

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
7 March 2002 (07.03.2002)

PCT

(10) International Publication Number
WO 02/18968 A2

(51) International Patent Classification⁷:

G01S

(21) International Application Number: PCT/US01/26466

(22) International Filing Date: 24 August 2001 (24.08.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/228,258 25 August 2000 (25.08.2000) US
09/938,076 23 August 2001 (23.08.2001) US

(71) Applicant: **QUALCOMM INCORPORATED** [US/US];
5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

(72) Inventor: **SHEYNBBLAT, Leonid**; 1208 North Road, Belmont, CA 94002 (US).

(74) Agents: **WADSWORTH, Philip, R.** et al.; Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



WO 02/18968 A2

(54) Title: METHOD AND APPARATUS FOR USING SATELLITE STATUS INFORMATION IN SATELLITE POSITIONING SYSTEMS

(57) Abstract: Methods and apparatuses for removing the effects of cross-correlation on a satellite positioning system's calculation of position are disclosed. The method includes receiving the SPS signals from in view SPS satellites and determining whether a first measurement, corresponding to a first SPS satellite which has been indicated to be a healthy satellite, is to be removed from a set of measurements to be used to solve for a position of a mobile SPS receiver. Determining includes testing the first measurement is derived from the SPS signals. In one embodiment, the signals from the first SPS satellite may be weaker than the signals from the second SPS satellite, which has been indicated to be an unhealthy satellite.

METHOD AND APPARATUS FOR USING SATELLITE STATUS INFORMATION IN SATELLITE POSITIONING SYSTEMS

5 RELATED APPLICATION

[0001] This application is related to and hereby claims the benefit of the filing date of a provisional application by the same inventor, Leonid Sheynblat. The provisional application is entitled, Method and Apparatus for Using Satellite Status Information in Satellite Positioning Systems, Serial No. 60/228,258, filed 10 on August 25, 2000.

FIELD OF THE INVENTION

[0002] The present invention relates generally to the field of satellite position systems (SPS), such as global positioning system (GPS) receivers, and more 15 particularly to processing of SPS signals.

BACKGROUND OF THE INVENTION

[0003] Global Positioning System (GPS) receivers normally determine their position by computing times of arrival of signals transmitted simultaneously 20 from a multiplicity of GPS (or NAVSTAR) satellites. These satellites transmit, as part of their message, both satellite positioning data as well as data on clock timing, so-called "ephemeris" data. The process of searching for and acquiring GPS signals, reading the ephemeris data for a multiplicity of satellites and computing the location of the receiver from this data is time consuming, often 25 requiring several minutes. In many cases, this lengthy processing time is unacceptable and, furthermore, greatly limits battery life in miniaturized portable applications.

[0004] GPS receiving systems have two principal functions. The first is the computation of the pseudoranges to the various GPS satellites, and the second is 30 the computation of the position of the receiver using these pseudoranges and satellite timing and ephemeris data. The pseudoranges are simply the times of arrival of satellite signals measured by a local clock. This definition of pseudorange is sometimes also called code phase. The satellite ephemeris and

timing data is extracted from the GPS signal once it is acquired and tracked. As stated above, collecting this information normally takes a relatively long time (18 seconds to several minutes) and must be accomplished with a good received signal level in order to achieve low error rates.

5 [0005] Most GPS receivers utilize correlation methods to compute pseudoranges. These correlation methods are performed in real time, often with hardware correlators. GPS signals contain high rate repetitive signals called pseudorandom (PN) sequences. The codes available for civilian applications are called coarse/acquisition (C/A) codes, and have a binary phase-reversal rate, or

10 10 “chipping” rate, of 1.023 MHz and a repetition period of 1023 chips for a code period of 1 millisecond. The code sequences belong to a family known as Gold codes, and each GPS satellite broadcasts a signal with a unique Gold code.

15 [0006] For a signal received from a given GPS satellite, following a downconversion process to baseband, a correlation receiver multiplies the received signal by a stored replica of the appropriate Gold code contained within its local memory, and then integrates, or low-pass filters, the product in order to obtain an indication of the presence of the signal. This process is termed a “correlation” operation. By sequentially adjusting the relative timing of this stored replica relative to the received signal, and observing the correlation

20 output, the receiver can determine the time delay between the received signal and a local clock. The initial determination of the presence of such an output is termed “acquisition.” Once acquisition occurs, the process enters the “tracking” phase in which the timing of the local reference is adjusted in small amounts in order to maintain a high correlation output. The correlation output during the

25 tracking phase may be viewed as the GPS signal with the pseudorandom code removed, or, in common terminology, “despread.” This signal is narrow band, with a bandwidth commensurate with a 50 bit per second binary phase shift keyed (BPSK) data signal which is superimposed on the GPS waveform.

30 [0007] The correlation acquisition process is very time consuming, especially if received signals are weak. To improve acquisition time, most GPS receivers utilize a multiplicity of correlators which allows a parallel search for correlation peaks.

[0008] Conventional GPS receiving equipment is typically designed to receive GPS signals in open spaces since the satellite signals are line-of-sight and can thus be blocked by metal and other materials. Improved GPS receivers provide signal sensitivity that allows tracking GPS satellite signals indoors, or in the 5 presence of weak multipath signals or signals that are pure reflections. The ability to acquire such weak GPS signals, however, typically causes other problems. For example, the simultaneous tracking of strong and weak signals may cause the receiver to lock on to a cross-correlated signal, which is not a true signal. Instead of finding a weak true peak, a stronger cross-correlated peak may 10 be acquired. Tracking a weak satellite signal does not guarantee that it is a direct signal. This weak signal may be a reflected signal or a combination of direct and indirect signals. The combined signals are referred to as multipath signals. The path of the reflected signal is typically longer than the path of the direct signal. This difference in path length causes the time-of-arrival measurement of the 15 reflected signal to be typically delayed or the corresponding code phase measurement to contain a positive bias. In general, the magnitude of the bias is proportional to the relative delay between the reflected and direct paths. The possible absence of a direct signal component makes the existing multipath mitigation techniques (such as a narrow correlator or a strobe correlator) 20 obsolete.

[0009] The GPS navigation message is the information transmitted to a GPS receiver from a GPS satellite. It is in the form of the 50 bit per second data stream that is modulated on the GPS signals.

[0010] The data message is contained in a data frame that is 1500 bits long. It 25 has five subframes each of which contains GPS system time. Each subframe consists of 10 words of 30 bits each. Subframes 1 through 3 are repeated every 30 seconds. There are twenty-five pages of data appearing in sequence in the fourth and fifth subframes; one every 30 seconds. Thus, each of these twenty-five pages repeats every 750 seconds.

[0011] Subframes 4 and 5 contain two types of health or status data for the GPS 30 satellites: (a) each of the 32 pages which contain the clock/ephemeris related almanac data provide an eight-bit satellite health status word regarding the satellite whose almanac data they carry, and (b) the 25th page of subframe 4 and

5 jointly contain six-bit health status data for up to 32 satellites. Additional satellite health data are given in subframe 1. Subframe 1 is part of the ephemeris data set.

[0012] Typically, a GPS receiver will receive information concerning the status 5 (e.g. "health") of a satellite and then process the GPS signals by not acquiring and not tracking unhealthy satellites while it acquires and tracks GPS signals from healthy satellites. Alternatively, standalone GPS receivers can be designed to acquire and track healthy and unhealthy satellites but avoid using unhealthy signals in the location computation after having read the health status data from 10 the ephemeris message from an unhealthy satellite's signal. No attempt has been made in the prior art to use the information concerning the health of a satellite in attempting to avoid using cross-correlation results or to detect such results. In addition, no attempt has been made to ensure that the satellite health status is made available to GPS receivers having no direct access to the satellite health 15 status. (Direct access is from SPS satellites or from previously downloaded data from the SPS satellites).

SUMMARY OF THE INVENTION

[0013] A method is presently described for processing satellite position system 20 (SPS) signals. The method includes receiving the SPS signals from in view SPS satellites and determining whether a first measurement, corresponding to a first SPS satellite which has been indicated to be a healthy satellite, is to be removed from a set of measurements to be used to solve for a position of a SPS receiver. This determining includes testing the first measurement for a cross-correlation 25 resulting from signals from the first SPS satellite and signals from a second SPS satellite. In one embodiment, the signals from the first SPS satellite may be weaker than the signals from the unhealthy second SPS satellite.

[0014] "In view" as used herein is defined broadly to mean SPS satellites in view of: a SPS reference receiver; a network of SPS reference receivers; a mobile SPS 30 receiver; or a cell or a group of cells of a cellular radio system. However, these are merely provided as examples. Therefore, it should be noted that an SPS satellite may be considered to be "in view" if the signals can be received by virtually any SPS receiver.

[0015] A computer readable medium containing executable computer program instructions is also disclosed. The computer medium causes the data processing system to perform a method for processing satellite positioning system (SPS) signals when the program instructions are executed by a data processing system.

5 The method includes attempting to acquire SPS signals from all in view SPS satellites regardless of whether the in view SPS satellites are unhealthy, and receiving health data specifying which of the in view SPS satellites are unhealthy. The method includes testing measurements obtained from acquiring SPS signals, for all of the in view SPS satellites, for a cross-correlation between
10 two different SPS satellites, where the testing is performed regardless of whether an in view SPS satellite is unhealthy.

[0016] A combined SPS receiver and communications system is also disclosed. In one embodiment, a satellite position system (SPS) reference receiver is configured to receive SPS signals from a plurality of in view SPS satellites. A
15 server is configured to communicate with the SPS reference receiver. A transmitter coupled with the SPS reference receiver transmits the SPS signals. In one embodiment, the server analyzes the in view SPS satellites' signals for a cross-correlation condition where a healthy SPS satellite's signal is influenced by an unhealthy SPS satellite's signal, the unhealthy SPS satellite's signal(s) and the
20 cross-correlated satellite's SPS signal(s) are then tested to determine if they should be removed, corrected, or used before a location is computed from the in view SPS satellites. The transmitter then optionally transmits the location.

[0017] Another embodiment of the disclosed apparatus includes a mobile SPS receiver coupled to a second receiver. The mobile SPS receiver receives the SPS
25 signals from the transmitter on the second receiver and analyzes the in view SPS satellites for a cross-correlation condition where a healthy SPS satellite's signal is influenced by an unhealthy SPS satellite's signal, the unhealthy SPS satellite's signal and the cross-correlated SPS satellite's signal is removed or corrected before a location is computed from the in view SPS satellites by the mobile SPS
30 receiver. In one embodiment, the transmitter and the second receiver is compatible with a cellular radio system.

[0018] In another embodiment, a computer readable medium containing executable computer program instructions performs a method for providing

assistance data to a mobile satellite positioning system (SPS) receiver which is coupled to a receiver. The method may include determining a cell site or a group of cell sites which is in communication with the receiver. Health data is determined for each of a plurality of in view SPS satellites and the health data is 5 transmitted to the receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The present invention is illustrated by way of example and is not limited in the figures of the accompanying drawings, in which like references indicate 10 similar elements.

[0020] **Figure 1** illustrates a method to use satellite position system (SPS) status data to improve a position calculation.

[0021] **Figure 2** illustrate a variety of "in view" satellite position system (SPS) satellites.

15 [0022] **Figure 3** illustrates a cellular communication system having a plurality of cells each of which is serviced by a cell site, and each of which is coupled to a cellular switching center.

[0023] **Figure 4** shows a representation of a cellular based information source which provides an association between sets of Doppler information at given 20 times relative to cellular service areas and/or cellular sites.

[0024] **Figure 5** illustrates an implementation of a basestation system according to one embodiment of the present invention.

[0025] **Figure 6** illustrates an example of a combined SPS receiver and communication system according to one embodiment of the present invention.

25

DETAILED DESCRIPTION

[0026] In the following detailed description of embodiments of the invention, reference is made to the accompanying drawings in which like references indicate similar elements, and in which is shown by way of illustration, specific 30 embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. The following detailed description is, therefore, not to be taken in a

limiting sense, and the scope of the invention is defined only by the appended claims.

[0027] A method and an apparatus for using satellite status information in SPS systems are disclosed. In one exemplary embodiment, a mobile SPS receiver 5 receives SPS signals from in view SPS satellites and determines (or attempts to determine) pseudoranges to all (in most cases) in view satellites. Information concerning the status of the satellites (e.g. satellite health) is also collected and this information is used in processing the SPS signals received by the mobile SPS receiver. Since, in most cases, the mobile SPS receiver determines code 10 phases/pseudoranges to all satellites (even for unhealthy satellites) it is possible to determine a cross-correlation between a healthy satellite's weak GPS signal and an unhealthy satellite's strong GPS signal. Once such a cross-correlation result is identified it may be possible to remove a cross-correlated measurement or attempt to correct it. Thus, according to one embodiment, a mobile SPS 15 determines code phase/pseudorange measurements to satellites which are known to be unhealthy.

[0028] The satellite's health information may be monitored by GPS reference receiver(s) that transmit this information to GPS server(s) (e.g. see the location servers described in co-pending U.S. Patent Application Serial No. 08/842,559, 20 filed April 15, 1997, now U.S. Patent No. 6,208,290, which is hereby incorporated herein by reference) and these servers may cause this information for all in view satellites to be either (a) used locally to process pseudorange measurements received from a mobile GPS receiver (in the case where the mobile GPS receiver does not compute the mobile's position but the location 25 server, or other system in a network, does compute the position) or (b) transmitted to the mobile GPS receiver (through for example a cellular telephone which is coupled to and housed with the mobile GPS receiver) for use by the mobile GPS receiver. The GPS reference receivers typically, according to this embodiment, acquire and track all GPS satellites in view whether healthy or 30 unhealthy; this will allow in one embodiment for the detection (by a location server or by a mobile GPS receiver itself) of cross-correlations between healthy and unhealthy satellite signals.

[0029] “In view,” as used in this detailed description is intended to be flexible. Accordingly, “in view satellites” or “in view SPS satellites” can be used to denote in view of the entire Wide Area Reference Network (WARN) or any subset of the WARN. For example, a non-exclusive list would include in view 5 of a single SPS reference receiver, in view of a plurality of SPS reference receivers, in view of a mobile SPS receiver, in view of a cell or any group of cells of a cellular (wireless) radio network. Various “in view SPS satellites” are shown in **Figure 2**. With reference to **Figure 2**, wide area reference network view area 200 is shown where satellites (SV) 202, SV 204, SV 206, SV 208, 10 SV210, SV 212, SV 214, SV 216, SV 218, SV 242, SV 244, SV 246, SV 248, SV 252, SV 254, and SV 256 are in view of the WARN. A subset of these satellites are in view of reference receiver view area 240, e.g., SV 242, SV 244, 15 SV 246, and SV 248. Another subset of theses satellites are in view of a second reference receiver view area 260, e.g., SV 210, SV 212, SV 214, SV 216, and SV 218. Another subset of these satellites are in view of a third reference receiver view are 270, e.g., SV 208, SV 210, SV 252, SV 254, and SV 256. Another 20 subset of satellites is in view of mobile SPS receiver view area 250, e.g., SV 252, SV 254, and SV 256. No limitation is implied by the selection of the satellites included in the view area 240, 250, 260, or the view area 270 or the size of the view areas. The view areas were chosen for illustration purposes only.

[0030] In one embodiment, the health status of “all” SPS satellites in view of the 25 WARN view area 200 are acquired. A subset of the satellite’s health information, could be transmitted to a mobile SPS receiver based on the satellites “in view” of the mobile SPS receiver’s location. “All” SPS satellites used herein depends on the particular implementation of acquisition. For example, taking 30 into account an elevation mask, or a signal-to-noise ratio mask on a signal to interface mask, etc. Thus “all” is flexible constructed. The GPS reference receiver(s) may collect satellite status information which is more current than the corresponding information in the satellite ephemeris (or almanac) information, and this updated status information may be transmitted to the location servers and/or the mobile GPS receivers for use according to the various embodiments of the invention. In one embodiment, the health status information may be received directly from the satellite. In another embodiment, the location server(s) may

derive an updated status information based on the information and/or measurements received from the GPS reference receiver(s). The updated status information may be a function of the quality of status (QoS) associated with the location request. For a given level of quality, the location server may determine 5 that a satellite which is marked healthy in the ephemeris and/or almanac data may not provide the desired level of accuracy. In such a case, the location server may update its health status information and send it to the remote SPS receiver(s) and optionally store it for further processing. An example of this processing may be the use of this updated health status to determine if the satellite should be used 10 in position computation, which is performed in the location server. Alternatively, the determination and update of the health status information may be performed by the mobile SPS receiver. An example of a network of GPS reference receivers which may be used to supply this updated status information is described in co-pending U.S. Patent Application Serial No. 09/067,407, filed 15 April 28, 1998, now U.S. Patent Number 6,215,441, which is hereby incorporated herein by reference.

[0031] **Figures 1, 5, 6, and 7A** from U.S. Patent 6,208,290 have been included herein for clarity and correspond to **Figures 3, 4, 5, and 6** respectively. With reference to the figures herein, **Figure 3** illustrates several cells within a cellular 20 service area where the mobile SPS receiver may receive assistance data from a communications network. In one embodiment, the communications network includes a location server, which can be represented by 26 in **Figure 3**. **Figure 4** may also contain satellite health status information (not shown) transmitted to the mobile SPS receiver by the communications network. For example, an SPS 25 receiver in one view area may receive one set of satellite health status information and an SPS receiver in another view area may receive another set of satellite health status information from the communication system. A base station illustrated in **Figure 5** may be associated with the reference receiver view areas shown in **Figure 2** and support the communications system including cells 30 within the cellular service area.

[0032] In one embodiment, **Figure 6** illustrates a cell phone 375, which couples a mobile SPS receiver 376 with a communications system transceiver 378 to receive the assistance information including satellite health status from the

communications system. In one embodiment, the location server determines a cell site or group of cell sites that is in communication with mobile SPS receiver 376, based on the cell site or group of cell sites. A group of in view satellites may then be determined by the location server and health information for all such 5 in view satellites may then be transmitted to cell phone 375 and be received by the communications transceiver 378. Mobile SPS receiver 376 may compute its location based on the assistance data received or the location server may determine the location of the mobile SPS receiver.

[0033] The health data given in subframes 1, 4 and 5 of some satellites may 10 differ from that shown in subframes 4 and/or 5 of another group of satellites since the latter may be updated at a different time.

[0034] Health summary in subframe 5 is only updated at the time of almanac upload. During extended operations the health summary may become outdated due to the length of time since the last upload.

15 [0035] This situation is even more exacerbated when the GPS receiver is indoors or in other signal restrictive environments. It may require as much as 17dB of additional signal sensitivity to be able to receive the satellite health status bits directly from the satellites. The GPS receiver may measure the pseudorange to the satellites based on the signal which is 17dB weaker than the signal which 20 contains the satellite health status bits (50 bits per second). Reception of satellite health status bits may also require continuous satellite signal tracking from 18 seconds to several minutes which is not generally possible in signal restrictive environments. Several critical performance aspects related to GPS radio-location may be affected by outdated or unavailable satellite health information. One 25 aspect is related to the use of unhealthy satellite signal(s) in location determination. It is commonly known that the use of the unhealthy satellite signal(s) may result in significant positional errors.

[0036] If the health summary becomes stale and does not accurately reflect the 30 status of the GPS constellation, the time-to-first-fix (TTFF) for a GPS receiver may be delayed. This is due to the time wasted on the possible acquisition of unhealthy satellites which were marked "healthy" by the stored health summary. Also, attempts to acquire healthy satellites which are marked unhealthy may not be made. As a result, extended operations without timely and correct satellite

health information updates may jeopardize missions of those users who require efficient TTFF. A fast TTFF is critical for emergency services and also affects the battery standby and talk times. In a wireless assisted GPS mode, a wireless network may provide timely and correct satellite health information for all 5 mobile GPS receivers communicating with such network.

[0037] Another reason for satellite health assistance is the protection against rogue satellite measurements. In the heavily obstructed signal environments, it's quite often that the GPS satellite signals are received with a very high dynamic range. Receiving GPS signals with signal strengths differing by more than 10 approximately 17dB may cause a GPS receiver to acquire a cross-correlated signal instead of a relatively weaker true signal. One procedure that may be used to detect and possibly correct or remove a cross-correlated measurement is described in co-pending U.S. Patent Application Serial No. 09/241,334, filed February 1, 1999, which is hereby incorporated herein by reference. However, 15 for a GPS receiver to detect a presence of cross-correlated signals, all signals from both healthy and unhealthy satellites should be acquired. A problem would arise if a strong "unhealthy" satellite signal cross-correlates with a weak "healthy" satellite signal. Unaware of the presence of an "unhealthy" signal, a GPS receiver may not be able to detect a cross-correlation condition. Another 20 problem may arise if only a subset of all visible satellites is acquired irrespective of the health status. If any of the acquired satellites in this subset exhibit weak signal behavior, then it may also be the case that the cross-correlation condition may go undetected.

[0038] In one embodiment of this invention, GPS reference receiver(s) which 25 provides reference data for location server(s) (also referred to as a Position Determination Entity (PDE) in CDMA cellular phone systems and Serving Mobile Location Centre (SMLC) in the GSM cellular phone systems) acquires and tracks all satellites in view: healthy and unhealthy. Further, GPS technologies (e.g. a GPS receiver) integrated with or connected to wireless 30 devices (e.g. a cellular telephone or a two-way pager) also acquire and track all satellites in view: healthy and unhealthy. In a wireless assisted GPS (WAG) mode (e.g. see examples described in co-pending U.S. Patent Application No. 08/842,559, filed April 15, 1997), location server(s) may provide a "health"

status information to the mobiles communicating with a wireless network served by the location server(s). This health status information may accompany any other assistance information provided by the location server(s). In general, assistance information allows fast acquisition of GPS signals in highly restrictive 5 signal environments. In order to achieve such performance improvements, assistance information may specify the satellites to be searched for, the estimated time of arrival of these signals and the expected frequency (Doppler) of the signals. This assistance information may be provided to improve a 3-dimensional search for a satellite signal. Other types of assistance such as 10 ephemeris and/or almanac, approximate location and time information may be provided to assist with location computation and/or fast acquisition of satellite signals. When the satellite's signals are acquired, pseudoranges, Dopplers and other satellite signal measurements are analyzed for cross-correlation conditions. In order to perform this analysis, the assistance should be provided and the 15 measurements should be made for all satellites in view: healthy and unhealthy. In this embodiment, the satellite health information is used to assist detection of a cross-correlation condition and then the cross-correlated and/or "unhealthy" satellites are analyzed to determine whether they should be included in the location computation process or corrected. In an alternate embodiment, where 20 the assistance information is provided for healthy satellites only (satellite health is implied by inclusion of the particular satellite in the satellite list) and the current and valid satellite health status information is not available to the mobile GPS receiver, the mobile may attempt to acquire only healthy satellites (e.g., the satellites included in the list). In this case, a possible presence of a "strong" 25 unhealthy satellite potentially cross-correlating with relatively weaker healthy satellites may not be known to the mobile and therefore may not be tested for. The information related to the current satellite constellation (including the list of visible satellites and health status) may not be known since it cannot not be guaranteed that the GPS receiver will have the necessary information, which is 30 current and available (e.g., stored in its memory). The use of undetected cross-correlated signals may lead to large positional errors thus affecting the quality of the location service.

[0039] The following example provides an illustration of the present invention. The data was collected in an urban canyon with a resulting horizontal positional error of 61.4 meters. Satellite SV PRN#10 (line 2 of **Table 1**) was removed from the solution since it was identified as a cross-correlation with satellite SV PRN 5 #17 (line 3 of **Table 1**). If satellite SV PRN#10 was used in the solution, the error in its pseudorange measurement of -37,903 meters would have caused a horizontal error in access of 50 kilometers.

[0040] This example also illustrates the need to provide assistance information for all satellites in view. If satellite SV PRN#17 had been declared unhealthy 10 and the wireless network did not provide the assistance for all four satellites, the mobile GPS receiver would have been unable to detect the cross-correlation and would have used satellite SV PRN#10 thereby introducing the horizontal error in excess of 50 kilometers, described above, into the position estimate of the mobile GPS receiver, an unacceptable result.

15

SV PRN	Azimuth (degrees)	Elevation (degrees)	Output SNR (dB)	Error (meters)	Used in solution
6	128	63	49	-1.1	Yes
10	44	8	14	-37903	No
17	330	65	52	-0.6	Yes
22	295	28	19	92.2	Yes

Table 1. Cross-Correlation Between Satellites SV PRN 17 and SV PRN 10

[0041] Alternatively, health information may be (or may have been) directly received from the satellites and this health information may be used in the same 20 manner described herein as the health information which is received from a transmitter at a cell site.

[0042] The health information may be transmitted from a cell site by broadcasting this information for all satellites in view of a cellular telephone basestation (“cell site”). Alternatively, it may be provided to a cellular telephone 25 upon request (on demand). The health information may be transmitted from the cellular telephone basestation to the cellular telephone which then provides the

health information to a GPS receiver which is coupled to the cellular telephone. In the case where the information is transmitted on demand, a location server may determine the appropriate (e.g. updated health) information based upon a cell site which is in cellular radio/wireless communication with the phone and

5 the cell site information may be used to determine an approximate location which is used to determine satellites in view of that location and the updated health information for these satellites is then caused to be transmitted (in one case) to the cellular telephone which in turn provides the information to the mobile GPS receiver for use in processing SPS signals in the GPS receiver.

10 Processing SPS signals may include cellular telephone's position determination. In another case, the location server may retain the updated health information or information used to determine the updated health information and use it to process the pseudoranges (e.g. correlation measurements which specify code phases) received from the mobile GPS receiver in order to determine the position

15 of the mobile GPS receiver. In both cases, pseudoranges, estimated Doppler and other measurements are determined even for known unhealthy GPS satellites so that cross-correlations can be detected as described herein. For example, a GPS receiver may receive the updated health information from a cell site but still acquire GPS signals from a GPS satellite which was indicated to be unhealthy in

20 the transmitted updated health information. In the example, where the GPS receiver may also compute the location information it may use the updated health information to determine which satellites may be used in the solution. Co-pending U.S. Application Serial No 08/842,559, filed April 15, 1997, describes a method for identifying a cell site which is in wireless communication with a

25 cellular telephone and which then determines satellite assistance data for in view satellites based upon an approximate location derived from identifying this cell site. This method may be used with the present invention where the satellite assistance data in this case is either satellite health (e.g. based on satellite almanac) or updated satellite health (e.g. more current than the existing satellite

30 almanac message's information concerning satellite health).

[0043] **Figure 1** shows an example according to one embodiment of the present invention. In this example, the location server provides assistance data to the mobile GPS receiver and then receives measurements back from the mobile SPS

receiver, and these measurements are then used to solve for the position of the mobile GPS receiver. The method shown in **Figure 1** assumes a certain sequence in which the location server provides assistance data through a cell site to the mobile device, and then the mobile device attempts to acquire all satellites

5 in view, including all healthy and unhealthy satellites in view, and then tests for cross-correlations on all of the correlation measurements which result from acquiring the satellite signals. It will be appreciated that a different sequence of operations may also be employed in accordance with the present invention. For example, the GPS receiver can attempt to acquire all satellites in view before

10 receiving the assistance data. Further, the testing for cross-correlation may be performed at the location server after the GPS receiver determines pseudorange data and transmits this data and other data necessary for the testing for cross-correlation back to the location server which can then perform the cross-correlation tests. In another alternative embodiment, the mobile device may

15 perform its own position calculations and thus operations 6, 7, and 8 of **Figure 1** are performed by a processing unit in the combined cell phone/GPS receiver device. In this case, operation 5 in which data is transmitted to the location server is not necessary. In yet another alternative embodiment, the location server may broadcast the appropriate health assistance data rather than providing

20 it on request to a mobile device. In this case, broadcasting may be performed from selected cell site(s) and no location server may be necessary except for the processor(s) located at the cell site(s) which determines the necessary health assistance data based upon the satellites in view at the cell site. This approach may also be applicable to on-demand delivery described herein.

25 [0044] While satellite health information may be obtained from receiving, demodulating and decoding the health data in the SPS signals from the SPS satellites, and used according to the various embodiments of the invention, it is also possible to use GPS receivers and processing systems which monitor (e.g. receive and measure characteristics of the SPS signals) the SPS signals and

30 determine from measured characteristics of the SPS signals that an SPS satellite is unhealthy (even though the demodulated and decoded health data in the SPS signals from this satellite or other satellites indicate that this satellite is healthy) or vice versa.

[0045] In this discussion, embodiments of the present invention have been described with reference to application in the United States Global Positioning System (GPS) system, which is an example of an SPS system. It should be evident, however, that these methods are equally applicable to other satellite 5 positioning systems, such as the Russian Glonass system. Thus, the term "GPS" used herein includes such alternative satellite positioning systems, including the Russian Glonass system. Likewise, the term "GPS signals" includes signals from alternative satellite positioning systems.

[0046] Furthermore, although embodiments of the present invention are 10 described with reference to GPS satellites, it will be appreciated that the teachings are equally applicable to positioning systems which utilize pseudolites or a combination of satellites and pseudolites. Pseudolites are ground based transmitters which broadcast a PN code (similar to a GPS signal) modulated on an L-band (or other frequency) carrier signal, generally synchronized with GPS 15 time. Each transmitter may be assigned a unique PN code so as to permit identification by a remote receiver. Pseudolites are useful in situations where GPS signals from an orbiting satellite might be unavailable, such as tunnels, mines, buildings, urban canyons, or other enclosed areas. The term "satellite", as used herein, is intended to include pseudolites or equivalents of pseudolites, and 20 the term GPS signals, as used herein, is intended to include GPS-like signals from pseudolites or equivalents of pseudolites.

[0047] It will be appreciated that the methods described in conjunction with the figures may be embodied in machine-executable instructions, e.g. software. The 25 instructions can be used to cause a general-purpose or special-purpose processor that is programmed with the instructions to perform the operations described. Alternatively, the operations might be performed by specific hardware components that contain hardwired logic for performing the operations, or by any combination of programmed computer components and custom hardware components. The methods may be provided as a computer program product that 30 may include a machine-readable medium having stored thereon instructions which may be used to program a computer (or other electronic devices) to perform the methods. For the purposes of this specification, the terms "machine-readable medium" shall be taken to include any medium that is capable of storing

or encoding a sequence of instructions for execution by the machine and that cause the machine to perform any one of the methodologies of the present invention. The term "machine-readable medium" shall accordingly be taken to include, but not be limited to, solid-state memories, optical and magnetic disks, 5 and carrier wave signals. Furthermore, it is common in the art to speak of software, in one form or another (e.g., program, procedure, process, application, module, logic...), as taking an action or causing a result. Such expressions are merely a shorthand way of saying that execution of the software by a computer causes the processor of the computer to perform an action or a produce a result.

10 [0048] Thus, a novel method and apparatus for using satellite status data is described. Although the invention is described herein with reference to specific preferred embodiments, many modifications therein will readily occur to those of ordinary skill in the art. Accordingly, all such variations and modifications are included within the intended scope of the invention as defined by the following 15 claims.

CLAIMS

What is claimed is:

1. A method for processing satellite position system (SPS) signals, the method comprising:
 - receiving the SPS signals from in view SPS satellites;
 - 4 determining whether a first measurement, corresponding to a first SPS satellite indicated to be healthy, is to be removed from a set of measurements to be used to solve for a position of a mobile SPS receiver.
2. The method of claim 1 wherein the determining comprises testing the first measurement for a cross-correlation resulting from signals from the first SPS satellite and signals from a second SPS satellite, and wherein the first measurement is derived from the SPS signals.
3. The method of claim 2 wherein the signals from the first SPS satellite are weaker than the signals from the second SPS satellite which has been indicated to be an unhealthy satellite.
4. The method of claim 1, wherein the in view SPS satellites are in view of at least one of a SPS reference receiver, a network of SPS reference receivers, the mobile SPS receiver, a cell of a cellular radio system, and a group of cells of a cellular radio system.

-19-

5. A method for processing satellite positioning system (SPS) signals, the
2 method comprising:
attempting to acquire SPS signals from in view SPS satellites regardless
4 of whether the in view SPS satellites are unhealthy;
receiving health data specifying which of the in view SPS satellites are
6 unhealthy;
testing measurements obtained from acquiring the SPS signals, for all of
8 the in view SPS satellites, for a cross-correlation between at least
two different SPS satellites, wherein the testing is performed
10 regardless of whether an in view SPS satellite is unhealthy.

6. The method of claim 5 further comprising:
2 removing from a set of measurements a first measurement, corresponding
to a first SPS satellite, wherein the set of measurements, after the
4 removing, is to be used to solve for a position of a mobile SPS
receiver, and wherein the first measurement is determined to be
6 removed by the testing.

7. The method of claim 6, wherein the first SPS satellite has been indicated
2 to be a healthy satellite.

8. The method of claim 5 further comprising:
2 analyzing a first measurement, corresponding to a first SPS satellite
which has been indicated to be a healthy satellite, to determine
4 whether to remove the first measurement from a set of

-20-

6 measurements or correct the first measurement for use in the set
8 of measurements, wherein the set of measurements is to be used
 to solve for a position of a mobile SPS receiver, and wherein the
 first measurement is selected for the analyzing as a result of the
 testing.

9. The method of claim 5, wherein the in view SPS satellites are in view of
2 at least one of a SPS reference receiver, a network of SPS reference receivers,
 the mobile SPS receiver, a cell cellular radio system, and a group of cells of a
4 cellular radio system.

10. A method for providing assistance data to a mobile satellite positioning
2 system (SPS) receiver which is coupled to a receiver, the method comprising:
 determining a cell site or a group of cell sites which is in communication
4 with the receiver;
 determining health data for each of a plurality of in view SPS satellites;
6 causing the health data to be transmitted to the receiver.

11. The method of claim 10 wherein the method is performed by a server
2 system which is coupled to the cell site.

12. The method of claim 10, wherein the in view SPS satellites are in view of
2 at least one of a SPS reference receiver, a network of SPS reference receivers,
 the mobile SPS receiver, a cell of a cellular radio system, and a group of cells of
4 a cellular radio system.

13. The method of claim 11, wherein a transmitter is coupled with the mobile
2 SPS receiver and the server system receives pseudorange data from the mobile
SPS receiver and determines a position of the mobile SPS receiver.

14. The method of claim 11, wherein the server system uses the health data to
2 select a subset of the plurality of the in view SPS satellites and then computes a
position of the mobile SPS receiver based on the subset.

15. The method of claim 10, wherein the mobile SPS receiver uses the health
2 data to compute a position of the mobile SPS receiver.

16. The method of claim 10, wherein the mobile SPS receiver uses the health
2 data to select a subset of the plurality of the in view SPS satellites and then
compute a position of the mobile SPS receiver based on the subset.

17. A computer readable medium containing executable computer program
2 instructions, which when executed by a data processing system, cause the data
processing system to perform a method for processing satellite position system
4 (SPS) signals, the method comprising:

receiving the SPS signals from in view SPS satellites;
6 determining whether a first measurement, corresponding to a first SPS
satellite which has been indicated to be a healthy satellite, is to be
8 removed from a set of measurements to be used to solve for a
position of a mobile SPS receiver.

18. The computer readable medium of claim 17, wherein the determining
2 comprises testing the first measurement for a cross-correlation resulting from
signals from the first SPS satellite and signals from a second SPS satellite, and
4 wherein the first measurement is derived from the SPS signals.

19. The computer readable medium of claim 18, wherein the signals from the
2 first SPS satellite are weaker than the signals from the second SPS satellite which
has been indicated to be an unhealthy satellite.

20. The computer readable medium of claim 17, wherein the in view SPS
2 satellites are in view of at least one of a SPS reference receiver, a network of SPS
reference receivers, the mobile SPS receiver, a cell of a cellular radio system,
4 and a group of cells of a cellular radio system.

21. A computer readable medium containing executable computer program
2 instructions, which when executed by a data processing system, cause the data
processing system to perform a method for processing satellite positioning
4 system (SPS) signals, the method comprising:

attempting to acquire SPS signals from in view SPS satellites regardless
6 of whether the in view SPS satellites are unhealthy;
receiving health data specifying which of the in view SPS satellites are
8 unhealthy;
testing measurements obtained from acquiring the SPS signals, for all of
10 the in view SPS satellites, for a cross-correlation between two

12 different SPS satellites, wherein the testing is performed
regardless of whether an in view SPS satellite is unhealthy.

22. The computer readable medium of claim 21, wherein the method further
2 comprises:

removing from a set of measurements a first measurement, corresponding
4 to a first SPS satellite which has been indicated to be a healthy
satellite, wherein the set of measurements, after the removing, is
6 to be used to solve for a position of a mobile SPS receiver, and
wherein the first measurement is determined to be removed by the
8 testing.

23. The computer readable medium of claim 21, wherein the method further
2 comprises:

analyzing a first measurement, corresponding to a first SPS satellite
4 which has been indicated to be a healthy satellite, to determine
whether to remove the first measurement from a set of
6 measurements or correct the first measurement for use in the set
of measurements, wherein the set of measurements is to be used
8 to solve for a position of a mobile SPS receiver, and wherein the
first measurement is selected for the analyzing as a result of the
10 testing.

-24-

24. The computer readable medium of claim 21, wherein the in view SPS
2 satellites are in view of at least one of SPS a reference receiver, a network of SPS
reference receivers, the mobile SPS receiver, a cell of a cellular radio system,
4 and a group of cells of a cellular radio system.

25. A computer readable medium containing executable computer program
6 instructions, which when executed by a data processing system, cause the data
processing system to perform a method for providing assistance data to a mobile
8 satellite positioning system (SPS) receiver which is coupled to a receiver, the
method comprising:

10 determining a cell site or a group of cell sites which is in communication
with the receiver;
12 determining health data for each of a plurality of in view SPS satellites;
causing the health data to be transmitted to the receiver.

26. The computer readable medium of claim 25, wherein the method is
2 performed by a server system which is coupled to the cell site.

27. The computer readable medium of claim 25, wherein the in view SPS
2 satellites are in view of at least one of a SPS reference receiver, a network of SPS
reference receivers, the mobile SPS receiver, a cell of a cellular radio system,
4 and a group of cells of a cellular radio system.

28. The computer readable medium of claim 26, wherein a transmitter is
2 coupled with the mobile SPS receiver and the server system receives

4 pseudorange data from the mobile SPS receiver and determines a position of the
mobile SPS receiver.

29. The computer readable medium of claim 26, wherein the server system
2 uses the health data to select a subset of the plurality of the in view SPS satellites
and then compute a position of the mobile SPS receiver based on the subset.

30. The computer readable medium of claim 25, wherein the mobile SPS
2 receiver uses the health data to compute a position of the mobile SPS receiver.

31. The computer readable medium of claim 25, wherein the mobile SPS
2 receiver uses the health data to select a subset of the plurality of the in view SPS
satellites and then compute a position of the mobile SPS receiver based on the
4 subset.

32. An apparatus comprising:
2 a satellite position system (SPS) reference receiver, configured to receive
SPS signals from a plurality of in view SPS satellites;
4 a server, configured to communicate with the SPS reference receiver
wherein the server updates satellite health status; and
6 a transmitter coupled with the SPS reference receiver to transmit data
relating to the SPS signals.

-26-

33. The apparatus of claim 32, wherein the server analyzes the in view SPS
2 satellites' signals for a cross-correlation condition wherein a healthy SPS
satellite's signal is influenced by an unhealthy SPS satellite's signal, the
4 unhealthy SPS satellite's signal and the cross-correlated satellite's SPS signal
being removed before a location is computed from the in view SPS satellites.

34. The apparatus of claim 32, wherein the server analyzes the in view SPS
2 satellites' signals for a cross-correlation condition wherein a healthy SPS
satellite's signal is influenced by an unhealthy SPS satellite's signal, the
4 unhealthy SPS satellite's signal and the cross-correlated satellite's SPS signal
being corrected before a location is computed from the in view SPS satellites.

35. The apparatus of claim 32, wherein the server analyzes the in view SPS
2 satellites' signals for a cross-correlation condition wherein a healthy SPS
satellite's signal is influenced by an unhealthy SPS satellite's signal, the
4 unhealthy SPS satellite's signal and the cross-correlated satellite's SPS signal
being used when a location is computed from the in view SPS satellites.

36. The apparatus of claim 32, wherein the location is transmitted.

37. The apparatus of claim 32, wherein the server is connected to a wireless
2 network.

38. The apparatus of claim 37, wherein the location is provided to another
2 server connected to the wireless network.

39. The apparatus of claim 32, further comprising:
2 a mobile SPS receiver, wherein the mobile SPS receiver receives the SPS
signals from the transmitter and analyzes the in view SPS
4 satellites for a cross-correlation condition wherein a healthy SPS
satellite's signal is influenced by an unhealthy SPS satellite's
6 signal, the unhealthy SPS satellite's signal and the cross-
correlated SPS satellite's signal being removed or corrected
8 before a location is computed from the in view SPS satellites by
the mobile SPS receiver.

40. The apparatus of claim 32, wherein the transmitter is compatible with a
2 cellular radio system.

41. The apparatus of claim 32, wherein the in view SPS satellites are in view
2 of at least one of the SPS reference receiver, a network of SPS
reference receivers, a mobile SPS receiver, a cell of a cellular
4 radio system, and a group of cells of a cellular radio system.

42. An apparatus comprising:
2 a mobile satellite position system (SPS) receiver to receive SPS signals;
and
4 a receiver coupled with the mobile SPS receiver, wherein the mobile SPS
receiver receives the SPS signals from a transmitter and analyzes
6 in view SPS satellites for a cross-correlation condition wherein a

8 healthy SPS satellite's signal is influenced by an unhealthy SPS
 satellite's signal, the unhealthy SPS satellite's signal and the
 cross-correlated SPS satellite's signal being removed or corrected
10 before a location is computed from the in view SPS satellites by
 the mobile SPS receiver.

43. An apparatus to receive satellite position system (SPS) signals from a
2 server comprising:

4 a mobile SPS receiver to receive the SPS signals; and
 4 a receiver coupled with the mobile SPS receiver, wherein the server
 analyzes in view SPS satellites for a cross-correlation condition
6 6 wherein a healthy SPS satellite's signal is influenced by an
 unhealthy SPS satellite's signal, the unhealthy SPS satellite's
 8 signal and the cross-correlated SPS satellite's signal being
 removed or corrected before a location is computed from the in
 10 view SPS satellites by the server.

44. The apparatus of claim 42, wherein the receiver is compatible with a
2 cellular radio system.

45. A method for processing satellite position system (SPS) signals, the
2 method comprising:
 4 receiving SPS signals from SPS satellites in view of a mobile SPS
 receiver;

6 determining whether a first measurement, corresponding to a first SPS
satellite which has been indicated to be a healthy satellite, is to be
removed from a set of measurements to be used to solve for a
8 position of the mobile SPS receiver.

46. The method of claim 45, wherein the determining comprises testing the
2 first measurement for a cross-correlation resulting from signals from the first
SPS satellite and signals from a second SPS satellite, and wherein the first
4 measurement is derived from the SPS signals.

47. The method of claim 46, wherein the signals from the first SPS satellite
2 are weaker than the signals from the second SPS satellite which has been
indicated to be an unhealthy satellite.

48. A method for processing satellite positioning system (SPS) signals, the
2 method comprising:
4 attempting to acquire SPS signals from all SPS satellites in view of a
mobile SPS receiver regardless of whether the SPS satellites are
unhealthy;
6 receiving health data specifying which SPS satellites in view of the
mobile SPS receiver are unhealthy;
8 testing, for all SPS satellites in view, measurements obtained from
acquiring SPS signals for a cross-correlation between two
10 different SPS satellites, wherein the testing is performed
regardless of whether an SPS satellite in view is unhealthy.

49. The method of claim 48, further comprising:

2 removing from a set of measurements a first measurement, corresponding
4 to a first SPS satellite which has been indicated to be a healthy
6 satellite, wherein the set of measurements, after the removing, is
wherein the first measurement is determined to be removed by the
testing.

50. The method of claim 48, further comprising:

2 analyzing a first measurement, corresponding to a first SPS satellite
4 which has been indicated to be a healthy satellite, to determine
6 whether to remove the first measurement from a set of
measurements or correct the first measurement for use in the set
8 of measurements, wherein the set of measurements is to be used
to solve for a position of the mobile SPS receiver, and wherein the
first measurement is selected for the analyzing as a result of the
testing.

51. A method for providing assistance data to a mobile satellite positioning
2 system (SPS) receiver which is coupled to a cellular radio system, the method
comprising:

4 determining a cell site or a group of cell sites which is in cellular radio
communication with the cellular radio system;

-31-

6 determining health data for each of a plurality of SPS satellites in view of
 the mobile SPS receiver based on the determining the cell site or
8 the group of cell sites;
 causing the health data to be transmitted to the cellular radio system.

52. The method of claim 51, wherein the method is performed by a server
2 system which is coupled to the cell site.

53. The method of claim 52, wherein the server system receives pseudorange
2 data from the mobile SPS receiver and determines a position of the mobile SPS
 receiver.

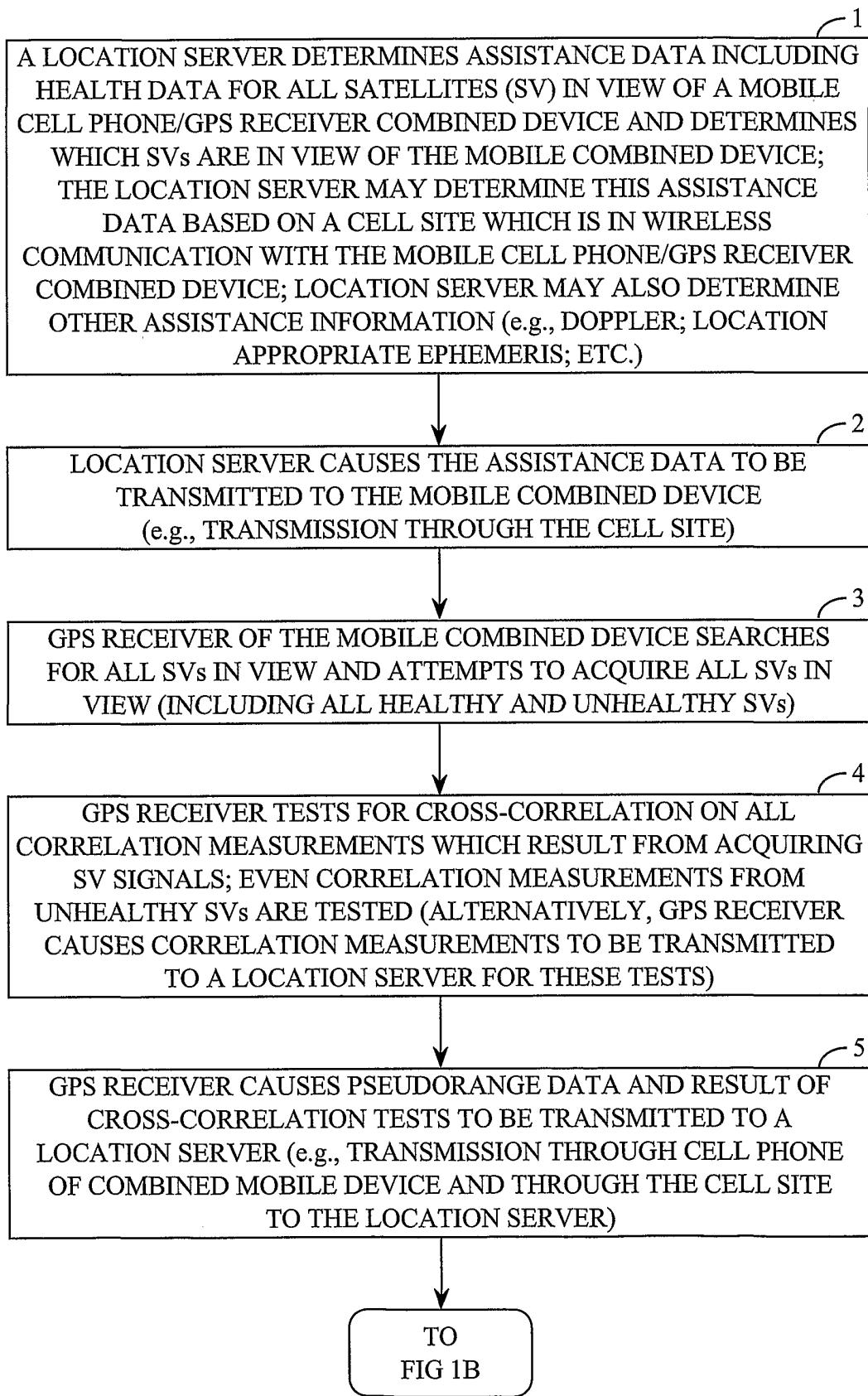


FIG. 1A

2/7

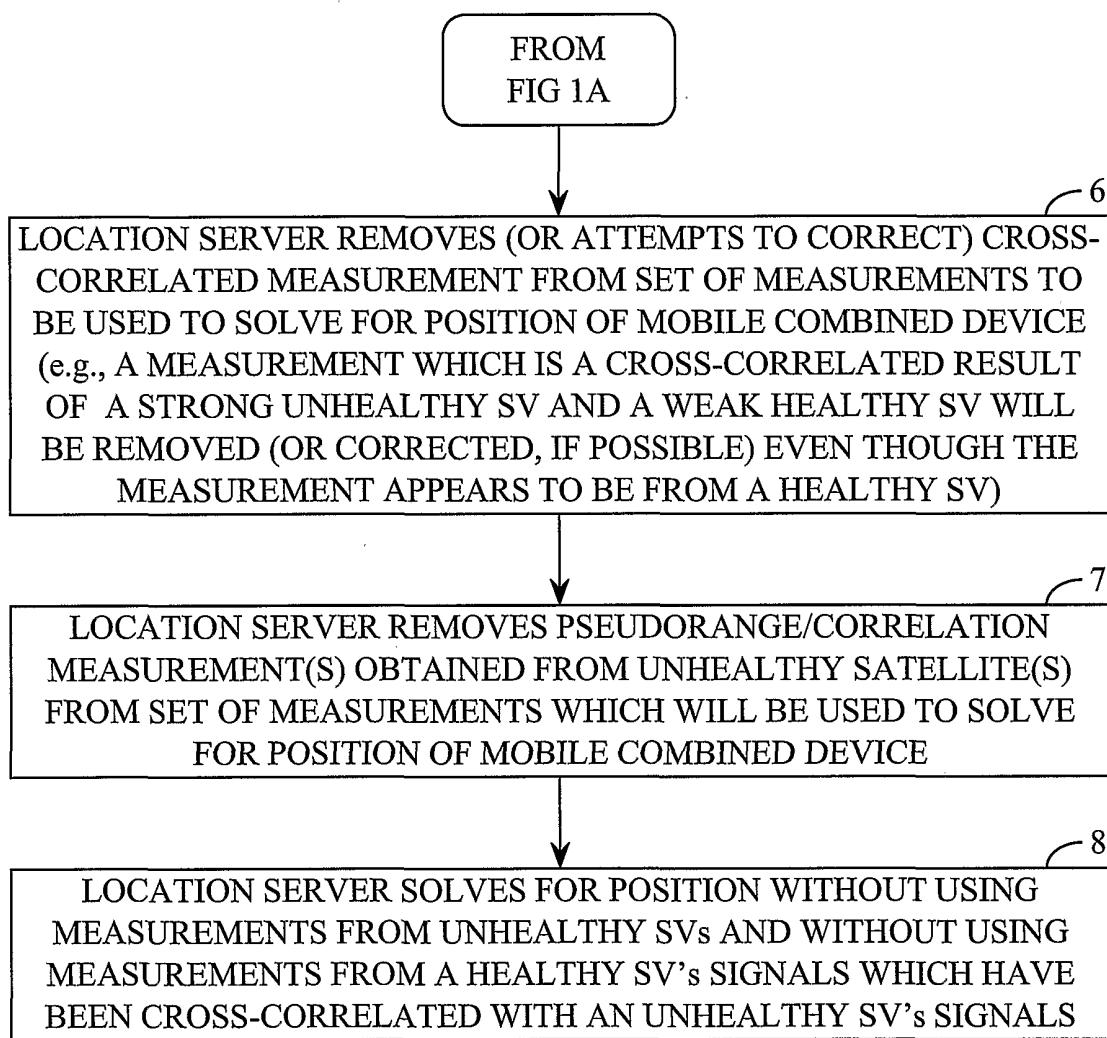


FIG. 1B

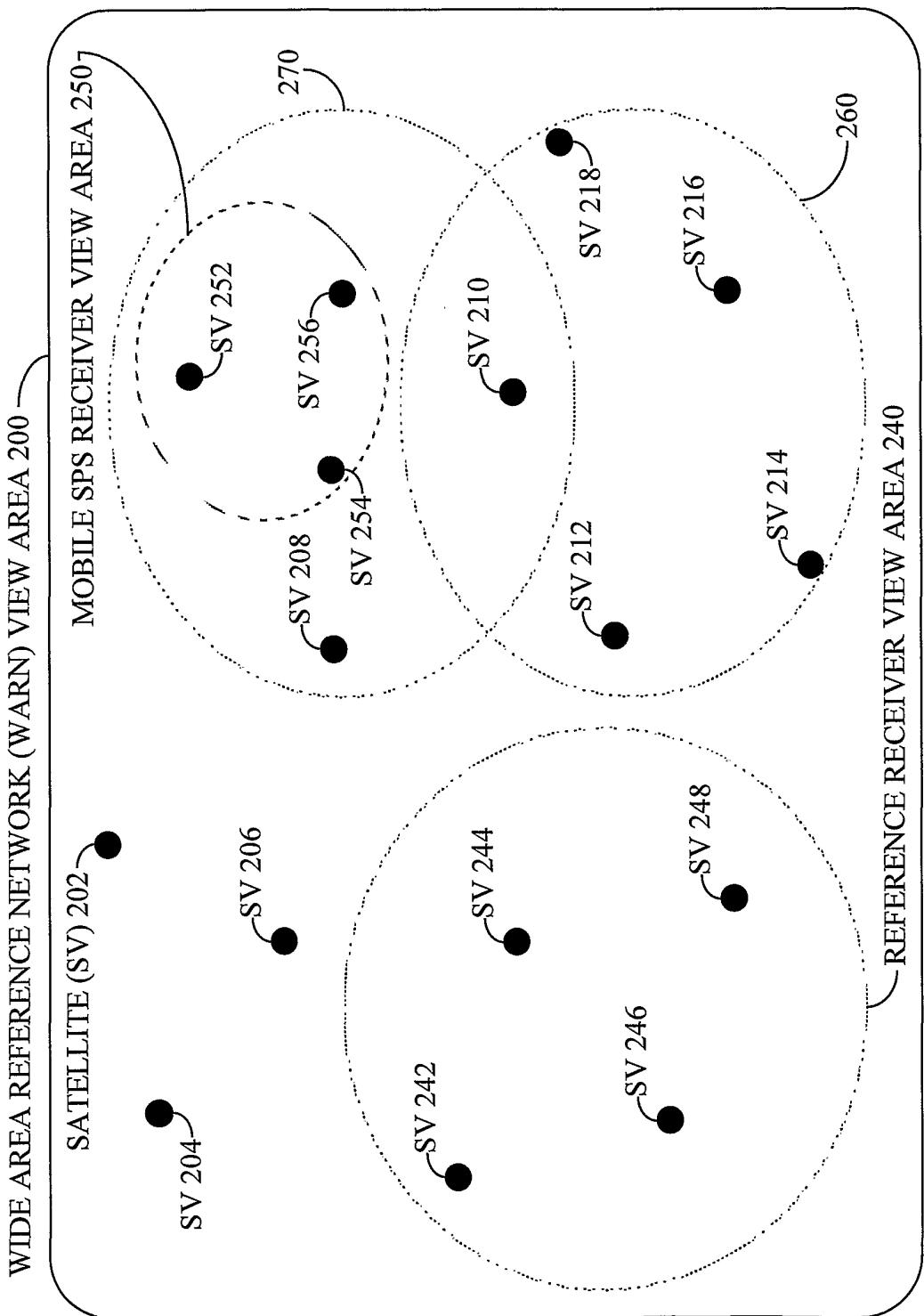


FIG. 2

4/7

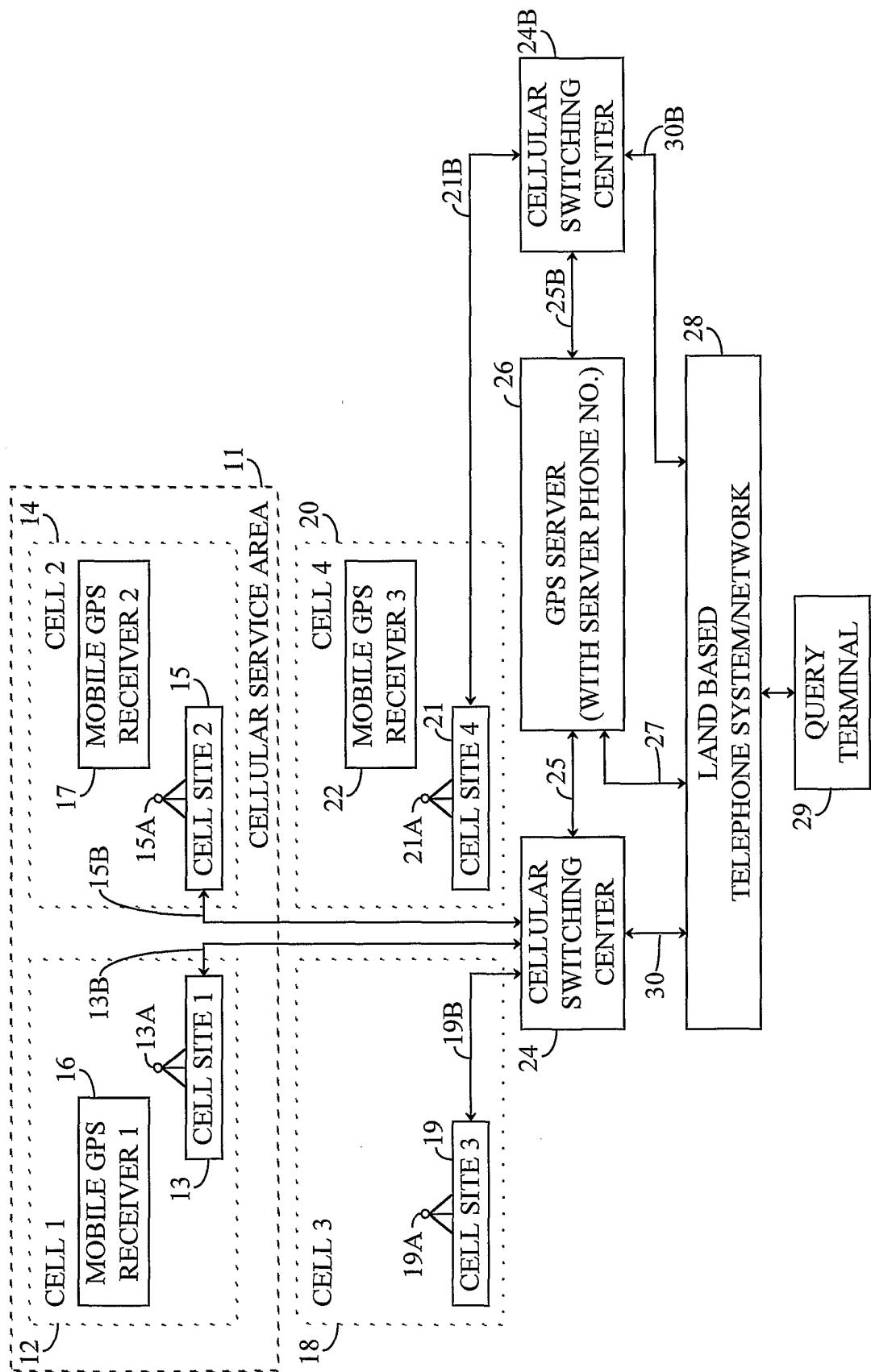


FIG. 3

5/7

C325

CELLULAR BASED INFORMATION SOURCE				
SERVICE AREA	CELL SITE #	SERVICE AREA # OR LOCATION	CELL SITE LOCATION	APPROXIMATE DOPPLER
A	-	LAT./LONG. A	-	DOPPLER SET A1 (t ₁) DOPPLER SET A2 (t ₂)
B	1	LAT./LONG. B	LAT./LONG. B1	DOPPLER SET B11 (t ₁) DOPPLER SET B12 (t ₂)
B	2	LAT./LONG. B	LAT./LONG. B2	DOPPLER SET B21 (t ₁) DOPPLER SET B22 (t ₂)
				325D
				325C
				325B
				325A
				325E

FIG. 4

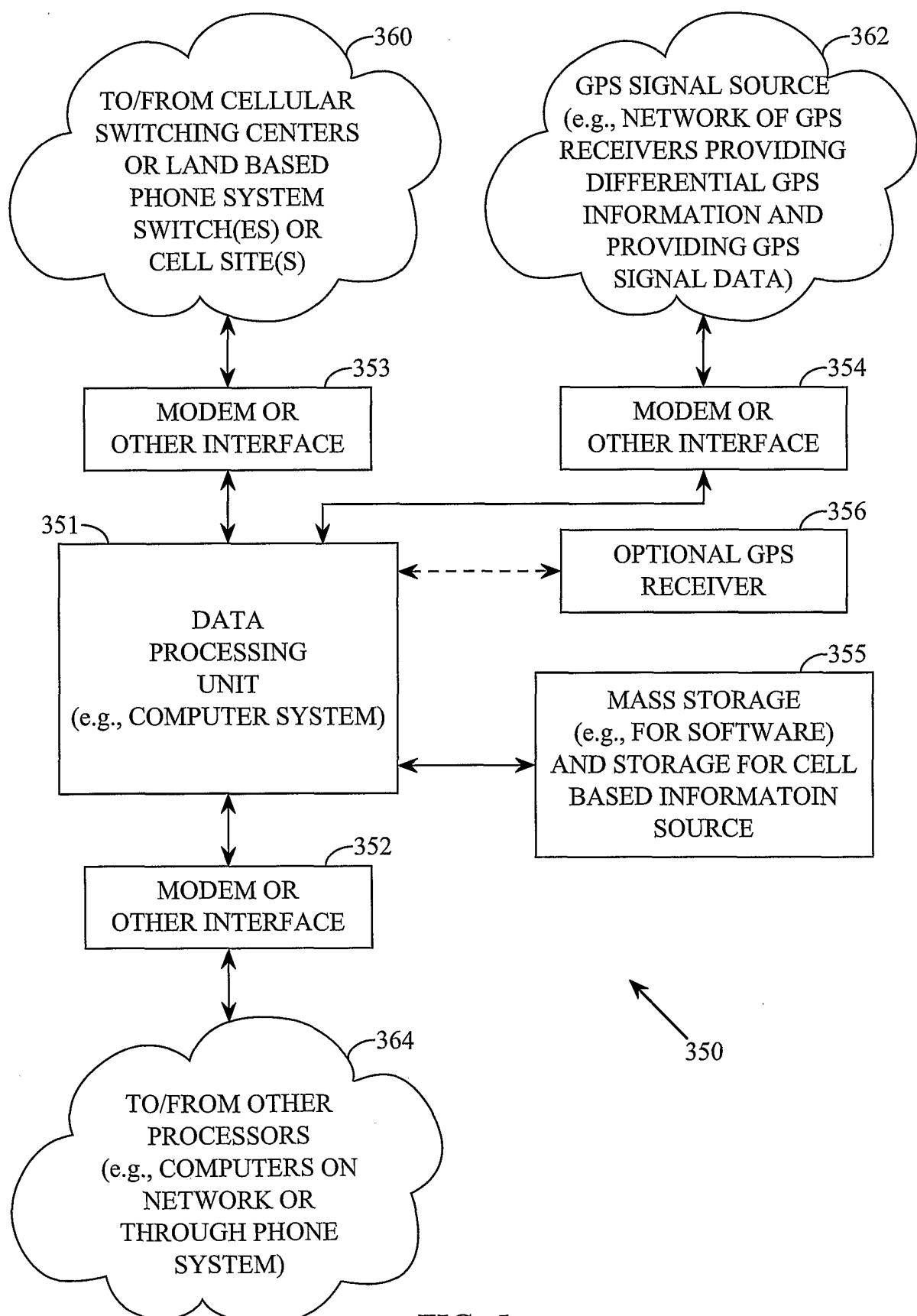


FIG. 5
SUBSTITUTE SHEET (RULE 26)

7/7

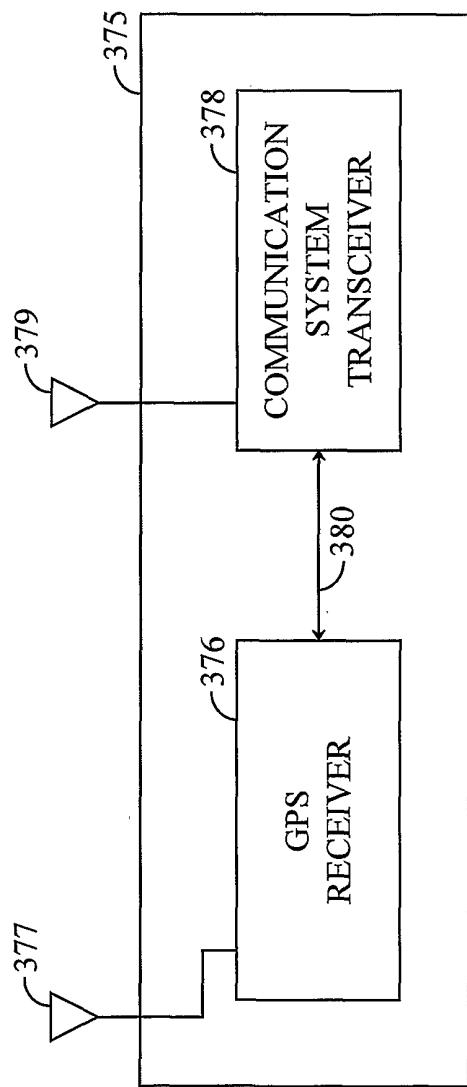


FIG. 6