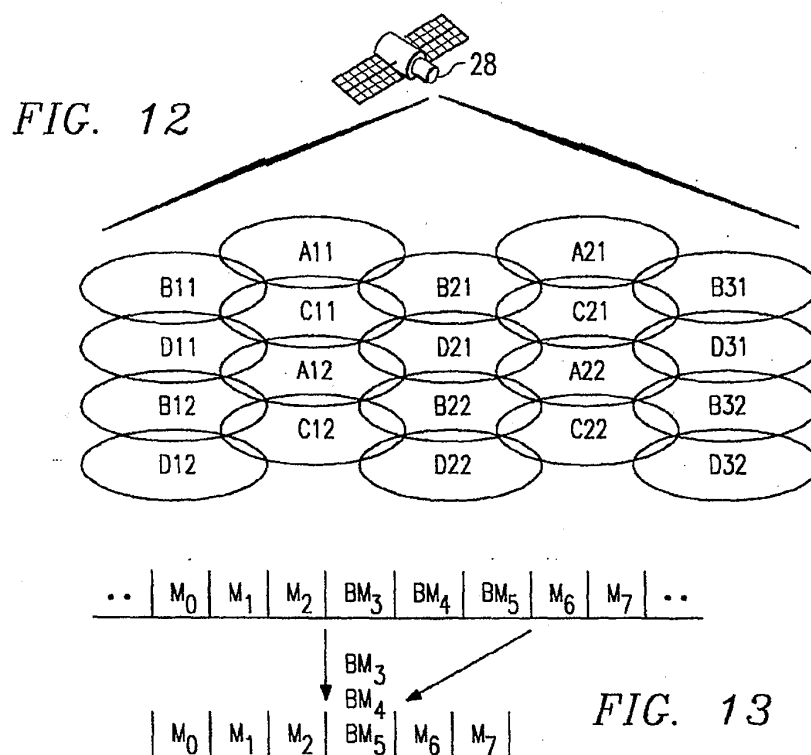
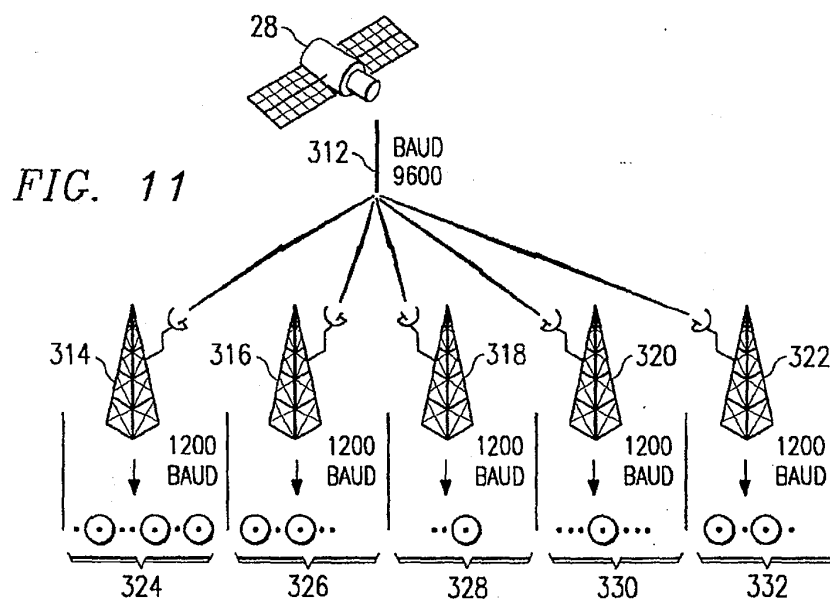


FIG. 10
TIME OF ARRIVAL



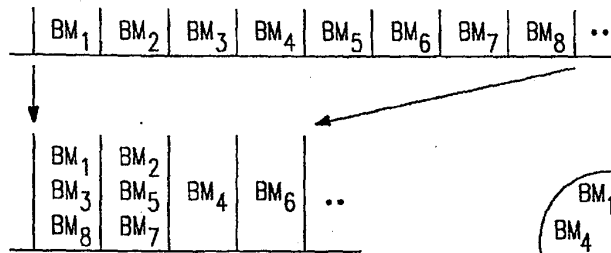


FIG. 14b

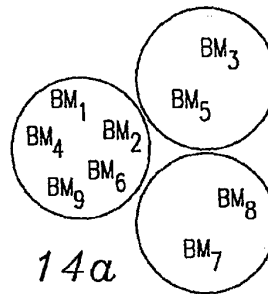


FIG. 14a

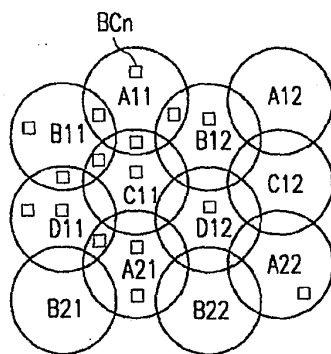


FIG. 15

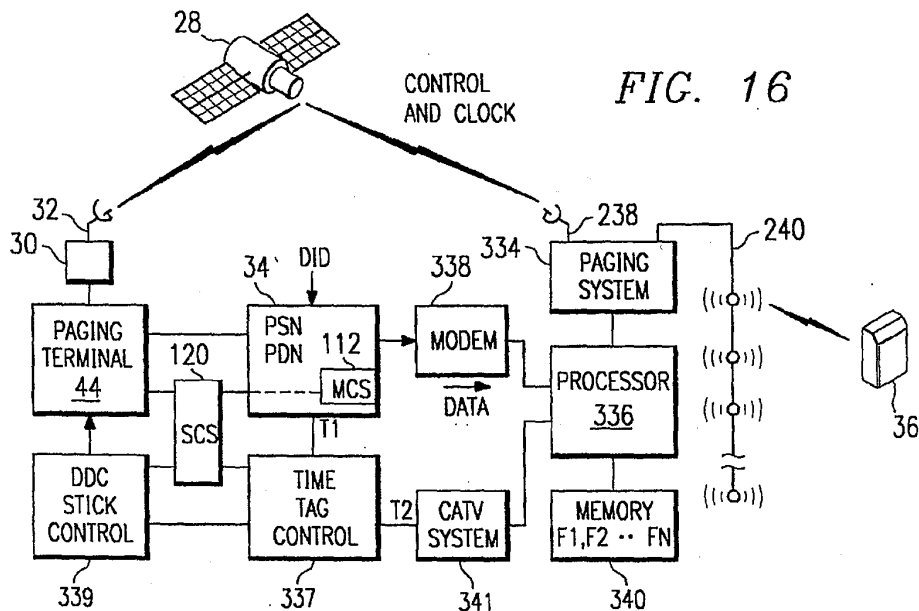
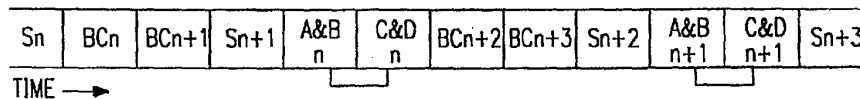
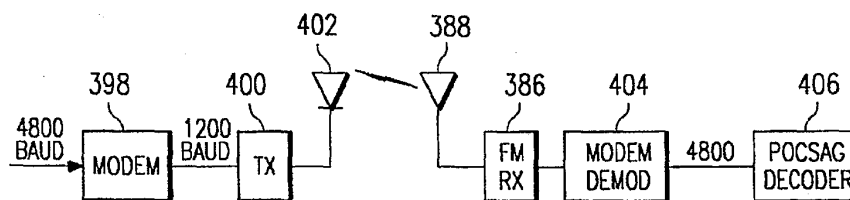
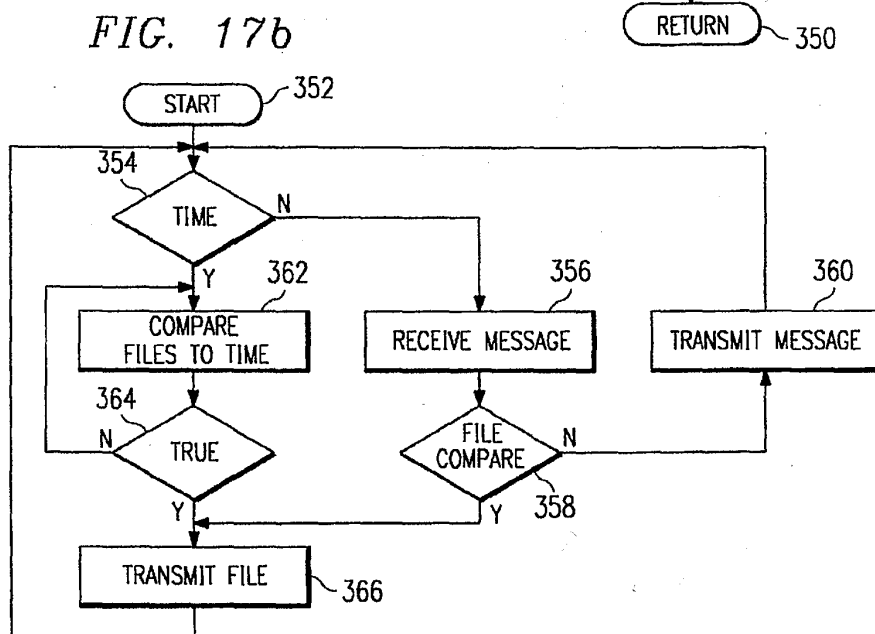
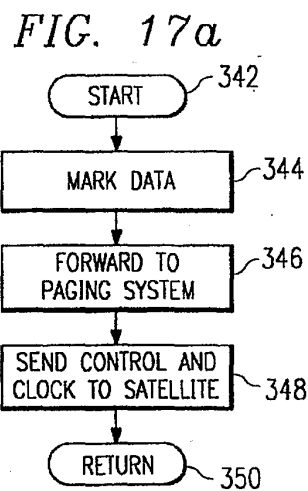
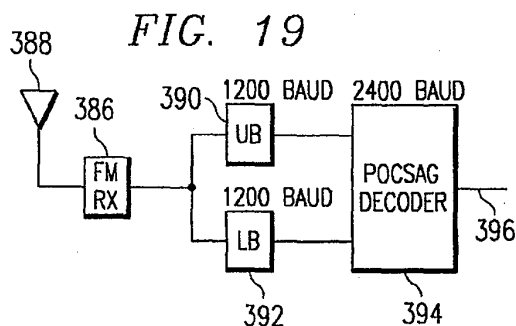
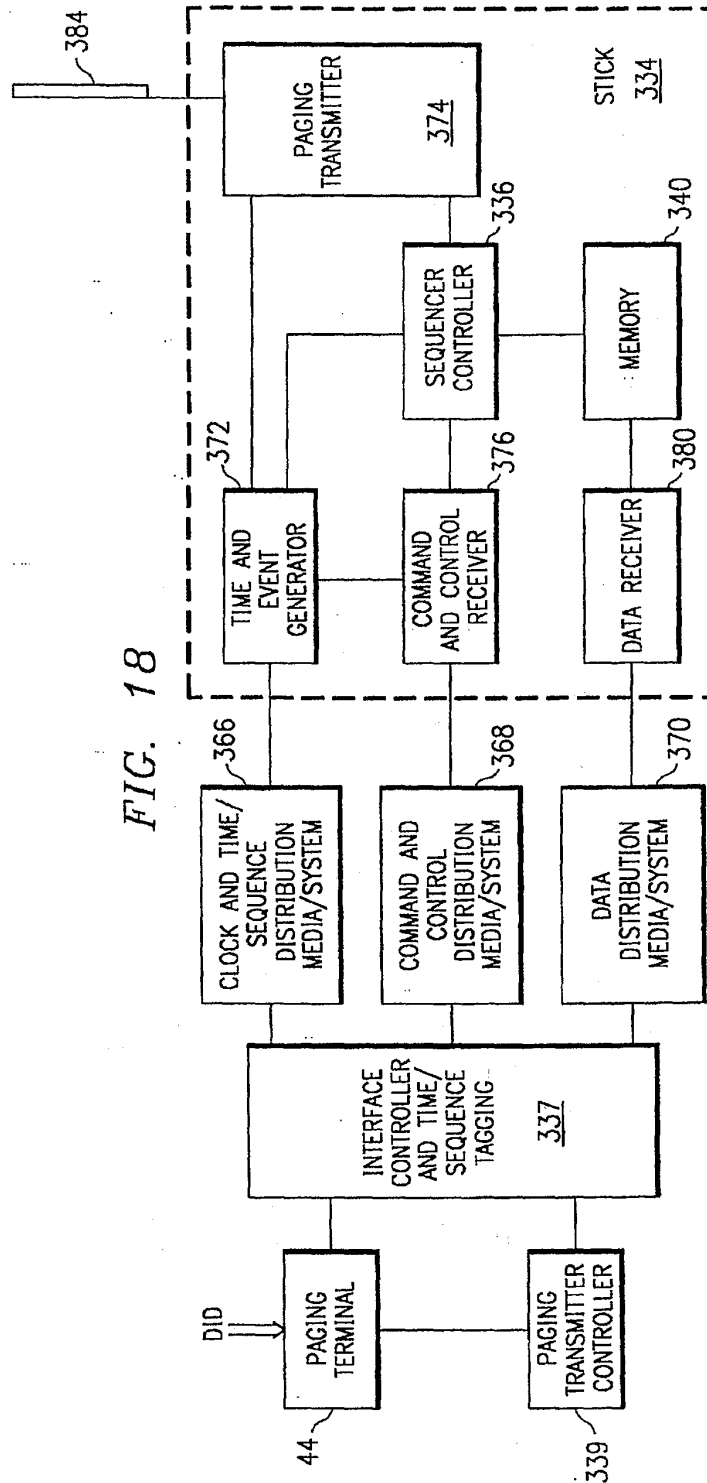


FIG. 16





ADAPTIVE CELLULAR PAGING SYSTEM WITH SELECTIVELY ACTIVATED CELLS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 07/661,078, filed Feb. 26, 1991 (Atty. Dkt. No. 19,977) entitled "Adaptive Cellular Paging System" now abandoned, which is co-pending with U.S. patent application Ser. No. 08/088,400, entitled "Personal Location Pager System" now abandoned (Atty. Dkt. No. 19,892).

TECHNICAL FIELD OF THE INVENTION

The present invention pertains in general to a system for determining the receiving location of a paging receiver and delivering data thereto and, more particularly, to a location detection system that operates in conjunction with an already existent paging system to determine location and adaptively divide the system into cells for delivery of messages to select cells.

BACKGROUND OF THE INVENTION

Tracking the location of an individual or an object that can move in unknown directions has been a concern for a number of years. This has particularly been so for designers of urban communications systems. There are a large number of applications which require knowledge of the location of the object or person, such as fleet management, felons subjected to "house arrest", tracking of patients in health care units, the location of stolen or lost vehicles, the general location of any individual, etc. These systems have employed a variety of techniques including radio location, dead-reckoning and proximity systems.

In one type of system termed "Automatic Vehicle Location" (AVL), various systems are employed to determine the location of a vehicle for the purpose of monitoring the location of a fleet or to find a lost or stolen vehicle. The systems have utilized a number of methods, one of which is the radio location method. In the radio location method, a number of towers are disposed at predetermined locations around a city to allow communication with vehicles in their vicinity. The location method typically utilizes triangulation which requires a comparison of a received signal from the vehicle with respect to a time base to determine the time of arrival of the signal at the receiving antennas. Typically, these antennas have very high powered transmitters that are operable to turn on the transmitter in the vehicle from a remote location by transmitting a request for ID to the vehicle and that vehicle, having the corresponding ID, then transmitting back an answer. It is the receipt of this answer that allows the triangulation method to be facilitated. However, this type of system suffers from a number of disadvantages. First, only very few vehicles can be located in this manner and it is desired to determine the movements of large fleets of vehicles with this method. Second, they require a dedicated system, which requires a specific request for an ID and the assumption that the vehicle is within the vicinity of the transmitter. Therefore, any one locale would be limited to the number of transmitters and/or receivers that are disposed at that one locale. AVL Systems are described in Steven Ritter and Jan McCoy, "Automatic Vehicle Location—An Overview", IEEE Transactions on Vehicular Technology, Vol. VT-26, No. 1, February 1977, which is incorporated herein by reference.

In another type of system, conventional location systems such as Loran-C and GPS Systems are utilized which are satellite-based systems. These are very sophisticated systems and have been typically utilized by large fleet management systems. These systems are typically expensive, but provide for fairly accurate location of a vehicle in substantially real time. Of course, these systems require some type of satellite receiver and obtain their accuracy by relying upon the very solid time base that is provided by the satellite.

In another type of system, a person's location is determined by their proximity to a receiver, or their lack of proximity thereto. In health care units, transmitters are attached to an individual and when the individual leaves a pre-defined zone, a receiver fails to pick up the transmitted signal and sounds an alarm. This type of system is also utilized with house arrest programs for convicted felons that are not considered to be dangerous and are allowed to exist outside penal institutions. Other systems require the felons to check in at random times and to interface a coded bracelet with the receiver on the telephone to confirm that they are, in fact, the individual that has answered the phone. These sometimes can be combined with video systems.

Once the location of an individual or an object is determined, this information is then useful in controlling a paging system for selective delivery of messages. In some paging systems, the location of a paging receiver in a paging system is defined in a database for one of a plurality of hubs. In this manner, throughput can be increased by transmitting different messages simultaneously to two different hubs and two different defined sets of users. Of course, this assumes that a paging receiver resides in the hub having the ID of the pager in its database. However, one problem in the past has been the mobility of the paging receivers which allows an individual to travel between various hubs. The only way to update the database at present is for the user to call in to a central station and have the paging terminal database updated with the new location. This, of course, needs to be done on a central level.

SUMMARY OF THE INVENTION

The present invention disclosed and claimed herein comprises an adaptive paging system for transmitting paging messages to a plurality of paging receivers. The paging system includes a plurality of paging systems for receiving the paging messages. Each of the paging systems has associated therewith a paging transmitter for transmitting the paging messages out to paging receivers. The paging receivers that are operable to receive the paging messages from the paging transmitters are those that are within an associated transmission locale about the one of the paging transmitters from which it receives the paging messages. The transmission locale defines the area within which the paging receivers can receive messages. A transmission device is provided for generating the paging messages for transmission to the paging receivers. The transmission link is operable to link the transmission device to the paging system. A paging terminal is operable to control the transmission device to transmit the paging messages to the paging systems for retransmission therefrom by the associated paging transmitters. The paging terminal operates in simulcast and cellular modes. In the simulcast mode, the paging terminal is operable to control transmission device to control the paging messages in a simulcast manner such that all the paging systems receive the transmitted paging messages at substantially the same time. In the cellular mode, the paging terminal is operable to control the transmission device to

transmit the paging messages to only select ones of the paging systems at a given time for retransmission to the associated paging transmitters. In another aspect of the present invention, the transmission device is operable to transmit the paging messages to the paging systems and the paging transmitters associated therewith are then operable to transmit the paging messages within the associated transmission locale in substantially the same time frame. The transmission device, when controlled by the paging terminal to operate in the cellular mode is operable to transmit different ones of the paging messages to different ones of the paging systems at substantially the same time. Further, portions of the transmission locales for adjacent ones of the paging systems are allowed to overlap.

In yet another aspect of the present invention, a location system is provided to determine in which of the predetermined locales associated with the paging systems that select ones of the paging receivers can receive predesignated messages. The predesignated messages are generated by the transmission device for transmission to the select ones of the paging receivers. Routing control circuitry is provided that is operable during the cellular mode of operation to determine which of the predesignated messages is transmitted to which of the paging systems in accordance with the predetermined location of the select ones of the paging receivers.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

FIG. 1 illustrates a perspective view of the paging system of the present invention;

FIG. 2 illustrates a diagrammatic view of the triangulation method for detecting location;

FIG. 3 illustrates a block diagram of the system;

FIG. 4 illustrates a more detailed block diagram of the system illustrating one base station;

FIG. 5 illustrates a detailed block diagram of the HUB;

FIG. 6 illustrates a detailed block diagram of the personal location unit;

FIG. 7 illustrates a block diagram of the boosting receiver;

FIG. 8 illustrates a cross-sectional view of a building, illustrating a PTU and a PLU;

FIG. 9 illustrates a flowchart for the operation of the PLU;

FIG. 10 illustrates a flowchart for calculating the time-difference-of-arrival (TDA);

FIG. 11 illustrates a diagrammatic view of the cellular system illustrating data to selective locations or cells;

FIG. 12 illustrates a diagrammatic view of the various overlapping receive patterns;

FIG. 13 illustrates a diagrammatic view of the message string transmission;

FIGS. 14a and 14b illustrate the arrangement of batch messages for transmission to cellular sites;

FIG. 15 illustrates a diagrammatic view of the cellular sites and further including localized building sites;

FIG. 16 illustrates a block diagram for an alternate embodiment illustrating transmission of data over a phone line or CATV line;

FIGS. 17a and 17b illustrate flowcharts for the system of FIG. 16;

FIG. 18 illustrates a more detailed block diagram for the system of FIG. 16;

FIG. 19 illustrates a block diagram of the receiver in the PLU for receiving upper and lower sideband signals, to allow orthogonal coding; and

FIG. 20, illustrates a block diagram of an alternate embodiment for increasing the throughput of the system utilizing precoding.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, there is illustrated a perspective view of the system of the paging system of the present invention. Three antenna towers 10, 12 and 14 are illustrated, which are referred to as "sticks". The sticks 10-14 represent only three of a plurality of sticks that are utilized in a paging system. Essentially, each stick 10-14 has a predetermined coverage area which is provided from paging transmitter antennas 16, 18 and 20, respectively. Each of the antennas operates to provide a relatively even coverage in all directions from the antennas 16-20 with respect to signal strength. The patterns are designed such that they overlap. The general operation of the paging portion of the present invention is described in U.S. patent application Ser. No. 612,064 now U.S. Pat. No. 5,239,671, filed Nov. 13, 1990, and entitled, "Satellite Control Link", which is incorporated herein by reference.

Each of the sticks 10-14 has associated therewith a satellite receiver 22, 24 and 26, respectively. Each of the satellite receivers 22-26 is designed to receive paging information from a geosynchronous satellite 28 in a simulcast mode. Paging information is transferred to a satellite 28 from an uplink 30 and associated satellite transmitting antenna 32. Therefore, paging information can be queued up at the paging terminal 44 and then transmitted by the uplink 30 from the antenna 32 to the satellite 28 for re-transmission to all the antennas 22-26 on sticks 10-14, respectively, in a simulcast manner. In this manner, the transmission arrives at each of the sticks 10-14 and their associated satellite receivers 22-26, at substantially the same time. Further, as will be described hereinbelow, the base station equipment associated with each of the sticks 10-14 has a clock that is synchronized with the clock of a public switched network (PSN) 34, and which transmitted signal to the satellite 28 is also synchronized. Therefore, in addition to the time of arrival of the signal at the satellite receivers 22-26 being the same, the data clocks are also synchronized and use for clock recovery synchronization at the base station. This negates the need for a highly stable local oscillator at each base station.

A personal location unit (PLU) 36 is provided that is attached to either an individual or an object which can move relative to the fixed location of the sticks 10-14. The PLU 36 is essentially a modified pager that is of conventional construction. The PLU 36 is operable to receive a paging message in a conventional manner from the paging transmitter antennas 16-20, provided that it is within transmission range and the signal is above the noise level of the PLU 36. In a conventional manner, the PLU 36 will receive paging messages from the one of the paging transmitter antennas 16-20 that has the highest signal level, i.e., it locks onto the strongest signal. In this manner, there will be no contention for the reception of this information.

A modification feature of the PLU 36 relative to a conventional pager is that the PLU 36 has stored internal

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thereto sufficient memory to store the ID or call sign of the one of the paging transmitters associated with paging transmitter antennas 16-20 that it receives information from. FCC regulations require that this call sign be transmitted on a periodic basis, typically every fifteen or thirty minutes, or once per transmission transaction. The PLU 36 is sequenced on and looks for sync and paging messages or station ID transmitted thereto. If the sync word and paging message is the assigned vector stating that the following sequence is the station ID or call sign, the receiver will switch to call sign or station ID detection for the following period. The base station ID transmission is preceded by a POCSAG batch with an idle address plus data that is a unique vector designated to mean that the base station ID's are to follow this POCSAG batch. An alternate to this is the modulo-two add a vector with the sync word to designate the following time slot for station call signs or IDs. Even though a message is not designated for the PLU 36, it does receive the ID of the one of the sticks 10-14 that is closest thereto and which has the strongest signal, as will be described hereinbelow. This ID information is stored, and at a later time, a message can be transmitted to the PLU 36 via the conventional paging network and antennas 16-20 to request location information from the PLU 36. In response to this request, the PLU 36 transmits on another frequency the information to the system, which is received at each of the sticks 10-14 on a receiving antenna 38, 40 and 42, respectively, assuming that the receiving antennas 38-42 are within the transmission range of the PLU 36. For power considerations, it should be understood that the power level on the transmitter portion of the PLU 36 is relatively low.

The information that is transmitted to the antennas 38-42 provides the last received ID or call sign, which was transmitted thereto on the periodic basis from one of the antennas 16-20. The information received by the receiving antennas 38-42 is transmitted to the PSN 34 and then back to a paging terminal 44 through a data entry unit (DEU) 46. This information is utilized to determine the location of the PLU 36, as will be described in more detail hereinbelow.

In the above described operation, two methods are utilized by which to determine the general location of the PLU 36. First, by knowing the general ID of the stick 10-20, a rough idea of the location of the PLU 36 can be determined. For example, in a paging system where specific hubs are defined around the country with each hub defining a different locale, it would be desirable to know which of the hubs the PLU 36 is in. To increase throughput, it is desirable to minimize the number of messages that are sent to any given hub, since it is only necessary to transmit the messages to the hub in which the PLU 36 is located. Present systems provide for this, but these systems must assume which location the PLU 36 is in. Of course, the user of the PLU 36 could phone in a change of location and their ID could be redirected to a different hub. The present invention, however, provides for automatic determination of the location of the PLU 36 for the purposes of transmitting messages thereto. Therefore, by knowing the ID of the sticks that are in the general vicinity of the PLU 36, the hub in which the PLU 36 resides can be determined and messages can be routed to that hub without requiring them to be routed to all of the hubs in the network, which significantly decreases throughput.

Additionally, the system of the present invention also can determine that the PLU 36 is disposed within the transmission range of any one of the sticks 10-14 or the other sticks in the system. Of course, the accuracy of this determination depends upon the time lapse between transmission of the ID from the associated sticks 10-14 and the time of the location

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determination and the time that a message is transmitted to the PLU 36. Of course, if the PLU 36 is associated with an individual or an object that has not moved in that time, then the integrity of the data is high. However, there is no knowledge as to the mobility of the PLU 36 and, therefore, as this time lapse increases, the integrity of the location data decreases. Therefore, to increase the integrity of the data, the sticks 10-14 are controlled to transmit their ID followed by a request for location for a given PLU 36. This method of locating provides a rough approximation of which best radio link location the PLU 36 is in. Of course, by knowing only the location of the PLU 36 relative to the one of the sticks 10-14 having the highest signal received by the PLU 36, the system is provided with the location of the PLU 36 within the radius of the transmitted energy from only one of the sticks 10-14. Since the radius can be upward of five miles, this is a relatively inexact location method, and is primarily used to determine which of the hubs or stick the PLU 36 has best RF link communication in.

A second method to further define the location of the PLU 36 is that utilizing a triangulation method. This is basically a radio location method. The PLU 36 is operable to receive a request for transmission and transmit this request to the receiving antennas 38-42 at each of the sticks 10-14 and any other sticks that are operable to receive the transmission. Upon receipt of the transmitted data which includes the ID of the PLU 36, the data is time-marked. This time-marked data is then transmitted to the PSN 34 for transmission back to the paging terminal 44 and there processed in accordance with various "time of arrival" algorithms. In this manner, a relatively precise measurement of location can be made, knowing the location of the sticks that receive the data. The general systems for determining a various Time-Difference-of-Arrival estimation is described in W. A. Gardner and C. K. Chen, "Interference-Tolerant Time-Difference-Of-Arrival Estimation for Modulated Signals", IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. 36, No. 9, September 1988, which is incorporated herein by reference.

The basic Time-Difference-of-Arrival system (TDA) operates as illustrated in FIG. 2. Each of the sticks 10-14 have associated therewith a transmission pattern, 50, 52 and 54. The request signal is picked up by the PLU 36 as a result of it being in at least one of the transmission patterns 50-54. Of course, the signal having the highest amplitude will be captured by the PLU 36 and only the message received from that associated stick 10-14 will be processed and the message decoded therefrom. Thereafter, the internal transmitter in the PLU 36 will transmit the unique ID of the PLU 36 and the prestored call sign ID of the last received call sign ID back to the sticks 10-14. The call sign ID may be combinations of the FCC required station ID, the unique identifier and a unique vector during idle address and/or data. Of course, depending upon the power level and the transmission characteristics of the surrounding environment, other sticks in the proximity may also receive the signal. The receiving antennas associated with the sticks 10-14 are then operable to receive the transmitted message from the PLU 36 and time-stamp it. The clocks at each of the sticks 10-14 are synchronized to provide a very stable time base and therefore reduce error when the TDA algorithm estimation is made. The data is then transmitted from the sticks 10-14 back to a central processing center through the PSN 34. Since the message requesting data transmission from the PLU 36 was transmitted in a particular time slot, the central system at the paging terminal 44 can determine when the data for that particular PLU 36 has been received.

Referring now to FIG. 3, there is illustrated a block diagram of the location portion of the present invention. The