PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01S 5/14 A1

(11) International Publication Number: WO 99/56145

(43) International Publication Date: 4 November 1999 (04.11.99)

(21) International Application Number: PCT/US99/08083

(22) International Filing Date: 13 April 1999 (13.04.99)

(30) Priority Data:
09/067,407 28 April 1998 (28.04.98) US

(71) Applicant: SNAPTRACK, INC. [US/US]; Suite 250, 4040 Moorpark Avenue, San Jose, CA 95117 (US).

(72) Inventors: MOEGLEIN, Mark; 635 Fontes Drive, Fremont, CA 94539 (US). SHEYNBLAT, Leonid; 1208 North Road, Belmont, CA 94002 (US). KRASNER, Norman, F.; 117 Coventry Court, San Carlos, CA 94070 (US).

(74) Agents: SCHELLER, James, C., Jr. et al.; Blakely, Sokoloff, Taylor & Zafman LLP, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025 (US).

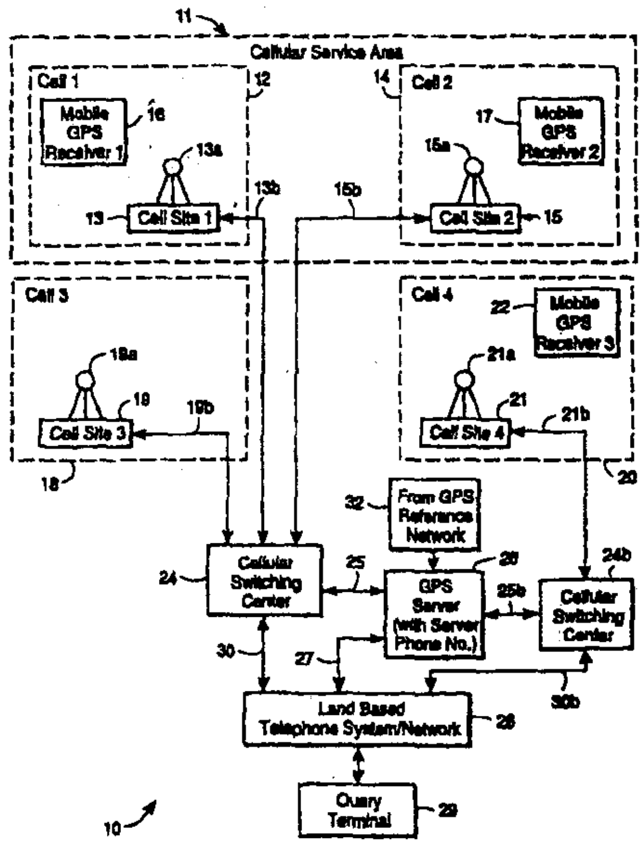
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, 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), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: SATELLITE POSITIONING REFERENCE SYSTEM AND METHOD

(57) Abstract

Satellite ephemeris data, received from SPS satellites in view of the particular SPS reference receiver. A plurality of digital processing system are coupled to the communication network to receive the satellite ephemeris data which is transmitted through the communication network. A digital processing system receives a pseudorange data from a SPS mobile receiver and calculates position information of the SPS mobile receiver from a representation of the pseudorange data and from satellite ephemeris data received from the communication network. The digital processing system may also receive pseudorange corrections from the communication network and use these corrections to correct the pseudorange data to provide the representation of the pseudorange data. In one embodiment of this example of the invention, the mobile SPS receivers are communicatively coupled.



8

1028 X 12 = 12340

SATELLITE POSITIONING REFERENCE SYSTEM AND METHOD

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application Serial No. 08/842,559, filed on April 15, 1997 by Norman F. Krasner.

BACKGROUND OF THE INVENTION

The present invention relates to satellite position systems which use reference receivers and more particularly to a network of reference receivers for a satellite positioning system.

Conventional satellite positioning systems (SPS) such as the U.S. Global Positioning System (GPS) use signals from satellites to determine their position. Conventional GPS receivers normally determine their position by computing relative times of arrival of signals transmitted simultaneously from a multiplicity of GPS satellites which orbit the earth. Each satellite transmits, as part of its navigation message, both satellite positioning data as well as data on clock timing which specifies its position and clock state at certain times; this data, found in subframes 1-3 of the GPS navigation message, is often referred to as satellite clock and ephemeris data and will be referred to as satellite ephemeris data. Conventional GPS receivers typically search for and acquire GPS signals, read the navigation message from each signal to obtain satellite ephemeris data for its respective satellite, determine pseudoranges to these satellites, and compute the location of the GPS receiver from the pseudoranges and satellite ephemeris data from the satellites.

Improved position accuracy can be obtained by using a well known and conventional technique referred to as differential GPS. With conventional differential GPS, a single differential reference station broadcasts differential GPS corrections to users in a local region. Thus, there are typically three major components of a conventional differential GPS system. The first component is a reference station at a known location with a GPS receiver at a known location which is usually capable of observing all satellites in view and optionally with software at the reference station, which could be imbedded in the GPS receiver, to compute the pseudorange corrections and to code them for specific broadcast format. Another component is a radio link to transmit the differential corrections in real time to mobile GPS receivers. The third component is the mobile GPS receiver which also includes a receiver for receiving the differential corrections broadcast from the reference station.

The differential GPS corrections are used by the mobile GPS receivers in a conventional manner to correct the pseudorange data which is obtained by computing the relative times of arrival of signals of GPS signals transmitted from the GPS satellites. Conventional differential GPS does not have to operate in real time or provide corrections to the mobile GPS receiver, although this is often the case. There are many improvements on differential GPS which are described in both patent and non patent literature. These various improvements concentrate on the differential correction computation and application algorithms as well as methods of delivering the differential corrections. The differential corrections are for the most part in the measurement domain (pseudorange, accumulated delta-range, and range-rate error estimates).

Conventional differential GPS offers significant position accuracy improvement if both the reference receiver and the participating mobile GPS receiver are in close proximity to each other. However, the accuracy improvement from differential GPS degrades as the separation distance between the two receivers increases. One solution to rectify this degrading of accuracy is to provide a network of GPS reference receivers which are dispersed over a geographical area to provide area coverage which coincides with the area in which the mobile GPS receivers may operate such that they tend to see the same set of satellites. In this instance, a mobile GPS receiver may pick up differential corrections from more than one differential reference station, and the mobile GPS receiver may select those differential corrections for satellites in view based upon the relative proximity between the mobile GPS receiver and the two or more reference stations. The use of multiple reference stations in a differential GPS system is sometimes referred to as wide-area differential GPS (WADGPS).

A further form of a WADGPS reference system includes a network of GPS reference receivers and a master station which is in communication with the reference stations to receive their measurements and compute a merged set of ephemeris and clock correction estimates for each GPS satellite observed by the reference stations. This master station can then provide through a transmitter a differential GPS message with corrections applicable over an extended range.

Examples of such wide-area differential GPS reference systems include those described in U.S. Patent Nos. 5,323,322 and 5,621,646.

Independent of the coverage of the particular differential reference system, the prime objective of a differential GPS system is to provide differential service which helps the mobile GPS receiver to remove errors from the GPS measurements or measurement derived solution. The GPS system errors that the network attempts to remove is a function of the number of reference stations, their spatial placement, and the sophistication of the algorithms implemented at the central processing facility. The secondary function of the differential networks is to provide integrity and reliability to the differential service by performing various checks in the measurement and the state space domains.

While the foregoing systems provide improved accuracy to mobile GPS receivers, those systems are not compatible with a client/server GPS architecture in which a mobile GPS receiver functions as a client system and provides pseudorange measurements to a remotely positioned location server which completes the calculations for the position solution by using the pseudoranges obtained from the mobile GPS receiver and by using ephemeris data. The present invention provides an improved method and apparatus allowing flexibility in the positioning of location servers and also provides for improved efficiency and cost in a client/server system.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatuses for a satellite positioning system reference system.

In one aspect of the present invention, an exemplary method processes satellite position information by using at least two SPS reference receivers. According to this method, a first digital processing system receives a first satellite ephemeris data from a first SPS reference receiver which has a first known position. The first digital processing system also receives a second satellite ephemeris data from a second SPS reference receiver having a second known position. The first digital processing system further receives a plurality of pseudorange data from a mobile SPS receiver. The first digital processing system then typically calculates the position information (e.g. latitude and longitude and altitude) of the mobile SPS receiver using the plurality of pseudorange data and at

20

least one of the first satellite ephemeris data and the second satellite ephemeris data. In one particular embodiment of the present invention, the first satellite ephemeris data and the second satellite ephemeris data are a subset of the "raw" 50 bps satellite navigation message received respectively from the first SPS reference receiver and the second SPS reference receiver from the satellites in view of those two reference receivers. In one example, this satellite navigation message may be the 50 bit per second data message encoded into the GPS signals which has been received and decoded by the reference receivers and transmitted to the first digital processing system in real time or near real time.

According to another aspect of the present invention, a system for processing satellite position information includes a plurality of satellite positioning system (SPS) reference receivers, each having a known location. It also includes a plurality of digital processing systems. The plurality of SPS reference receivers is dispersed over a geographical region and each receives satellite ephemeris data from satellites in view of the respective SPS reference receiver. Each of the plurality of SPS receivers transmits, into a communication network, the satellite ephemeris data which it receives. This system also includes a plurality of digital processing systems, each of which is coupled to the communication network to receive at least some of the satellite ephemeris data transmitted through the communication network. In one embodiment, at least two such digital processing systems exist. A first digital processing system receives a first plurality of pseudorange from a first mobile SPS receiver and calculates a first position information (e.g. a latitude and a longitude) of the first mobile SPS receiver from the first plurality of pseudorange data and from satellite ephemeris data received from the communication network. Typically, the first digital processing system selectively receives from the network the proper satellite ephemeris data for at least those satellites which are in view of the first mobile SPS receiver. A second digital processing system receives a second plurality of pseudorange data from a second mobile SPS receiver and calculates a second position information of the second mobile SPS receiver from the second plurality of pseudorange data and from satellite ephemeris data received from the communication network. In one example of the invention, the second digital processing system selectively receives from the network the appropriate satellite ephemeris for those satellites in view of the second mobile SPS receiver. In another example of the invention, the first and second digital processing systems each receive from the network the most up-to-date satellite ephemeris data which are in view of the network.

In one further embodiment of the present invention, a further digital processing system may be coupled to the communication network in order to receive measurements (e.g. differential corrections) from the reference receivers and to produce a set of network differential corrections. Various other aspects and embodiments of the present invention are further described below.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

Figure 1 illustrates a cell based communication system having a plurality of cells each of which is serviced by a cell site, and each of which is coupled to a cell based switching center, which is sometimes referred to as a mobile switching center.

Figure 2 illustrates an implementation of a location server system according to one embodiment of the invention.

Figure 3A illustrates an example of a combined SPS receiver and communication system according to one embodiment of the present invention.

Figure 3B illustrates an example of a GPS reference station according to one embodiment of the present invention.

Figure 4 illustrates an SPS reference receiver network according to one embodiment of the present invention.

Figures 5A and 5B show a flowchart which describes a method according to one embodiment of the present invention.

Figure 6 shows a data flow for a network correction processor which may be used in one embodiment of the reference receiver network according to the present invention.

Figure 7 shows an example of the data flow associated with the location server according to one embodiment of the present invention.

DETAILED DESCRIPTION

The present invention provides a network of SPS reference receivers which provide at least a portion of the satellite navigation message, such as satellite ephemeris data for use by digital processing systems in the manner described below. Before describing various details with respect to this reference system, it will be useful to describe the context in which this reference receiver is typically used. Accordingly, a preliminary discussion which refers to **Figures 1, 2,** and **3A** will be provided before discussing the network of SPS reference receivers in the system of the present invention.

Figure 1 shows an example of a cell based communication system 10 which includes a plurality of cell sites, each of which is designed to service a particular geographical region or location. Examples of such cellular based or cell based communication systems are well known in the art, such as the cell based telephone systems. The cell based communication system 10 includes two cells 12 and 14, both of which are defined to be within a cellular service area 11. In addition, the system 10 includes cells 18 and 20. It will be appreciated that a plurality of other cells with corresponding cell sites and/or cellular service areas may also be included in the system 10 coupled to one or more cellular switching centers, such as the cellular switching center 24 and the cellular switching center 24b.

Within each cell, such as the cell 12, there is a wireless cell or cellular site such as cell site 13 which includes an antenna 13a which is designed to communicate through a wireless communication medium with a communication receiver which may be combined with a mobile GPS receiver such as the receiver 16 shown in **Figure 1**. An example of such a combined system having a GPS receiver and a communication system is shown in **Figure 3A** and may include both a GPS antenna 77 and a communication system antenna 79.

Each cell site is coupled to a cellular switching center. In **Figure 1**, cell sites 13, 15, and 19 are coupled to switching center 24 through connections 13b, 15b and 19b respectively and cell site 21 is coupled to a different switching center 24b through connection 21b. These connections are typically wire line connections between the respective cell site and the cellular switching centers 24 and 24b. Each cell site includes an antenna for communicating with communication systems serviced by the cell site. In one example, the cell site may be a cellular telephone cell site which communicates with mobile cellular telephones in the area serviced by the cell site. It will be appreciated that a communication system within one cell, such as receiver 22 shown in cell 4, may in fact communicate with cell site 19 in cell 18 due to blockage (or other reasons why cell site 21 cannot communicate with the receiver 22).

In a typical embodiment of the present invention, the mobile GPS receiver 16 includes a cell based communication system which is integrated with the GPS receiver such that both the GPS receiver and the communication system are enclosed in the same housing. One example of this is a cellular telephone having an integrated GPS receiver which shares common circuitry with the cellular telephone transceiver. When this combined system is used for cellular telephone communications, transmissions occur between the receiver 16 and the cell site 13. Transmissions from the receiver 16 to the cell site 13 are then propagated over the connection 13b to the cellular switching center 24 and then to either another cellular telephone in a cell serviced by the cellular switching center 24 or through a connection 30 (typically wired) to another telephone through the land-based telephone system/network 28. It will be appreciated that the term wired includes fiber optic and other non wireless connections such as copper cabling, etc. Transmissions from the other telephone which is communicating with the receiver 16 are conveyed from the cellular switching center 24 through the connection 13b and the cell site 13 back to the receiver 16 in the conventional manner.

The remote data processing system 26 (which may be referred to in some embodiments as a GPS server or a location server) is included in the system 10 and is used to determine the state (e.g. the position and/or velocity and/or time) of a mobile GPS receiver (e.g. receiver 16) using GPS signals received by the GPS receiver. The GPS server 26 may be coupled to the land-based telephone system/network 28 through a connection 27, and it may also be optionally coupled to the cellular switching center 24 through the connection 25 and also optionally coupled to center 24b through the connection 25b. It will be appreciated that connections 25 and 27 are typically wired connections, although they may be wireless. Also shown as an optional component of the system 10 is a query terminal 29 which may consist of another computer system which is coupled through the network 28 to the GPS server 26. This query terminal 29 may send a request, for the position and/or velocity of a particular GPS receiver in one of the

34

cells, to the GPS server 26 which then initiates a conversation with a particular GPS receiver through the cellular switching center in order to determine the position and/or velocity of the GPS receiver and report requested information back to the query terminal 29. In another embodiment, a position determination for a GPS receiver may be initiated by a user of a mobile GPS receiver; for example, the user of the mobile GPS receiver may press 911 on the cell phone to indicate an emergency situation at the location of the mobile GPS receiver and this may initiate a location process in the manner described herein.

It should be noted that a cellular based or cell based communication system is a communication system which has more than one transmitter, each of which serves a different geographical area, which is predefined at any instant in time. Typically, each transmitter is a wireless transmitter which serves a cell which has a geographical radius of less than 20 miles, although the area covered depends on the particular cellular system. There are numerous types of cellular communication systems, such as cellular telephones, PCS (personal communication system), SMR (specialized mobile radio), one-way and two-way pager systems, RAM, ARDIS, and wireless packet data systems. Typically, the predefined geographical areas are referred to as cells and a plurality of cells are grouped together into a cellular service area, such as the cellular service area 11 shown in **Figure 1**, and these pluralities of cells are coupled to one or more cellular switching centers which provide connections to land-based telephone systems and/or networks. Service area are often used for billing purposes. Hence, it may be the case that cells in more than one service area are connected to one switching center. For example, in **Figure 1**, cells 1 and 2 are in service area 11 and cell 3 is in service area 13, but all three are connected to switching center 24. Alternatively, it is sometimes the case that cells within one service area are connected to different switching centers, especially in dense population areas. In general, a service area is defined as a collection of cells within close geographical proximity to one another. Another class of cellular systems that fits the above description is satellite based, where the cellular basestations or cell sites are satellites that typically orbit the earth. In these systems, the cell sectors and service areas move as a function of time. Examples of such systems include Iridium, Globalstar, Orbcomm, and Odyssey.

3 ✓

Figure 2 shows an example of a GPS server 50 which may be used as the GPS server 26 in **Figure 1**. The GPS server 50 of **Figure 2** includes a data processing unit 51 which may be a fault-tolerant digital computer system. The SPS server 50 also includes a modem or other communication interface 52 and a modem or other communication interface 53 and a modem or other communication interface 54. These communication interfaces provide connectivity for the exchange of information to and from the location server shown in **Figure 2** between three different networks, which are shown as networks 60, 62, and 64. The network 60 includes the cellular switching center or centers and/or the land-based phone system switches or the cell sites. An example of this network is shown in **Figure 1** wherein the GPS server 26 represents the server 50 of **Figure 6**. Thus the network 60 may be considered to include the cellular switching centers 24 and 24b and the land-based telephone system/network 28 and the cellular service area 11 as well as cells 18 and 20. The network 64 may be considered to include the query terminal 29 of **Figure 1** or the "PSAP," which is the Public Safety Answering Point which is typically the control center which answers 911 emergency telephone calls. In the case of the query terminal 29, this terminal may be used to query the server 26 in order to obtain a state (e.g. position) information from a designated mobile SPS receiver located in the various cells of the cell based communication system. In this instance, the location operation is initiated by someone other than the user of the mobile GPS receiver. In the case of a 911 telephone call from the mobile GPS receiver which includes a cellular telephone, the location process is initiated by the user of the cellular telephone. The network 62, which represents the GPS reference network 32 of **Figure 1**, is a network of GPS receivers which are GPS reference receivers designed to provide differential GPS correction information and also to provide GPS signal data including at least a portion of the satellite navigation message such as the satellite ephemeris data to the data processing unit. When the server 50 serves a very large geographical area, a local optional GPS receiver, such as optional GPS receiver 56, may not be able to observe all GPS satellites that are in view of mobile SPS receivers throughout this area. Accordingly, the network 62 collects and provides at least a portion of the satellite navigation message such as satellite ephemeris data and differential GPS correction data over a wide area in accordance with one embodiment of the present invention.

As shown in **Figure 6**, a mass storage device 55 is coupled to the data processing unit 51. Typically, the mass storage 55 will include storage for software and data for performing the GPS position calculations after receiving pseudoranges from the mobile GPS receivers, such as a receiver 16 of **Figure 1**. These pseudoranges are normally received through the cell site and cellular switching center and the modem or other interface 53. The mass storage device 55 also includes software, at least in one embodiment, which is used to receive and use the satellite ephemeris data provided by the GPS reference network 32 through the modem or other interface 54.

In a typical embodiment of the present invention, the optional GPS receiver 56 is not necessary as the GPS reference network 32 of **Figure 1** (shown as network 62 of **Figure 2**) provides the differential GPS information as well as providing the raw satellite navigation message from the satellites in view of the various reference receivers in the GPS reference network. It will be appreciated that the satellite ephemeris data obtained from the network through the modem or other interface 54 may be used in a conventional manner with the pseudoranges obtained from the mobile GPS receiver in order to compute the position information for the mobile GPS receiver. The interfaces 52, 53, and 54 may each be a modem or other suitable communication interface for coupling the data processing unit to other computer systems, as in the case of network 64, and to cellular based communication systems, as in the case of network 60, and to transmitting devices, such as computer systems in the network 62. In one embodiment, it will be appreciated that the network 62 includes a dispersed collection of GPS reference receivers dispersed over a geographical region.

Figure 3A shows a generalized combined system which includes a GPS receiver and a communication system transceiver. In one example, the communication system transceiver is a cellular telephone. The system 75 includes a GPS receiver 76 having a GPS antenna 77 and a communication transceiver 78 having a communication antenna 79. The GPS receiver 76 is coupled to the communication transceiver 78 through the connection 80 shown in **Figure 3A**. In one mode of operation, the communication system transceiver 78 receives approximate Doppler information through the antenna 79 and provides this approximate Doppler information over the link 80 to the GPS receiver 76 which performs the pseudorange determination by receiving the GPS signals from the

GPS satellites through the GPS antenna 77. This pseudorange is then transmitted to a location server, such as the GPS server shown in **Figure 1** through the communication system transceiver 78. Typically the communication system transceiver 78 sends a signal through the antenna 79 to a cell site which then transfers this information back to the GPS server, such as GPS server 26 of **Figure 1**. Examples of various embodiments for the system 75 are known in the art. For example, U.S. Patent 5, 663,734 describes an example of a combined GPS receiver and communication system which utilizes an improved GPS receiver system. Another example of a combined GPS and communication system has been described in co-pending Application Serial No. 08/652,833, which was filed May 23, 1996. The system 75 of **Figure 3A**, as well as numerous alternative communication systems having SPS receivers, may be employed with the methods of the present invention to operate with the GPS reference network of the present invention.

Figure 3B shows one embodiment for a GPS reference station. It will be appreciated that each reference station may be constructed in this way and coupled to the communication network or medium. Typically, each GPS reference station, such as GPS reference station 90 of **Figure 3B**, will include a single or dual frequency GPS reference receiver 92 which is coupled to a GPS antenna 91 which receives GPS signals from GPS satellites in view of the antenna 91. GPS reference receivers are well known in the art. The GPS reference receiver 92, according to one embodiment of the present invention, provides at least two types of information as outputs from the receiver 92. Pseudorange outputs 93 are provided to a processor and network interface 95, and these pseudorange outputs are used to compute pseudorange corrections in the conventional manner for those satellites in view of the GPS antenna 91. The processor and network interface 95 may be a conventional digital computer system which has interfaces for receiving data from a GPS reference receiver as is well known in the art. The processor 95 will typically include software designed to process the pseudorange data to determine the appropriate pseudorange correction for each satellite in view of the GPS antenna 91. These pseudorange corrections (and/or the pseudorange data outputs) are then transmitted through the network interface to the communication network or medium 96 to which other GPS reference stations are also coupled. The GPS reference receiver 92 also provides in one embodiment a representation of at least a portion of the satellite navigation message such as a satellite ephemeris data output 94. This data is provided to the processor and network interface 95 which then transmits this data onto the communication network 96.

In one embodiment, the entire satellite navigation message is transmitted into the network from each reference receiver at a higher than normal rate. Certain conventional GPS receivers can output raw (digital) navigation message data once every 6 seconds (which may be considered a normal rate); e.g. certain NovAtel GPS receivers have this capability. These receivers collect in a buffer the digital data of one subframe of the navigation message (300 bits in the case of a standard GPS signal), and then provide this data at the output of the receiver by shifting out the data in the buffer (after buffering a full subframe of 300 bits) once every 6 seconds. However, in one embodiment of the invention, at least a portion of a representation of the digital navigation message is transmitted into the network at a rate of once every 600 milliseconds. This high data rate makes it possible to perform a method for measuring time as described in co-pending U.S. Patent Application Serial No. 08/794,649, filed February 3, 1997. In this embodiment of the invention, a portion of the navigation message is transmitted into the network once every 600 milliseconds by collecting in a buffer only a portion of a subframe (e.g. 30 bits) and shifting out this portion once the portion is collected. Thus, the packets of data which are transmitted from the processor 95 into the network have a smaller portion of the navigation message than what could be provided at in packets created from a buffer of one full subframe (of 300 bits). It will be appreciated that once the buffer has collected the portion of the subframe (e.g. 30 bits), the data may be shifted out into packets which are transmitted at very high data rates (e.g. 512K bps) over the network of the present invention. These packets (containing fewer than a full subframe) are then reassembled at a receiving digital processing system by extracting and concatenating data from several packets to recreate the full subframe.

In one embodiment of the invention, each GPS reference station transmits a representation of at least a portion of the satellite navigation message and the pseudorange data (rather than the pseudorange correction data). The pseudorange correction data can be derived from pseudorange and ephemeris information for a particular satellite. Thus, a GPS reference station may transmit into the network either pseudorange correction data or ephemeris (or both). However, in a preferred embodiment, pseudorange data (instead of pseudorange correction data) is transmitted from each GPS reference station into the network because corrections from different receivers may be derived from different sets of ephemeris data, causing discrepancies in the corrections from different receivers. With this preferred embodiment, a central correction processor (such as network correction processor 110 shown in **Figure 4**) uses a consistent set of the most recent ephemeris data received from any of the GPS reference receivers, thus avoiding these discrepancies. The set is consistent because it consists of a group of ephemeris, range measurements (e.g. pseudoranges) and/or corrections from a plurality of satellites which is applicable at one particular instant in time. A set may be merged with other sets of data as long as the times of applicability of each set overlap.

Referring back to **Figure 3B**, the satellite ephemeris data output 94 provides typically at least part of the entire raw 50 baud navigation binary data encoded in the actual GPS signals received from each GPS satellite. The satellite ephemeris data is part of the navigation message which is broadcast as the 50 bit per second data stream in the GPS signals from the GPS satellites and is described in great detail in the GPS ICD-200 document. The processor and network interface 95 receives this satellite ephemeris data output 94 and transmits it in real time or near real time to the communication network 96. As will be described below, this satellite ephemeris data which is transmitted into the communication network is later received through the network at various location servers according to aspects of the present invention.

In certain embodiments of the present invention, only certain segments of the satellite navigation message may be sent to location servers in order to lower the bandwidth requirements for the network interfaces and for the communication network. Also, this data may not need to be provided continuously. For example, only the first three subframes which contain ephemeris information rather than all 5 subframes together may be transmitted into the communication network 96 when they contain updated information. It will be appreciated that in one embodiment of the present invention, the location server may use the navigation message data transmitted from one or more GPS reference receivers in order to perform a method for measuring time related to satellite data messages, such as the method described in co-pending U.S. Patent Application Serial No. 08/794,649, which

JN

was filed February 3, 1997, by Norman F. Krasner. It will be also understood that the GPS reference receiver 92 decoded the different GPS signals from the different GPS satellites in view of the reference receiver 92 in order to provide the binary data output 94 which contains the satellite ephemeris data.

Typically, the packets of data are not addressed to specific location servers and include portions of the navigation message and include an identifier of which data was received from which satellite; in some embodiments, the packets may also specify an identifier of the transmitting reference station. In some embodiments, the optional GPS receiver 56 may be the primary source of navigation message data which is used by the local location server and the network of the present invention may provide information on demand.

Figure 4 shows an example of a GPS reference receiver network. In the example of **Figure 4**, the entire system 101 includes two location servers 115 and 117 which are coupled to a communication network or medium 103 which corresponds to the communication network 96 of **Figure 3B**. Network correction processors 110 and 112 are also coupled to the communication network 103. Five GPS reference stations 104, 105, 106, 107, and 108 are shown in **Figure 4**. Each of these reference stations is coupled to the communication network 103. Each GPS reference station, such as GPS reference station 104, corresponds to the exemplary GPS reference station 90 shown in **Figure 3B**, and the communication network 103 corresponds to the communication network 96 shown in **Figure 3B**. It will be appreciated that the GPS reference stations, such as reference stations 104-108 are dispersed over a geographical region in order to provide receiver coverage for GPS signals which may also be received by mobile GPS receivers. Typically this coverage between adjacent reference stations overlaps such that a complete geographical area is completely covered. The geographical region for the entire network of reference stations may span the entire world or any subset thereof such as a city, a state, a nation, or a continent. Each GPS reference station, such as GPS reference station 104, provides pseudorange correction data to the communication network 103 and also provides the raw navigation data message which is used by the location servers as described herein, such as location server 115. As described below, the location servers may be fewer in number than the reference stations and thus will be processing pseudorange data from widely separated mobile GPS receivers. For example, one location server may be processing pseudorange data from a mobile GPS receiver in California and a reference station in California, and the same location server may be processing pseudorange data for a mobile GPS receiver in New York and a reference station in New York. Thus a single location server may be receiving navigation messages from two or more reference stations which may be widely dispersed. As shown in **Figure 4**, the communication network may be a data network such as a frame relay or ATM network or other high speed digital communication network.

Figure 4 also shows two network correction processors 110 and 112; these processors provide merged network corrections for multiple reference stations in one embodiment and may also provide ionospheric data to the location servers. The operation in one embodiment of a network correction processor is described further below. Typically, these processors determine the proper pseudorange corrections from pseudoranges and ephemeris having the same applicable time and merge the appropriate sets of corrections and ephemeris data into one set having the same or overlapping applicable time. The merged set is then retransmitted on the network for receipt by the location servers which are coupled to the network.

Figures 5A and **5B** show in flowchart form a method of one embodiment of the present invention. In this method 200, each GPS reference receiver receives satellite ephemeris data from GPS satellites in view of the particular reference receiver and transmits the satellite ephemeris data (navigation message) into a communication network, such as a packetized data network 103 shown in **Figure 4**. In a typical embodiment of this step 201, each GPS signal from a GPS satellite in view of the particular reference receiver is decoded to provide the binary 50 bit per second data stream which is present in the GPS signal, and this 50 bit per second data stream is transmitted into the communication network in real time or near real time. In an alternative embodiment, only portions of this data stream may be transmitted into the network as noted above. In step 203, each GPS reference receiver determines pseudorange corrections for pseudoranges to GPS satellites in view of the reference receiver; this operation may be performed in the conventional manner using a controller computer, such as the processor and network interface 95 shown in **Figure 3B**. These pseudorange corrections from each GPS reference receiver are then transmitted into the

yr

communication network, such as the communication network 96 or network 103 of **Figure 4**. In step 205, a processor, such as a network correction processor 110, which is coupled to the communication network, such as communication network 103, receives satellite ephemeris data and the pseudorange corrections. The network correction processor may produce a set of merged pseudorange corrections and perform other operations as described below. These merged pseudorange corrections are then transmitted into the communication network, such as communication network 103, in order that this information may be received by the various location servers which are also coupled to the communication network.

The method continues in step 207 in which a first location server receives at least a portion of the navigation message, such as satellite ephemeris data, and the merged pseudorange corrections from the network. Thus, for example, location server 115 may receive navigation message data which has been transmitted into the network by various GPS reference stations. This data is typically provided in a near real time manner, and typically each location server will receive at least satellite ephemeris data from two reference stations and often many more. Typically, the received satellite navigation message data is decoded by the location server to provide satellite clock and ephemeris data and is stored on the server, allowing the location server to calculate satellite positions and clock states on demand. This ephemeris data is used to calculate the position of a mobile GPS receiver after that receiver provides pseudoranges to satellites in view of the mobile GPS receiver. Thus, in step 209, the first location server receives pseudoranges from a first mobile GPS receiver and determines a position of the first mobile GPS receiver from satellite ephemeris data received from the network and from pseudoranges originating from the first mobile GPS receiver. The use of the network of reference stations allows the location server to calculate positions of mobile GPS receivers over a dispersed area which corresponds to the area of coverage of a GPS reference receiver network. Thus, rather than having a single GPS receiver located at the location server and providing ephemeris data to a location server, the dispersed network of GPS reference stations as shown in **Figure 4** allows the location server to provide position calculations for widely dispersed mobile GPS receivers. As shown in **Figure 4**, a second location server may also be coupled to the communication network 103 in order to provide position solution calculations for mobile GPS receivers. It will be appreciated that in one embodiment the location server 117 may be a redundant/backup server for the location server 115 in case the location server 115 fails. Typically, each location server will be a fault-tolerant computer system. In situations where high data processing demands may be placed on a particular location server due to the dense population in a region covered by the location server, several location servers may be deployed in this region in addition to redundant location servers. Step 211 and 213 illustrate the use of the second location server in a method of the present invention. In step 211, a second location server receives satellite ephemeris data and corrected pseudorange corrections from the communication network. It will be appreciated that the satellite ephemeris data received from the network may be satellite-specific for those satellites which are in view of the reference stations in the corresponding area served by the location server 117. This may be performed by placing header packets or other addressing data with the satellite ephemeris data transmitted from a reference station and the corrected pseudorange corrections in order to address the data to a particular location server. In step 213, the second location server receives pseudoranges from a second mobile GPS receiver and determines the state (e.g. position) of the second mobile GPS receiver from the satellite navigation message data received from the network and from the pseudoranges originating from the second mobile GPS receiver.

Figure 6 illustrates an example of the data flow in connection with a network correction processor, such as the processor 110 of **Figure 4**. Each network correction processor merges corrections from multiple reference stations into a single set of corrections (and adjustments) having substantially the same applicable time for use by a location server. In one embodiment, one particular location server may, if it fails to receive correction data from a particular network correction processor, request the same information from a backup network correction processor in a geographically diverse location. Upon arrival at a network correction processor, each correction set is buffered in memory for lookup and use as necessary. Atmospheric errors are removed, and the corrections are merged to form a best estimate of ranging error due to satellite clock and position errors (including SA dither). These merged network corrections are then transmitted, along with key ionospheric data and the most up-to-date navigation message for appropriate satellites in view. In one particular embodiment, this information is transmitted to all designated location servers (which has been designated as the addressees of the corrections from the network correction processor). Because each satellite vehicle is tracked by more than one reference receiver in one embodiment, each set of network corrections can be checked to ensure internal consistency. Thus, a pseudorange correction from a first reference station may be compared against a pseudorange correction to the same satellite from an adjacent reference station to ensure internal consistency. As shown in **Figure 6**, the reference stations 301 represent the geographically dispersed reference stations such as the stations 104-108 shown in **Figure 4**. The pseudorange correction data 303 and the navigation message data which includes, in one embodiment, at least a portion of the 50 bit data stream contained within the GPS signals is transmitted to a network correction processor. The network correction processor extracts iono parameters 310 and creates a correction set for a single epoch 309. Atmospheric delays are removed and merged corrections are created 316. The data flow of the various operations described herein is further shown in **Figure 6**.

Figure 7 illustrates an example of the flow of data in connection with a location server. **Figure 7** illustrates at least three different components of the system which are typically remotely located relative to the location server. The reference receiver network 401 corresponds to the reference stations 104-108 of **Figure 4**. These reference stations are coupled to the location server through a communication network, such as the network 103 of **Figure 4**. The reference receiver network 401 provides corrections and/or pseudorange data via the data network 403 and provides at least a portion of the navigation message 405 also via the data network. This navigation message typically includes the so-called satellite ephemeris data which is in one embodiment the 50 baud data stream in the GPS signals from each GPS satellite. The corrections 406 are merged, and checked for internal consistency in a correction processor and passed to the location server as corrections 408 and, optionally, geographic corrections, through the communication network. The navigation message data 407 is used to extract the ephemeris data for state (e.g. position) calculations for mobile GPS receivers. The state (e.g. position) calculation 410 may be aided by altitude estimates 412 from a terrain elevation database 411. The location server typically receives on a continuous basis both the correction data and the navigation message data via the communication network, such as the network 103. It will be appreciated therefore that the source of the satellite ephemeris data is not from a local GPS receiver which is co-located with the location server, but rather from a network of GPS reference receivers, such as the reference stations 104-108 of **Figure 4**. In this manner, the location server may serve a large geographical area which would not be possible with a reference GPS receiver co-located with the location server.

While the location server continues to receive at least a portion of the satellite navigation message data and correction data from the GPS reference receiver network, it may receive requests for the position of a mobile GPS receiver, which is shown as clients 424. A typical transaction with a mobile GPS receiver begins with the exchange of data. Typically, Doppler data 423 is provided to a mobile GPS receiver 424 (based upon approximate position data from the mobile receiver or a cellular network element) and then pseudorange data 425 is provided by a mobile GPS receiver to a client interface 420 on the location server. This location transaction may, as pointed out above, be initiated at the mobile GPS receiver by pressing 911 in the case of a cellular telephone, or it may be initiated by a remote operator 422 which may be considered to correspond to the query terminal 29 of **Figure 1**. As shown in **Figure 7**, the Doppler prediction 414 is provided from the location server through the client interface 420 to the mobile GPS receiver 424, and the mobile GPS receiver typically responds with pseudorange data 425 which is used in conjunction with the ephemeris data 409 to determine the position of the mobile GPS receiver. The position calculation may be performed with any of various conventional position calculation algorithms found in typical GPS receivers. This position, shown as navigation solution 414, may then be provided to client interface 420 which then may transfer this information through an executive module 421, which is typically a software module, to a remote operator 422. In one embodiment, the remote operator 422 is a PSAP (Public Safety Answering Point) which is the control center which answers 911 telephone calls.

The client interface 420 manages the communication link between the location server and the client, such as a mobile GPS receiver. In one embodiment, one client interface object is allocated to each mobile GPS receiver by the executive interface. The client interface may typically be implemented by software operating on the location server. The executive module 421, which is also typically software operating on the location server, assigns interfaces to address remote operation requests. It also controls the interface to external databases and performs network management and other external interactions as necessary. Typically, a particular location server will provide multiple remote operator interfaces. For example, standard frame relay, X.25, and TCP/IP network connectivity may be provided to meet remote operator requirements.

While the foregoing description has assumed a certain architecture (in which a mobile SPS receiver receives SPS signals from SPS satellites and determines pseudoranges to those satellites and then transmits the pseudoranges, with a time stamp, to a location server which determines the mobile receiver's position), it will be appreciated that other architectures may be employed with the present invention. For example, a mobile SPS receiver may determine its own position by receiving SPS signals and determining pseudoranges and by receiving and using satellite ephemeris data (e.g. from a location server which sends appropriate satellite ephemeris data based on the approximate location of the mobile SPS receiver determined from the cell site which is communicating with the mobile SPS receiver). In this example, the location server receives the satellite ephemeris data from the receivers of the reference network and upon a request for the location of the mobile receiver, transmits the appropriate satellite ephemeris data to the mobile receiver through the cell based communication system (e.g. a cellular telephone system). The satellite ephemeris data which is appropriate is typically determined from an approximate location of the mobile receiver; this approximate location may be determined from the location of the cell site which has established a cell based wireless communication link with the mobile receiver. The location server may determine this approximate location from an identifier provided by the cell site; various techniques for determining and using the approximate location are described in co-pending U.S. patent application Serial No. 08/842,559, filed April 15, 1997 by Norman F. Krasner, which application is hereby incorporated herein by reference. The approximate location will determine the satellites in view, and the location server may then transmit satellite ephemeris data for those satellites through a mobile switching center and the cell site to the mobile receiver. The location server may also transmit Doppler prediction data and/or satellite almanac and/or pseudorange corrections to the mobile SPS receiver in this example.

Although the methods and apparatus of the present invention have been 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 carrier signal, generally synchronized with GPS 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 or other enclosed areas. The term "satellite", as used herein, is intended to include pseudolite or equivalents of pseudolites, and the term GPS signals, as used herein, is intended to include GPS-like signals from pseudolites or equivalents of pseudolites.

In the preceding discussion the invention has been described with reference to application upon the United States Global Positioning Satellite (GPS) system. It should be evident, however, that these methods are equally applicable to similar satellite positioning systems, and in, particular, the Russian Glonass system. The Glonass system primarily differs from GPS system in that the emissions from different satellites are differentiated from one another by utilizing slightly different carrier frequencies, rather than utilizing different pseudorandom codes. In this situation substantially all the circuitry and algorithms described previously are applicable with the exception that when processing a new satellite's emission a different exponential multiplier corresponding to the different carrier frequencies is used to preprocess the data. The term "GPS" used herein includes such alternative satellite positioning systems, including the Russian Glonass system.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

CLAIMS

What is claimed is:

1. A method of processing satellite position information in a satellite positioning system (SPS), said method comprising:

receiving at a first digital processing system a first satellite ephemeris data from a first SPS receiver having a first known position;

receiving at said first digital processing system a second satellite ephemeris data from a second SPS receiver having a second known position;

receiving at said first digital processing system a plurality of pseudorange data from a mobile SPS receiver;

calculating a position information of said mobile SPS receiver using said plurality of pseudorange data and at least one of said first satellite ephemeris data and said second satellite ephemeris data.

2. A method as in claim 1 wherein said first digital processing system calculates said position information.

3. A method as in claim 1 wherein said first digital processing system is remotely positioned relative to said first known position and wherein said first SPS receiver is a first reference receiver.

4. A method as in claim 3 wherein said first digital processing system is remotely positioned relative to said second known position, and wherein said second SPS receiver is a second reference receiver.

5. A method as in claim 1 wherein said first satellite ephemeris data is received from a first set of SPS satellites in view of said first SPS receiver and wherein said second satellite ephemeris data is received from a second set of SPS satellites in view of said second SPS receiver.

6. A method as in claim 1, said method further comprising:

receiving at said first digital processing system a first pseudorange correction data from said first SPS receiver;

receiving at said first digital processing system a second pseudorange correction data from said second SPS receiver.

7. A method as in claim 6 wherein at least one of said first pseudorange correction data and said second pseudorange correction data is used to correct said plurality of pseudorange data from said mobile SPS receiver to provide a corrected plurality of pseudorange data.

8. A method as in claim 7 wherein said position information is calculated from said corrected plurality of pseudorange data and from at least one of said first satellite ephemeris data and said second satellite ephemeris data.

9. A method as in claim 5 wherein said first satellite ephemeris data comprises navigation messages from said first set of SPS satellites and said second satellite ephemeris data comprises navigation messages from said second set of SPS satellites.

10. A method as in claim 1, said method further comprising:

receiving at a second digital processing system a first pseudorange data from said first SPS receiver;

receiving at said second digital processing system a second pseudorange data from said second SPS receiver;

performing a correction using said first pseudorange data to provide a merged first pseudorange correction data and performing a correction using said second pseudorange data to provide a merged second pseudorange correction data;

transmitting at least one of said merged first pseudorange correction data and said merged second pseudorange correction data to said first digital processing system.

11. A method as in claim 10 wherein at least one of said merged first pseudorange correction data and said merged second pseudorange correction data is used to correct said plurality of pseudorange data from said mobile SPS receiver to provide a corrected plurality of pseudorange data.

12. A method as in claim 11 wherein said position information is calculated from said corrected plurality of pseudorange data and from at least one of said first satellite ephemeris data and said second satellite ephemeris data.

13. A method as in claim 12 wherein said first satellite ephemeris data is derived from navigation messages from a first set of SPS satellites which are in view of said first SPS receiver and said second satellite ephemeris data is derived from navigation messages from a second set of SPS satellites which are in view of said second SPS receiver.

14. A method as in claim 13 wherein said first satellite ephemeris data is received from said first SPS receiver through said second digital processing system, and said second satellite ephemeris data is received from said second SPS receiver through said second digital processing system.

15. A method as in claim 12 wherein said first digital processing system comprises a first fault tolerant computer system and said second digital processing system comprises a second fault tolerant computer system and wherein said first pseudorange data comprises at least one of first pseudoranges to satellites in view of said first SPS receiver and first corrections for pseudoranges to satellites in view of said first SPS receiver.

16. A method as in claim 12 wherein said first digital processing system is coupled to said mobile SPS receiver through a wireless cell based communication system.

17. A method as in claim 16 wherein said wireless cell based communication system comprises a mobile switching center.

18. A method as in claim 17 wherein said first SPS receiver, said second SPS receiver, said first digital processing system and said second digital processing system are coupled together through a packet data network.

19. A method as in claim 10, said method further comprising:

receiving at a third digital processing system said first pseudorange data from said first SPS receiver;

receiving at said third digital processing system said second pseudorange data from said second SPS receiver;

performing at said third digital processing system a correction using said first pseudorange data to provide said merged first pseudorange correction data and performing a correction using said second pseudorange correction data to provide said merged second pseudorange correction data, wherein said first digital processing system is capable of receiving said merged first pseudorange correction data and said merged second pseudorange correction data from said third digital processing system.

20. A system for processing satellite position information, said system comprising:

a plurality of satellite positioning system (SPS) reference receivers, each having a known position, said plurality of SPS reference receivers being dispersed over a geographical region, each of said plurality of SPS reference receivers transmitting, into a communication network, satellite ephemeris data received from satellites in view of each of said plurality of SPS reference receivers;

a plurality of digital processing systems, each coupled to said communication network to receive satellite ephemeris data transmitted through said communication network, said plurality of digital processing systems comprising a first digital processing system and a second digital processing system, said first digital processing system receiving a first plurality of pseudorange data from a first mobile SPS receiver and calculating a first position information of said first mobile SPS receiver from said first plurality of pseudorange data and from satellite ephemeris data received from said communication network, and said second digital processing system receiving a second plurality of pseudorange data from a second mobile SPS receiver and calculating a second position information of said second mobile SPS receiver from said second plurality of pseudorange data and from satellite ephemeris data received from said communication network.

21. A system as in claim 20 wherein said first digital processing system is communicatively coupled to said first mobile SPS receiver through a wireless cell based communication system, and said second digital processing system is communicatively coupled to said second mobile SPS receiver through said wireless cell based communication system.

22. A system as in claim 21 wherein said communication network is a packet data network.

23. A system as in claim 21 wherein said first digital processing system is remotely located relative to at least some of said plurality of SPS reference receivers.

24. A system as in claim 21 wherein said plurality of SPS reference receivers comprises a first SPS reference receiver and a second SPS reference receiver, and wherein said first SPS reference receiver transmits into said communication network a first satellite ephemeris data which is obtained from navigation messages received from a first set of SPS satellites which are in view of said first SPS reference receiver, and wherein said second SPS reference receiver transmits into said communication network a second satellite ephemeris data which is obtained from navigation messages from a second set of SPS satellites which are in view of said second SPS reference receiver.

25. A system as in claim 24 wherein said first digital processing system is capable of using said first satellite ephemeris data and said second satellite ephemeris data in calculating said first position information of said first mobile SPS receiver and said second digital processing system is capable of using said first satellite ephemeris data and said second satellite ephemeris data in calculating said second position information of said second mobile SPS receiver.

26. A system as in claim 24 wherein said first and said second digital processing systems receive a first pseudorange correction data derived from data from said first SPS reference receiver and a second pseudorange correction data derived from data from said second SPS reference receiver.

27. A system as in claim 26 wherein said first SPS reference receiver transmits said first pseudorange correction data into said communication network and said second SPS reference receiver transmits said second pseudorange correction data into said communication network.

28. A system as in claim 27 wherein at least one of said first pseudorange correction data and said second pseudorange correction data is used to correct said first plurality of pseudorange data to provide a first merged plurality of pseudorange data and wherein said first position information is determined from said first merged plurality of pseudorange data and at least one of said first satellite ephemeris data and said second satellite ephemeris data.

29. A system as in claim 24 further comprising:

a further digital processing system coupled to said communication network, said further digital processing system receiving a first pseudorange data from said first SPS reference receiver and receiving a second pseudorange data from said second SPS reference receiver, said further digital processing system performing a correction on said first pseudorange data to provide a merged first pseudorange correction data and performing a correction on said second pseudorange data to provide a merged second pseudorange correction data, and said further digital processing system transmitting at least one of said merged first pseudorange correction data and said merged second pseudorange correction data to said first digital processing system.

30. A computer readable storage medium containing executable computer program instructions which when executed cause a first digital processing system to perform a method comprising:

receiving at said first digital processing system a first satellite ephemeris data from a first satellite positioning system (SPS) receiver having a first known position;

receiving at said first digital processing system a second satellite ephemeris data from a second SPS receiver having a second known position;

receiving at said first digital processing system a plurality of pseudorange data from a mobile SPS receiver;

calculating a position information of said mobile SPS receiver using said plurality of pseudorange data and at least one of said first satellite ephemeris data and said second satellite ephemeris data.

31. A computer readable storage medium as in claim 30 wherein said first digital processing system is remotely positioned relative to said first known position and wherein said first SPS receiver is a reference receiver.

32. A computer readable storage medium as in claim 30 wherein said first satellite ephemeris data is received from a first set of SPS satellites in view of said first SPS receiver and wherein said second satellite ephemeris data is received from a second set of SPS satellites in view of said second SPS receiver.

33. A computer readable storage medium as in claim 30, said method further comprising:

receiving at said first digital processing system a first pseudorange correction data derived from said first SPS receiver;

receiving at said first digital processing system a second pseudorange correction data derived from said second SPS receiver.

34. A computer readable storage medium as in claim 33 wherein at least one of said first pseudorange correction data and said second pseudorange correction data is used to correct said plurality of pseudorange data from said mobile SPS receiver to provide a corrected plurality of pseudorange data.

35. A computer readable storage medium as in claim 34 wherein said position information is calculated from said corrected plurality of pseudorange data and

from at least one of said first satellite ephemeris data and said second satellite ephemeris data.

36. A system for processing satellite position information, said system comprising:

a communication medium;

a first satellite positioning system (SPS) reference receiver having a first known position and having a first communication interface which is coupled to said communication medium, said first SPS reference receiver transmitting a first satellite ephemeris data into said communication medium;

a second SPS reference receiver having a second known position and having a second communication interface which is coupled to said communication medium, said second SPS reference receiver transmitting a second satellite ephemeris data into said communication medium; and

a first digital processing system coupled to said communication medium to receive at least one of said first satellite ephemeris data and said second satellite ephemeris data and to provide satellite information for a mobile SPS receiver in order to determine a navigation solution of a position information for said mobile SPS receiver.

37. A system as in claim 36 wherein said first satellite ephemeris data is received from a first set of SPS satellites in view of said first SPS reference receiver and wherein said second satellite ephemeris data is received from a second set of SPS satellites in view of said second SPS reference receiver.

38. A system as in claim 37 wherein said communication medium comprises a packet data network, and wherein said first communication interface and said second communication interface respectively provide said first satellite ephemeris data and said second satellite ephemeris data in packet data form.

39. A system as in claim 37 wherein said first SPS receiver transmits a first pseudorange data into said communication medium and said second SPS receiver

transmits a second pseudorange data into said communication medium and wherein said first pseudorange data comprises at least one of first pseudoranges to satellites in view of said first SPS reference receiver and first corrections for pseudoranges to satellites in view of said first SPS reference receiver.

40. A system as in claim 39, said system further comprising:

a second digital processing system which is coupled to said communication medium, said first digital processing system receiving said first pseudorange data and receiving said second pseudorange data, and wherein said first digital processing system corrects said first pseudorange data to provide a first corrected pseudorange correction data which is transmitted into said communication medium and corrects said second pseudorange data to provide a second corrected pseudorange correction data which is transmitted into said communication medium.

41. A system for processing satellite position information, said system comprising:

a communication medium;

a first satellite positioning system (SPS) reference receiver having a first known position and having a first communication interface which is coupled to said communication medium, said first SPS reference receiver transmitting first packets of a first satellite ephemeris data into said communication medium, each of said first packets having less than a subframe of satellite ephemeris data;

a second SPS reference receiver having a second known position and having a second communication interface which is coupled to said communication medium, said second SPS reference receiver transmitting second packets of a second satellite ephemeris data into said communication medium, each of said second packets having less than a subframe of satellite ephemeris data.

42. A system as in claim 41 wherein said first satellite ephemeris data is received from a first set of SPS satellites in view of said first SPS reference

receiver and wherein said second satellite ephemeris data is received from a second set of SPS satellites in view of said second SPS reference receiver.

43. A system as in claim 42 wherein said communication medium comprises a packet data network, and wherein said first communication interface and said second communication interface respectively provide said first satellite ephemeris data and said second satellite ephemeris data in packet data form.

44. A system as in claim 42 wherein said first SPS receiver transmits a first pseudorange data into said communication medium and said second SPS receiver transmits a second pseudorange data into said communication medium and wherein said first pseudorange data comprises at least one of first pseudoranges to satellites in view of said first SPS reference receiver and first corrections for pseudoranges to satellites in view of said first SPS reference receiver.

45. A system as in claim 44, said system further comprising:

a first digital processing system which is coupled to said communication medium, said first digital processing system receiving said first pseudorange data and receiving said second pseudorange data, and wherein said first digital processing system corrects said first pseudorange data to provide a first corrected pseudorange correction data which is transmitted into said communication medium and corrects said second pseudorange data to provide a second corrected pseudorange correction data which is transmitted into said communication medium.

46. A system for processing satellite position information, said system comprising:

a communication medium;

a first satellite positioning system (SPS) reference receiver having a first known position and having a first communication interface which is coupled to said communication medium, said first SPS reference receiver transmitting first packets of a first satellite ephemeris data into said communication medium, each of said first packets having less than a subframe of satellite ephemeris data such that said first packets are transmitted into said communication medium at a high packets per second rate.

47. A system as in claim 41 wherein said first satellite ephemeris data is received from a first set of SPS satellites in view of said first SPS reference receiver.

48. A system as in claim 42 wherein said communication medium comprises a packet data network, and wherein said first communication interface provides said first satellite ephemeris data in packet data form.

49. A system as in claim 42 wherein said first SPS receiver transmits a first pseudorange data into said communication medium and wherein said first pseudorange data comprises at least one of first pseudoranges to satellites in view of said first SPS reference receiver and first corrections for pseudoranges to satellites in view of said first SPS reference receiver.

50. A system as in claim 44, said system further comprising:
a first digital processing system which is coupled to said communication medium, said first digital processing system receiving said first pseudorange data, and wherein said first digital processing system corrects said first pseudorange data to provide a first corrected pseudorange correction data which is transmitted into said communication medium.

51. A system as in claim 36 wherein said satellite information comprises at least one of satellite ephemeris data for satellites in view of said mobile SPS receiver or Doppler prediction data for said satellites in view or satellite almanac data and wherein said satellite information is transmitted to said mobile SPS receiver from said first digital processing system, and wherein said satellite ephemeris data for satellites in view of said mobile SPS receiver is obtained from at least one of said first satellite ephemeris data and said second satellite ephemeris data.

27

52. A system as in claim 51 wherein said mobile SPS receiver determines said navigation solution.

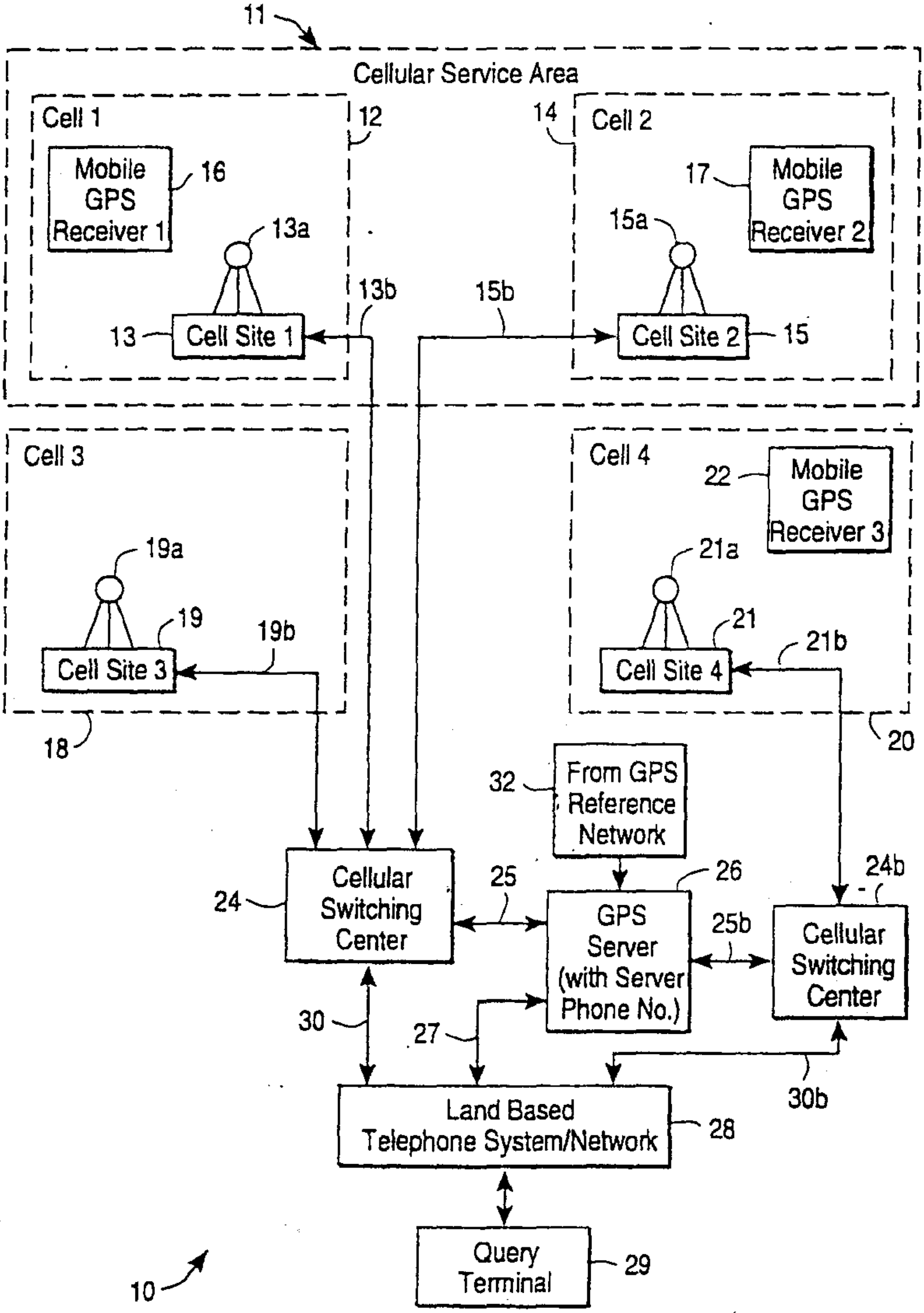

11
Cellular Service Area
Cell 1
12
14
Cell 2
Mobile GPS Receiver 1
16
17
Mobile GPS Receiver 2
13a
15a
13b
15b
13
Cell Site 1
Cell Site 2
15
Cell 3
Cell 4
22
Mobile GPS Receiver 3
19a
21a
19
19b
21
21b
Cell Site 3
Cell Site 4
18
20
32
From GPS Reference Network
26
24b
24
Cellular Switching Center
25
GPS Server (with Server Phone No.)
25b
Cellular Switching Center
30
27
30b
Land Based Telephone System/Network
28
Query Terminal
29
10

FIG. 1

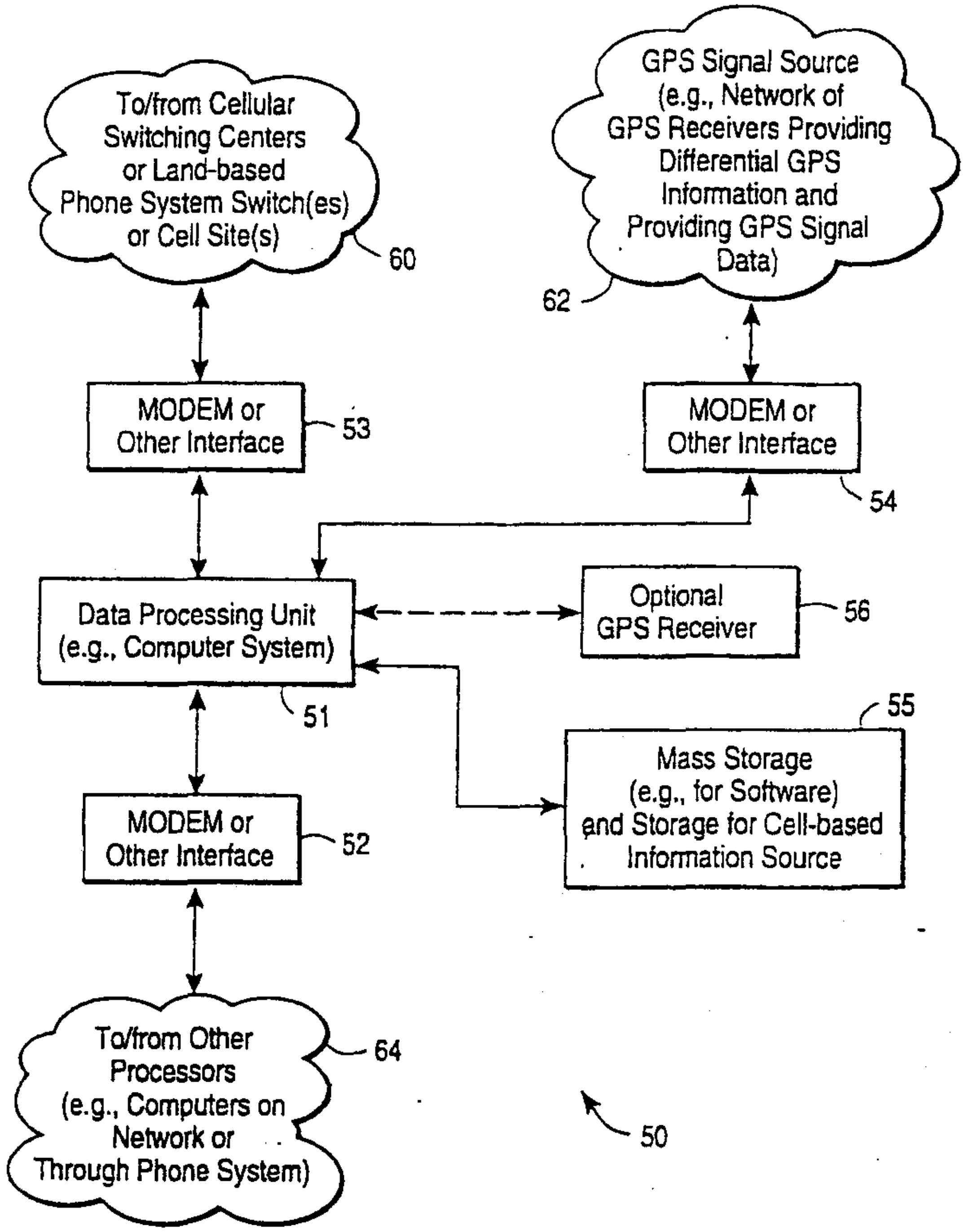

To/from Cellular Switching Centers or Land-based Phone System Switch(es) or Cell Site(s)
60
GPS Signal Source (e.g., Network of GPS Receivers Providing Differential GPS Information and Providing GPS Signal Data)
62
MODEM or Other Interface
53
MODEM or Other Interface
54
Data Processing Unit (e.g., Computer System)
51
Optional GPS Receiver
56
55
Mass Storage (e.g., for Software) and Storage for Cell-based Information Source
MODEM or Other Interface
52
To/from Other Processors (e.g., Computers on Network or Through Phone System)
64
50

FIG. 2

10

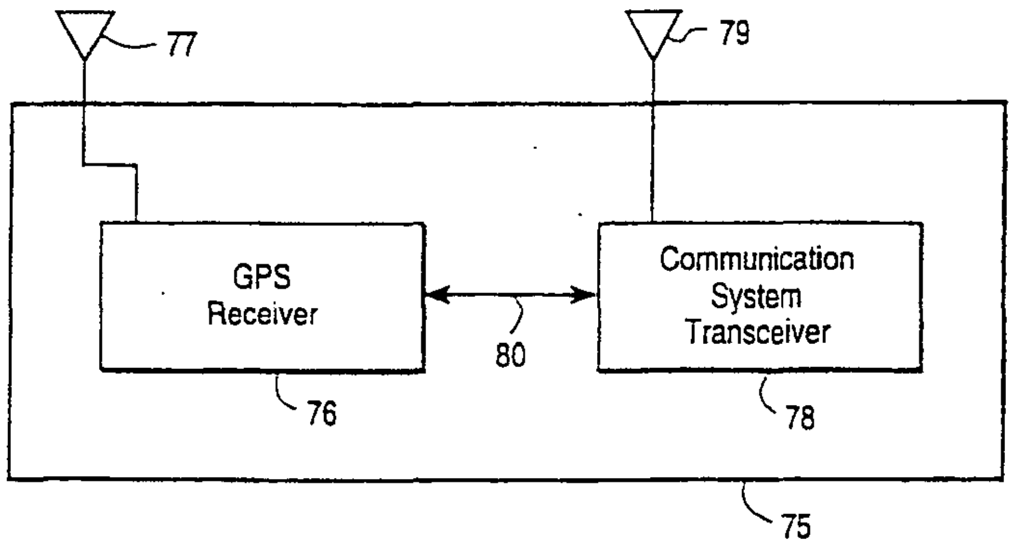

77
79
GPS
Receiver
Communication
System
Transceiver
80
76
78
75

FIG. 3A

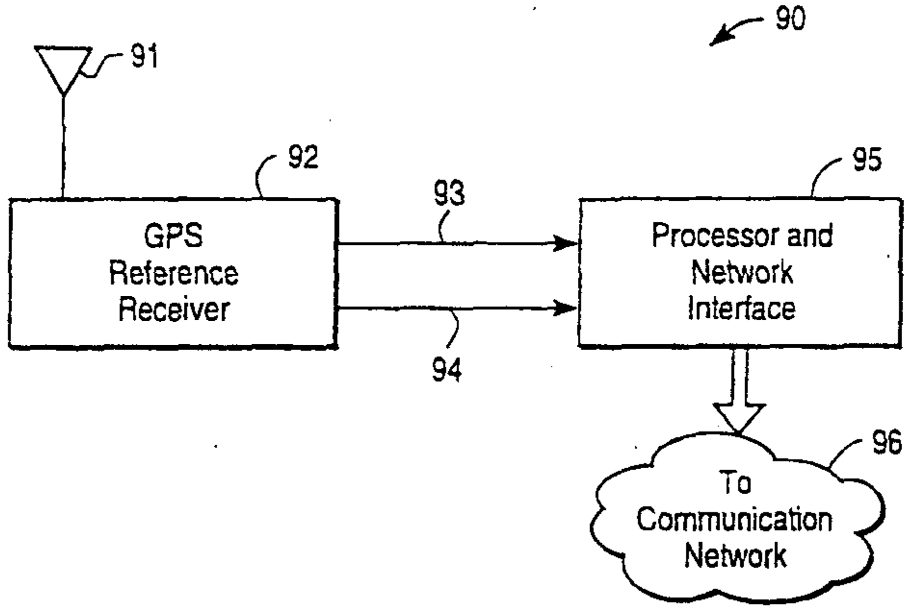

90
91
92
GPS
Reference
Receiver
93
94
95
Processor and
Network
Interface
96
To
Communication
Network

FIG. 3B

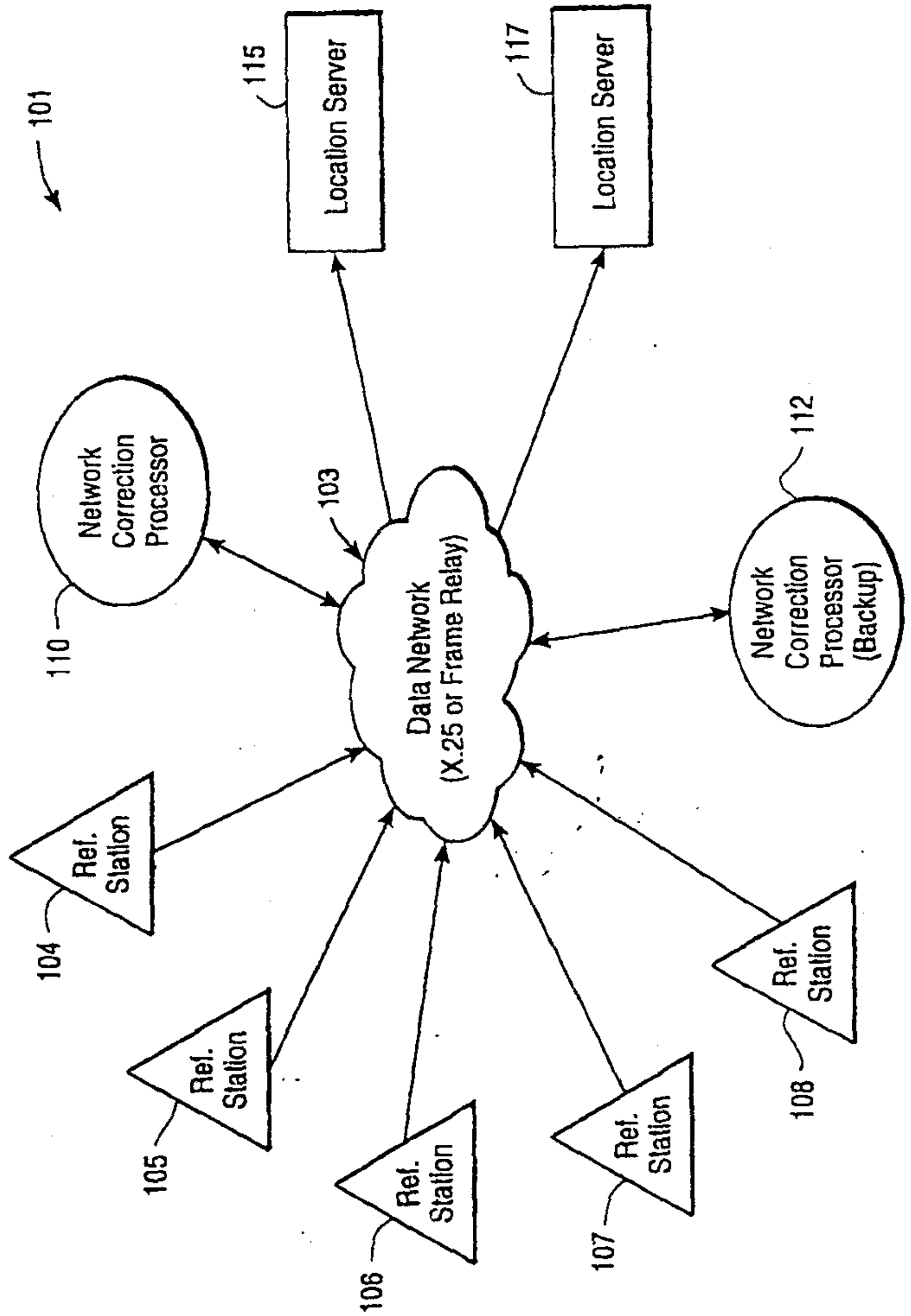

101
Location Server
115
Location Server
117
Network Correction Processor
110
103
Data Network (X.25 or Frame Relay)
Network Correction Processor (Backup)
112
Ref. Station
104
Ref. Station
105
Ref. Station
106
Ref. Station
107
Ref. Station
108

FIG. 4

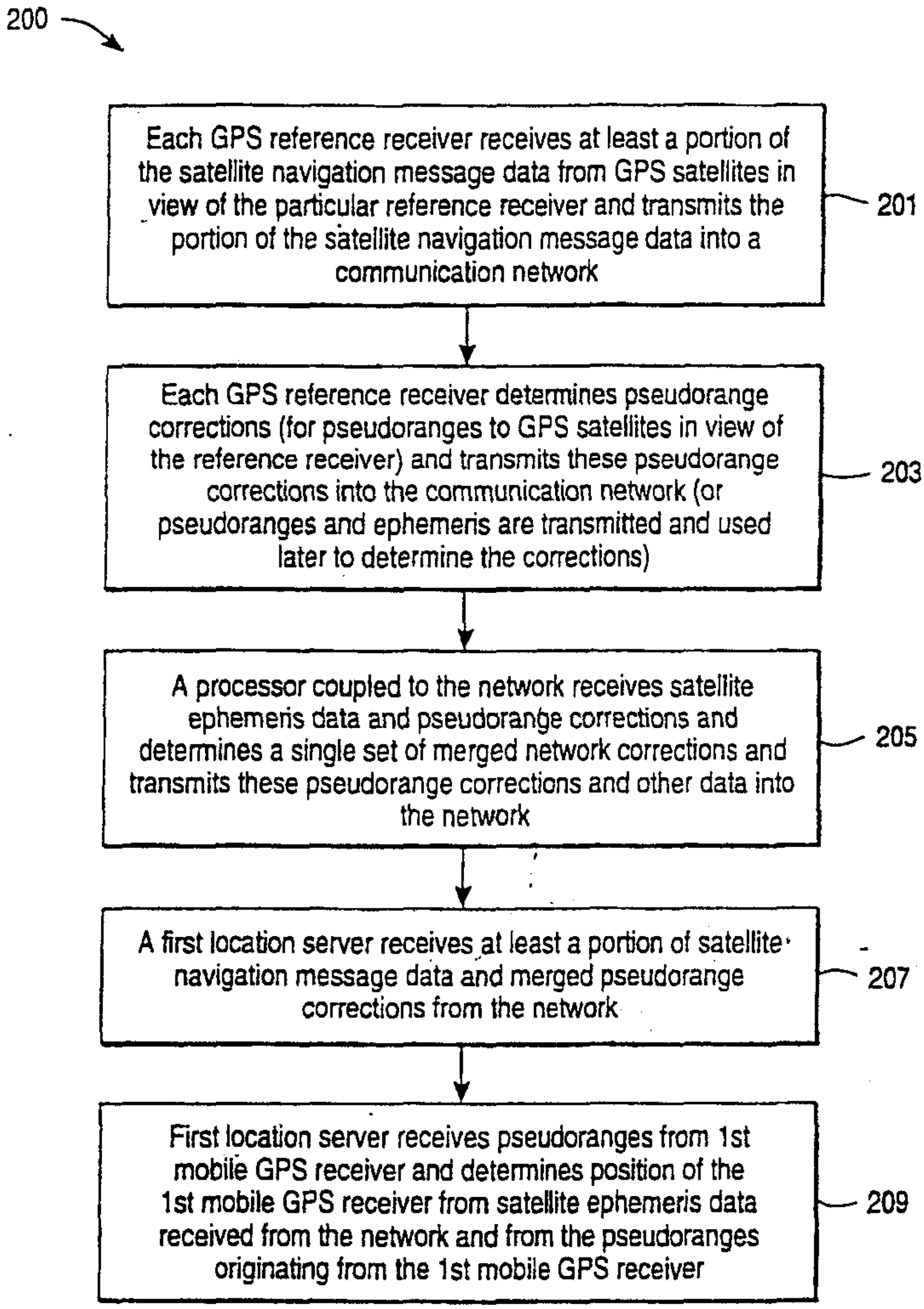

200
Each GPS reference receiver receives at least a portion of the satellite navigation message data from GPS satellites in view of the particular reference receiver and transmits the portion of the satellite navigation message data into a communication network
201
Each GPS reference receiver determines pseudorange corrections (for pseudoranges to GPS satellites in view of the reference receiver) and transmits these pseudorange corrections into the communication network (or pseudoranges and ephemeris are transmitted and used later to determine the corrections)
203
A processor coupled to the network receives satellite ephemeris data and pseudorange corrections and determines a single set of merged network corrections and transmits these pseudorange corrections and other data into the network
205
A first location server receives at least a portion of satellite navigation message data and merged pseudorange corrections from the network
207
First location server receives pseudoranges from 1st mobile GPS receiver and determines position of the 1st mobile GPS receiver from satellite ephemeris data received from the network and from the pseudoranges originating from the 1st mobile GPS receiver
209

FIG. 5A

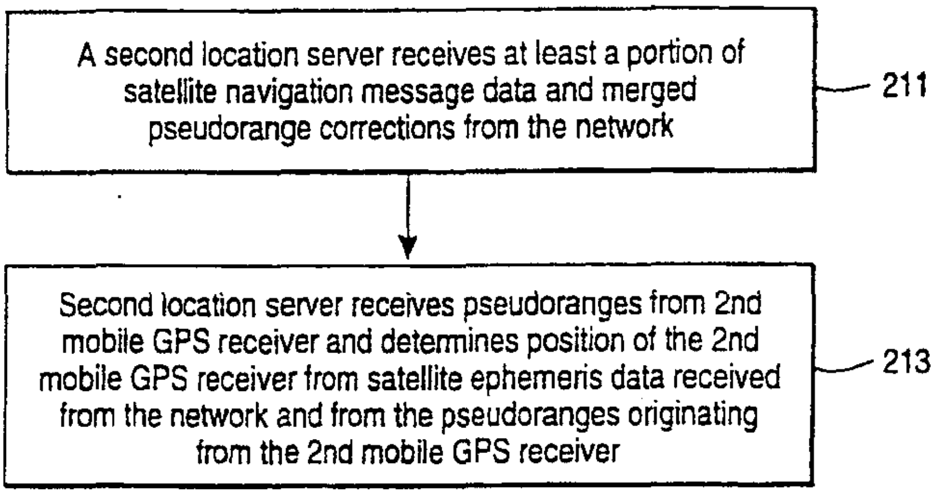

A second location server receives at least a portion of satellite navigation message data and merged pseudorange corrections from the network
211
Second location server receives pseudoranges from 2nd mobile GPS receiver and determines position of the 2nd mobile GPS receiver from satellite ephemeris data received from the network and from the pseudoranges originating from the 2nd mobile GPS receiver
213

FIG. 5B

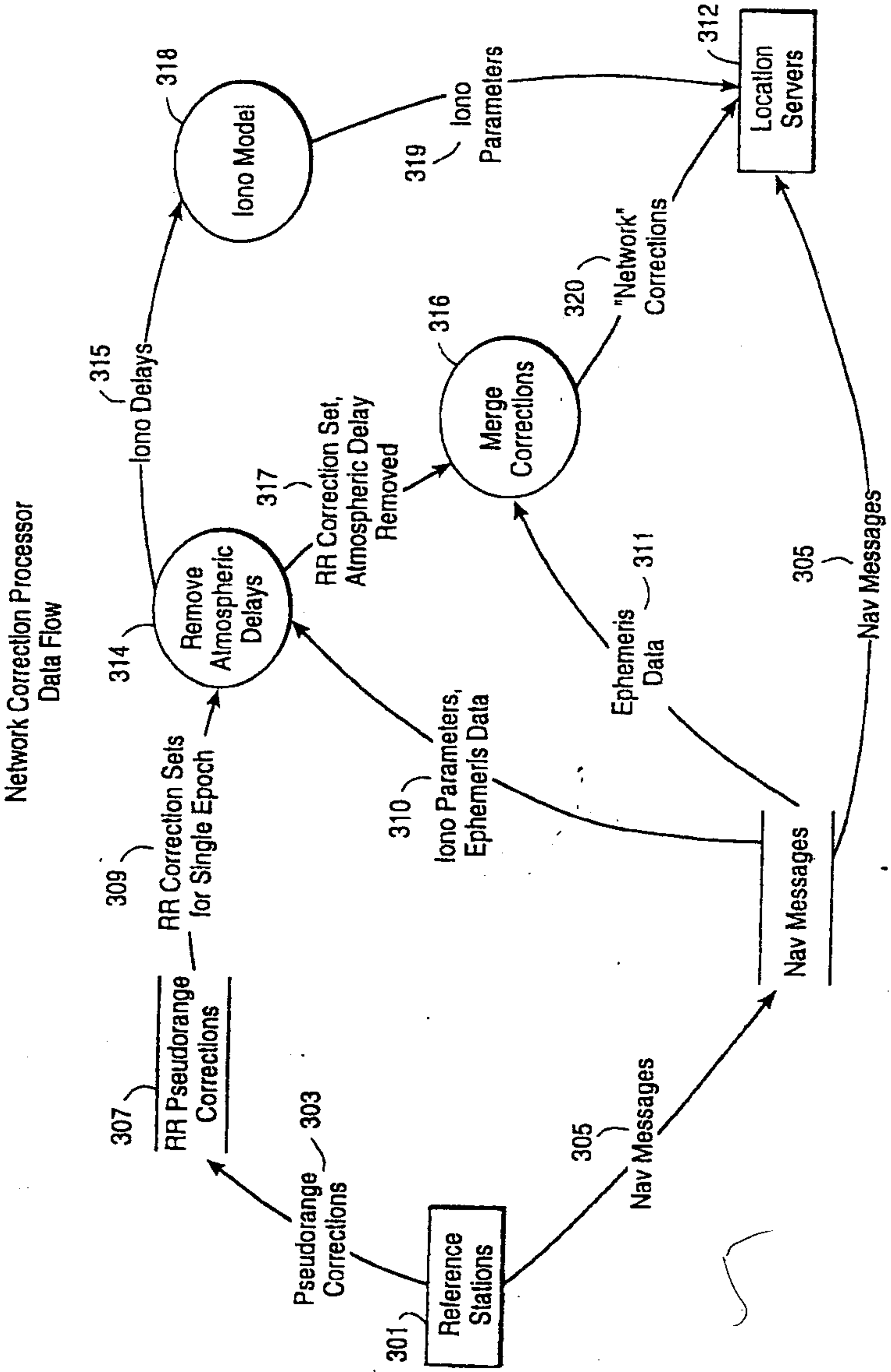

Network Correction Processor Data Flow
301
Reference Stations
Pseudorange Corrections
303
307
RR Pseudorange Corrections
309
RR Correction Sets for Single Epoch
314
Remove Atmospheric Delays
315
Iono Delays
318
Iono Model
319
Iono Parameters
312
Location Servers
317
RR Correction Set, Atmospheric Delay Removed
316
Merge Corrections
320
"Network" Corrections
310
Iono Parameters, Ephemeris Data
311
Ephemeris Data
305
Nav Messages
Nav Messages
305
Nav Messages

FIG. 6

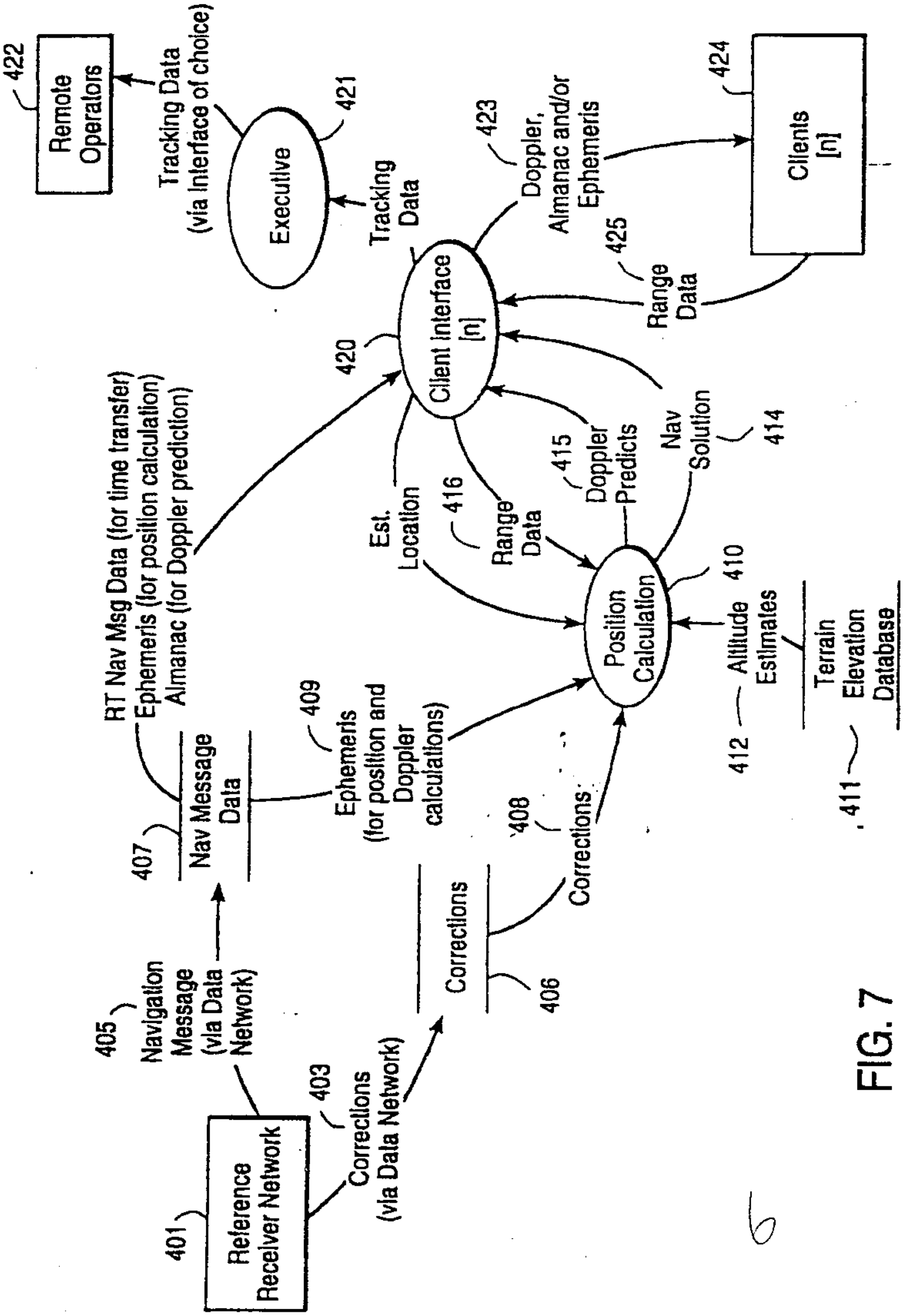

Remote Operators
422
Tracking Data (via Interface of choice)
Executive
421
Tracking Data
Clients [n]
424
Doppler, Almanac and/or Ephemeris
423
Range Data
425
Client Interface [n]
420
RT Nav Msg Data (for time transfer)
Ephemeris (for position calculation)
Almanac (for Doppler prediction)
Est. Location
416
Range Data
415
Doppler Predicts
Nav Solution
414
Position Calculation
410
Altitude Estimates
412
Terrain Elevation Database
411
Nav Message Data
407
409
Ephemeris (for position and Doppler calculations)
408
Corrections
Corrections
406
Navigation Message (via Data Network)
405
Corrections (via Data Network)
403
Reference Receiver Network
401

FIG. 7

[19]中华人民共和国国家知识产权局

[51]Int. Cl⁷

G01S 5/14

[12]发明专利申请公开说明书

[21]申请号 99807934.0

[43]公开日 2001年8月8日

[11]公开号 CN 1307683A

[22]申请日 1999.4.13 [21]申请号 99807934.0

[30]优先权

[32]1998.4.28 [33]US [31]09/067,407

[86]国际申请 PCT/US99/08083 1999.4.13

[87]国际公布 WO99/56145 英 1999.11.4

[85]进入国家阶段日期 2000.12.27

[71]申请人 施耐普特拉克股份有限公司

地址 美国加利福尼亚州

[72]发明人 M·默格林 L·希恩布莱特

N·F·克拉斯纳

[74]专利代理机构 上海专利商标事务所

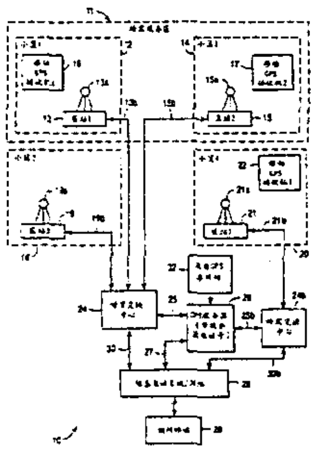
代理人 李家麟

权利要求书7页 说明书14页 附图页数9页

[54]发明名称 卫星定位参照系统与方法

[57]摘要

从看得到特定SPS参照接收机的SPS卫星接收卫星星历表数据。多个数据处 理系统耦接到通信网接收通过通信网发射的卫星星历表数据。数字处理系统从SPS移动接收机接收伪距离数据,并根据伪距离数据和从通信网接收的星历表数据计 算该SPS移动接收机的位置信息;该系统还从通信网接收伪距离校正值,并用该 校正值校正伪距离数据。



ISSN1008-4274

知识产权出版社出版

权　利　要　求　书

1. 一种在卫星定位系统（SPS）中处理卫星位置信息的方法，所述方法包括：

在第一数字处理系统处接收来自具有第一已知位置的第一 SPS 接收机的第一卫星星历表数据；

在所述第一数字处理系统处接收来自具有第二已知位置的第二 SPS 接收机的第二卫星星历表数据；

在所述第一数字处理系统处接收来自移动 SPS 接收机的多个伪距离数据；

用所述多个伪距离数据和所述第一与第二卫星星历表数据中的至少一种数据计算所述移动 SPS 接收机的位置信息。

2. 如权利要求 1 所述的方法，其特征在于，所述第一数字处理系统计算所述位置信息。

3. 如权利要求 1 所述的方法，其特征在于，所述第一数字处理系统相对于所述第一已知位置位于远端，其中所述第一 SPS 接收机是第一参照接收机。

4. 如权利要求 3 所述的方法，其特征在于，所述第一数字处理系统相对于所述第二已知位置位于远端，其中所述第二 SPS 接收机是第二参照接收机。

5. 如权利要求 1 所述的方法，其中所述第一卫星星历表数据是从看得到所述第一 SPS 接收机的第一组 SPS 卫星接收的，其中，所述第二卫星星历表数据是从看得到所述第二 SPS 接收机的第二组 SPS 卫星接收的。

6. 如权利要求 1 所述的方法，其特征在于，所述方法还包括：

在所述第一数字处理系统处接收来自所述第一 SPS 接收机的第一伪距离校正数据；

在所述第一数字处理系统处接收来自所述第二 SPS 接收机的第二伪距离校正数据。

7. 如权利要求 6 所述的方法，其特征在于，所述第一与第二伪距离校正数据中至少有一个用来校正来自所述移动 SPS 接收机的所述多个伪距离数据，以提供经校正的多个伪距离数据。

8. 如权利要求 7 所述的方法，其特征在于，所述位置信息是根据所述校正的多个伪距离数据和所述第一与第二卫星星历表数据中至少一个数据计算的。

9. 如权利要求 5 所述的方法，其特征在于，所述第一卫星星历表数据包括来自所述第一组 SPS 卫星的导航信息，所述第二卫星星历表数据包括来自所述第

二组 SPS 卫星的导航信息。

10 如权利要求 1 所述的方法，其特征在于，所述方法还包括：

在第二数字处理系统处接收来自所述第一 SPS 接收机的第一伪距离数据；

在所述第二数字处理系统处接收来自所述第二 SPS 接收机的第二伪距离数据；

用所述第一伪距离数据作校正以提供合并的第一伪距离校正数据，并用所述第二伪距离数据作校正以提供合并的第二伪距离校正数据；

向所述第一数字处理系统发射所述合并的第一伪距离校正数据与第二伪距离校正数据中的至少一个数据。

11．如权利要求 10 所述的方法，其特征在于，所述合并的第一与第二伪距离数据中的至少一个用来校正来自所述移动 SPS 接收机的所述多个伪距离数据，以提供多个校正的伪距离数据。

12．如权利要求 11 所述的方法，其特征在于，所述位置信息是根据所述校正的多个伪距离数据和所述第一与第二卫星星历表数据二者中的至少一个数据计算的。

13．如权利要求 12 所述的方法，其特征在于，所述第一星历表数据是从来自第一组看得到所述第一 SPS 接收机的 SPS 卫星的导航信息中导出的，而所述第二卫星星历表数据是从来自第二组看得到所述第二 SPS 接收机的 SPS 卫星的导航信息中导出的。

14．如权利要求 13 所述的方法，其特征在于，所述第一卫星星历表数据是通过所述第二数字处理系统从所述第一 SPS 接收机收到的，所述第二卫星星历表数据是通过所述第二数字处理系统从所述第二 SPS 接收机接收到的。

15．如权利要求 12 所述的方法，其特征在于，所述第一数字处理系统包括第一容错计算机系统，而所述第二数字处理系统包括第二容错计算机系统，其中所述第一伪距离数据包括相对于看得到所述第一 SPS 接收机的卫星的第一伪距离和相对于看得到所述第一 SPS 接收机的卫星的第一伪距离校正值中的至少一个。

16．如权利要求 12 所述的方法，其特征在于，所述第一数字处理系统通过无线通信系统耦接至所述移动 SPS 接收机。

17．如权利要求 16 所述的方法，其特征在于，所述小区无线通信系统包括移动交换中心。

18．如权利要求 17 所述的方法，其特征在于，所述第一与第二 SPS 接收机

和所述第一与第二数字处理系统都通过分组数据网耦接在一起。

19. 如权利要求 10 所述的方法，其特征在于，所述方法还包括：

在第三数字处理系统处从所述第一 SPS 接收机接收所述第一伪距离数据；

在所述第三数字处理系统处从所述第二 SPS 接收机接收所述第二伪距离数据；

在所述第三数字处理系统处用所述第一伪距离数据作校正，以提供所述合并的第一伪距离校正数据，并用所述第二伪距离校正数据作校正，以提供所述合并的第二伪距离校正数据，其中，所述第一数字处理系统能从所述第三数字处理系统接收所述合并的第一与第二伪距离校正数据。

20. 一种处理卫星位置信息的系统，其特征在于，所述系统包括：

多个卫星定位系统（SPS）参照接收机，各自有一已知的位置，所述多个 SPS 参照接收机散布于某一地域，所述多个 SPS 参照接收机中的每一个将从看得到多个所述 SPS 参照接收机的卫星接收到的卫星星历表数据发射入通信网；

多个数据处理系统，各自耦接到所述通信网，以接收通过所述通信网发射的卫星星历表数据，所述多个数字处理系统包括第一与第二数字处理系统，所述第一数字处理系统从第一移动 SPS 接收机接收第一多个伪距离数据，并根据所述第一多个伪距离数据和从所述通信网接收到的卫星星历表数据计算所述第一移动 SPS 接收机的第一位置信息，所述第二数字处理系统从第二移动 SPS 接收机接收第二多个伪距离数据，并根据所述第二多个伪距离数据和从所述通信网接收到的卫星星历表数据计算所述第二移动 SPS 接收机的第二位置信息。

21. 如权利要求 20 所述的系统，其特征在于，所述第一数字处理系统通过小区无线通信系统以通信方式耦接至所述第一移动 SPS 接收机，所述第二数字处理系统通过所述小区无线通信系统以通信方式耦接至所述第二移动 SPS 接收机。

22. 如权利要求 21 所述的系统，其特征在于，所述通信网是一种分组数据网。

23. 如权利要求 21 所述的系统，其特征在于，所述第一数字处理系统相对于所述多个 SPS 参照接收机中的至少某些接收机来说位于远端。

24. 如权利要求 21 所述的系统，其特征在于，所述多个 SPS 参照接收机包括第一与第二 SPS 参照接收机，其中，所述第一与第二 SPS 参照接收机分别将第一与第二卫星星历表数据发射入所述通信网，所述第一卫星星历表数据从看得到所述第一 SPS 参照接收机的第一组 SPS 卫星接收的导航信息中得到，而所述第二

卫星星历表数据从看得到所述第二 SPS 参照接收机的第二组 SPS 卫星发出的导航信息中得到。

25．如权利要求 24 所述的系统，其特征在于，所述第一数字处理系统能用所述第一与第二卫星星历表数据计算所述第一移动 SPS 接收机的所述第一位置信息，所述第二数字处理系统能用所述第一与第二卫星星历表数据计算所述第二移动 SPS 接收机的所述第二位置信息。

26．如权利要求 24 所述的系统，其特征在于，所述第一与第二数字处理系统接收由来自所述第一 SPS 参照接收机的数据导出的第一伪距离校正数据和由来自所述第二 SPS 参照接收机的数据导出的第二伪距离校正数据。

27．如权利要求 26 所述的系统，其特征在于，所述第一 SPS 参照接收机将所述第一伪距离校正数据发射入所述通信网，所述第二 SPS 参照接收机将所述第二伪距离校正数据发射入所述通信网。

28．如权利要求 27 所述的系统，其特征在于，至少一个所述第一与第二伪距离校正数据用来校正所述第一多个伪距离数据，以提供合并的第一多个伪距离数据，而其中所述第一位置由所述合并的第一多个伪距离数据和所述第一与第二卫星星历表数据二者中的至少一个来确定。

29．如权利要求 24 所述的系统，其特征在于，它还包括：

耦接到所述通信网的再一个数字处理系统，所述再一个数字处理系统接收来自所述第一 SPS 参照接收机的第一伪距离数据和来自所述第二 SPS 参照接收机的第二伪距离数据，并对所述第一伪距离数据进行校正以提供合并的第一伪距离校正数据，对所述第二伪距离数据进行校正以提供合并的第二伪距离校正数据，所述再一个数字处理系统再将所述第一合并的伪距离校正数据与第二合并的伪距离校正数据发送给所述第一数字处理系统。

30．一种含有可执行计算机程序指令的计算机可读存储媒体，执行程序指令时，所述程序指令使第一数据处理系统执行某种方法，其特征在于，所述方法包括：

在第一数字处理系统处接收来自具有第一已知位置的第一卫星定位系统(SPS)接收机的第一卫星星历表数据；

在所述第一数字处理系统处接收来自具有第二已知位置的第二 SPS 接收机的第二卫星星历表数据；

在所述第一数字处理系统处接收来自移动 SPS 接收机的多个伪距离数据；

用所述多个伪距离数据和所述第一与第二卫星星历表数据中的至少一种数据计算所述移动 SPS 接收机的位置信息。

31．如权利要求 30 所述的计算机可读存储媒体，其特征在于，所述第一数字处理系统相对于所述第一已知位置位于远端，其中所述第一 SPS 接收机是一参照接收机。

32．如权利要求 30 所述的计算机可读存储媒体，其特征在于，所述第一卫星星历表数据是从看得到所述第一 SPS 接收机的第一组 SPS 卫星接收的，其中所述第二卫星星历表数据是从看得到所述第二 SPS 接收机的第二组 SPS 卫星接收的。

33．如权利要求 30 所述的计算机可读存储媒体，其特征在于，所述方法还包括：

在所述第一数字处理系统处接收来自所述第一 SPS 接收机的第一伪距离校正数据；

在所述第一数字处理系统处接收来自所述第二 SPS 接收机的第二伪距离校正数据。

34．如权利要求 33 所述的计算机可读存储媒体，其特征在于，所述第一与第二伪距离校正数据中至少有一个用来校正来自所述移动 SPS 接收机的所述多个伪距离数据，以提供校正的多个伪距离数据。

35．如权利要求 34 所述的计算机可读存贮媒体，其特征在于，所述位置信息是根据所述校正的多个伪距离数据和所述第一与第二卫星星历表数据中至少一个数据计算的。

36．一种处理卫星位置信息的系统，其特征在于，所述系统包括：

通信媒体；

具有第一已知位置和耦接至所述通信媒体的第一通信接口的第一卫星定位系统（SPS）参照接收机，所述第一 SPS 参照接收机把第一卫星星历表数据发射入所述通信媒体；

具有第二已知位置和耦接至所述通信媒体的第二通信接口的第二 SPS 参照接收机，所述第二 SPS 参照接收机把第二卫星星历表数据发射入所述通信媒体；及

耦接到所述通信媒体的第一数字处理系统，用于接收所述第一与第二卫星星历表数据中的至少一个，并向移动 SPS 接收机提供卫星信息，以对所述移动 SPS 接收机确定位置信息的导航解。

37．如权利要求 36 所述的系统，其特征在于，所述第一卫星星历表数据是

从看得到所述第一 SPS 参照接收机的第一组 SPS 卫星接收的，其中所述第二卫星星历表数据是从看提到所述第二 SPS 参照接收机的第二组 SPS 卫星接收的。

38. 如权利要求 37 所述的系统，其特征在于，所述通信媒体包括一分组数据网，其中所述第一通信接口和所述第二通信接口分别以分组数据形式提供所述第一与第二卫星星历表数据。

39. 如权利要求 37 所述的系统，其特征在于，所述第一与第二 SPS 接收机分别把第一与第二伪距离数据发射入所述通信媒体，其中所述第一伪距离数据包括至少一个相对于看得到所述第一 SPS 参照接收机的诸卫星的第一伪距离以及相对于看得到所述第一 SPS 参照接收机的诸卫星的第一伪距离校正值。

40. 如权利要求 39 所述的系统，其特征在于，所述系统还包括：

耦接至所述通信媒体的第二数据处理系统，所述第一数字处理系统接收所述第一和第二伪距离数据，并校正所述第一伪距离数据以提供发射入所述通信媒体的第一校正的伪距离校正数据，且校正所述第二伪距离数据以提供发射入所述通信媒体的第二校正的伪距离校正数据。

41. 一种处理卫星位置信息的系统，其特征在于，所述系统包括：

通信媒体；

具有第一已知位置和耦接至所述通信媒体的第一通信接口的第一卫星定位系统（SPS）参照接收机，所述第一 SPS 参照接收机把第一卫星星历表数据的第一分组发射入所述通信媒体，每个所述第一分组少于卫星星历表数据的一个子帧；

具有第二已知位置和耦接至所述通信媒体的第二通信接口的第二 SPS 参照接收机，所述第二 SPS 参照接收机把第二卫星星历表数据的第二分组发射入所述通信媒体，每个所述第二分组少于卫星星历表数据的一个子帧。

42. 如权利要求 41 所述的系统，其特征在于，所述第一卫星星历表数据是从看得到所述第一 SPS 参照接收机的第一组 SPS 卫星接收的，其中所述第二卫星星历表数据是从看提到所述第二 SPS 参照接收机的第二组 SPS 卫星接收的。

43. 如权利要求 42 所述的系统，其特征在于，所述通信媒体包括一分组数据网，其中所述第一通信接口和所述第二通信接口分别以分组数据形式提供所述第一与第二卫星星历表数据。

44. 如权利要求 42 所述的系统，其特征在于，所述第一与第二 SPS 接收机分别把第一与第二伪距离数据发射入所述通信媒体，其中所述第一伪距离数据包括至少一个相对于看得到所述第一 SPS 参照接收机的诸卫星的第一伪距离以及相

对于看得到所述第一 SPS 参照接收机的诸卫星的第一伪距离校正值。

45. 如权利要求 44 所述的系统，其特征在于，所述系统还包括：

耦接至所述通信媒体的第一数字处理系统，所述第一数字处理系统接收所述第一和第二伪距离数据，并校正所述第一伪距离数据以提供发射入所述通信媒体的第一校正的伪距离校正数据，且校正所述第二伪距离数据以提供发射入所述通信媒体的第二校正的伪距离校正数据。

46. 一种处理卫星位置信息的系统，其特征在于，所述系统包括：

通信媒体；

具有第一已知位置和耦接至所述通信媒体的第一通信接口的第一卫星定位系统（SPS）参照接收机，所述第一 SPS 参照接收机把第一卫星星历表数据的第一分组发射入所述通信媒体，每个所述第一分组少于卫星星历表数据的一个子帧，从而所述第一分组以每秒较高的分组速率发射入所述通信媒体。

47. 如权利要求 41 所述的系统，其特征在于，所述第一卫星星历表数据是从看得到所述第一 SPS 参照接收机的第一组 SPS 卫星接收的。

48. 如权利要求 42 所述的系统，其特征在于，所述通信媒体包括一分组数据网，其中所述第一通信接口以分组数据形式提供所述第一卫星星历表数据。

49. 如权利要求 42 所述的系统，其特征在于，所述第一 SPS 接收机把第一伪距离数据发射入所述通信媒体，而其中所述第一伪距离数据包括至少一个相对于看得到所述第一 SPS 参照接收机的诸卫星的第一伪距离以及相对于看得到所述第一 SPS 参照接收机的诸卫星的第一伪距离校正值。

50. 如权利要求 44 所述的系统，其特征在于，所述系统还包括：

耦接至所述通信媒体的第一数字处理系统，所述第一数字处理系统接收所述第一伪距离数据，并校正所述第一伪距离数据，以提供被发射入所述通信媒体的第一校正的伪距离校正数据。

51. 如权利要求 36 所述的系统，其特征在于，所述卫星信息包括至少一个看得到所述移动 SPS 接收机的诸卫星的卫星星历表数据或所述看得到的诸卫星的多谱勒测算数据或卫星年历数据，其中所述卫星信息从所述第一数字处理系统发射到所述移动 SPS 接收机，而且其中看得到所述移动 SPS 接收机的诸卫星的所述卫星星历表数据是从所述第一与第二卫星星历表数据中的至少一个得到的。

52. 如权利要求 51 所述的系统，其特征在于，所述移动 SPS 接收机确定所述导航解。

说　明　书

卫星定位参照系统与方法

相关申请

本申请是 Norman F. krasner 于 1997 年 4 月 15 日提出的美国专利申请序号 No.08/842,559 的部分续展申请。

发明的技术背景

本发明涉及应用参照接收机的卫星定位系统，特别涉及一种卫星定位系统的参照接收机网络。

常规卫星定位系统(SPS)，诸如美国的全球定位系统(GPS)，都应用来自卫星的信号确定其位置。常规 GPS 接收机一般通过计算从绕地球轨道运行的许多 GPS 卫星同时发射的信号的相对到达时间来确定其位置。每颗卫星都发射作为其导航信息一部分的卫星定位数据与时钟计时数据，而时钟计时数据在一定进刻限定了其位置与时钟状态；出现在 GPS 导航信息子帧 1—3 中的这种数据往往被称为卫星时钟与星历表数据，也称为卫星星历表数据。常规 GPS 接收机通常搜索捕获 GPS 信号，从每个信号中读取导航信息，以对其各自的卫星获得卫星星历表数据，确定与这些卫星的伪距离，并根据伪距离与来自卫星的卫星星历表数据计算 GPS 接收机的位置。

应用某种已知的称为差分 GPS 的常规技术，可以提高定位精度。利用常规差分 GPS，单个差分参照台对局部区域的用户广播不同的 GPS 校正，因而一般有三种常规差分 GPS 系统的主要组成部分。第一组成部分是在某一已知地点的参照台，在某一已知地点有一 GPS 接收机，通常能观察到所有卫星，而且该参照台选用的软件可置入 GPS 接收机，用于计算伪距离校正值并对特定的广播制式对其编码。另一个组成部分是将不同的校正值实时发送给移动 GPS 接收机的无线电链路。第三个组成部分是移动 GPS 接收机，它还包括一台用于接收来自参照台的差分校正广播的接收机。

移动 GPS 接收机以常规方式用差分 GPS 校正值校正伪距离数据，该数据是通过计算 GPS 卫星发射的 GPS 信号的相对到达时间而得到的。常规差分 GPS 不一定要实时完成工作或将校正值提供给移动 GPS 接收机，尽管常常是这么

做的。在专利与非专利文献中，已经描述过许多对差分 GPS 的改进方法，主要集中于差分校正计算、应用算法和提供差分校正值的方法。在测量领域中(伪距离、累计增量距离和临近速度误差估算)。多半是差分校正。

如果参照接收机与参加的移动 GPS 接收机相互十分靠近，常规差分 GPS 能大大提高定位精度。然而，随着两接收机的分离距离增大，差分 GPS 的精度提高就变差了。一种补救办法是提供一个散布于某一地区的 GPS 参照接收机网络，其区域覆盖与移动 GPS 接收机可能工作的区域相一致，因而看得到同组的诸卫星。这样，移动 GPS 接收机可以拾取一个以上差分参照台的差分校正值，而移动 GPS 接收机可以根据它与两个或多个参照台之间的相对接近度，对观察的卫星选择这些差分校正值。有时把多个参照台应用于差分 GPS 系统称作宽区域差分 GPS(WADGPS)。

WADGPS 参照系统的另一种形式包括一个 GPS 参照接收机与主控台网络，主控台与诸参照台通信以接收它们的测量结果，并对参照台观察的每颗 GPS 卫星计算一组合并的星历表与时钟校正估计值。于是，该主控台可以通过发射机提供一种差分 GPS 信息，其校正值适用于某个传播范围。此类宽区域差分 GPS 参照系统的例子包括美国专利 No.5,323,322 和 5.621,646 所描述的例子。

不考虑特定差分参照系统的覆盖范围，差分 GPS 系统的主要目的在于提供差分服务，帮助移动 GPS 接收机消除 GPS 测量结果或测量导出的解中的误差。该网络试图消除的 GPS 系统误差与多个参照台、它们的空间位移和在中央处理机构执行的算法的复杂度有关。差分网络的第二个作用是通过测量与状态空间域的各种检查为差分服务提供完整性与可靠性。

上述系统虽然提高了移动 GPS 接收机的精度，但是这些系统与客户/服务器 GPS 结构不兼容。在客户/服务器 GPS 结构中，移动 GPS 接收机作为客户系统，向远地的服务器提供伪距离测量结果，服务器则利用从移动 GPS 接收机得到的该伪距离并利用唾历表数据，对位置求解作计算。本发明提供一种改进的方法与设备，在定位服务器的定位方面具有灵活性，并且提高了客户/服务系统的效率，降低了成本。

<u>发明内容</u>

本发明提供的方法与设备适用于卫星定位系统参照系统。

本发明的一个方面是一种示例性方法，它使用至少两台 SPS 参照接收机处理卫星定位信息。根据本方法，第一数字处理系统从具有第一已知位置的第一 SPS 参照接收机接收第一卫星星历表数据，还从具有第二已知位置的第二 SPS 参照接收机接收第二卫星星历表数据，再从移动 SPS 接收机接收多个伪距离数据，然后利用多个伪距离数据和第一与第二卫星星历表数据中的至少一个数据，计算该移动 SPS 接收机的位置信息(如纬度、经度和高度)。在本发明一特定实施例中，第一与第二卫星星历表数据都是“原始(raw)”50 bps 卫星导航信息的子集，而卫星导航信息分别由第一与第二 SPS 参照接收机从看得到这两台参照接收机的卫星接收。在一个例子中，这种卫星导航信息可以是编码成 GPS 信号的 50 位/秒数据信息，GPS 信号已被参照接收机接收和译码，并以实现或接近实行的方式发送给第一数字处理系统。

根据本发明的另一方面，卫星位置信息处理系统包括多台地点已知的卫星定位系统(SPS)参照接收机，还包括多个数字处理系统。多台 SPS 参照接收机散布在某一地区，每台接收机接收来自看得到该接收机的卫星发送的卫星星历表数据，并将接收的卫星星历表数据发射到通信网。该系统还包括多个数字处理系统，每个系统耦合至通信网接收至少某些经通信网发送的卫星星历表数据。在一个实施例中，至少有两个这样的数字处理系统。第一数字处理系统接收第一多个来自第一移动 SPS 接收机的伪距离，并根据这些伪距离数据和从通信网收到的卫星星历表数据，计算第一移动 SPS 的第一位置信息(如纬度与经度)。一般情况下，第一数字处理系统至少对看得见第一移动 SPS 接收机的那些卫星有选择地从网中接收合适的卫星星历表数据。第二数字处理系统接收来自第二移动 SPS 接收机的第二多个伪距离数据，并根据这些数据和从通信网收到的卫星星历表数据，计算第二移动 SPS 接收机的第二位置信息。在本发明一个例子中，第二数字处理系统对那些看得见第二移动 SPS 接收机的卫星，有选择地从该网接收合适的卫星星历表。在本发明另一例子中，第一与第二数字处理系统各自从该网中接收看得见该网的最新卫星星历表数据。

在本发明再一个实施例中，为了接收来自诸参照接收机的测量结果(如差分校正值)并产生一组网络差分校正值，可对通信网耦接另一个数字处理系统。下面进一步描述本发明的各其它方面和实施例。

附图简述

下面举例说明本发明内容，但不限于附图内容，图中同样的标号表示同类元件。

图 1 示出一种小区通信系统，它有多个小区，每个小区由区站服务，每个区站接至小区交换中心(有时称移动交换中心)。

图 2 示出本发明一实施例的定位服务器系统的实施方案。

图 3A 示出一例本发明一实施例的组合式 SPS 接收机与通信系统。

图 3B 示出一例本发明一实施例的 GPS 参照台。

图 4 示出本发明一实施例的 SPS 参照接收机网络。

图 5A 与 5B 是描绘本发明一实施例方法的流程图。

图 6 示出网络校正处理器的数据流，可用于本发明参照接收机网络的一实施例中。

图 7 示出一例数据流，它与本发明一实施例的定位服务器相关。

发明内容的详细描述

本发明提出的 SPS 参照接收机网络，至少提供一部分如卫星星历表数据等卫星导航信息，供数字处理系统按下述方式应用。在对该参照系统作各种细节描述之前，先描述一下这种参照接收机的一般使用情况。因此。在讨论本发明系统中的 SPS 参照接收机网络之前，先参照图 1、2 和 3A 作一初步讨论。

图 1 示出一例小区通信系统 10，它包括多个区站，每个区站服务于特定的地理区域或地点。这类蜂窝或小区通信系统的例子，在本领域中是众所周知的，诸如小区电话系统。小区通信系统 10 包括两个小区 12 与 14，二者都限于蜂窝服务区 11 内。此外，系统 10 还包括小区 18 与 20。显然，在耦接到一个或多个蜂窝交换中心(如蜂窝交换中心 24 与 24b)的系统 10 中，还可包括多个具有对应的区站和/或蜂窝服务区的其它小区。

在每个小区内，如小区 12 内，有一个无线区站或蜂窝点(如区站 13)，它包括的天线 13a 通过无线通信媒体与通信接收机通信，而该接收机可以与图 1 所示的接收机 16 等移动 GPS 接收机组合在一起。这种配有 GPS 接收要和通信系统的一例组合系统如图 3A 所示，可以包括 GPS 天线 77 和通信系统天线 79。

每个区站耦接至蜂窝交换中心。图 1 中，区站 13、15 与 19 分别通过接

线 13、15b 与 19b 耦接到切换中心 24，区站 21 通过接线 21b 耦接到不同的交换中心 24b。这些接线通常是各区站与蜂窝交换中心 24 和 24b 之间的导线连接。各区站包括一根天线，用于与该区站服务的通信系统进行通信。在一实施例中，区站可以是一个蜂窝电话区站，与该区站服务区中的移动蜂窝电话通信。显然，一个小区内的通信系统，如小区 4 中的接收机 22，由于阻塞(或区站 21 无法与接收机 22 通信的其它原因)，实际上可以与小区 18 中的区站 19 通信。

在本发明一典型实施例中，移动 GPS 接收机 16 包括一个与 GPS 接收机集成起来的小区通信系统，故 GPS 接收机与通信系统装在同一机壳里。其一个例子是一种具有集成式 GPS 接收机的蜂窝电话，该接收机与蜂窝电话收发器共享公用电路。将这种组合式系统应用于蜂窝电话通信时，就在接收机 16 与区站 13 间实现传输。于是，从接收机 16 到区站 13 的传输就通过接线 13b 传播到蜂窝交换中心 24，然后再传到该中心 24 服务的小区中的另一个蜂窝电话，或者通过接线 30(通常为导线)经陆基电话系统/网络 28 传到另一个电话。显然，导线包括光纤和其它非无线接线(如铜质电缆等)。与接收机 16 正在通信的另一电话的传输，可用常规方法由蜂窝交换中心 24 经接线 13b 和区站 13 传回给接收机 16。

系统 10 中包含的远程数据处理系统 26(在有些实施例中可称为 GPS 服务器或定位服务器)，可利用 GPS 接收机收到的 GPS 信号确定移动 GPS 接收机(如接收机 16)的状态(如位置和/或速度和/或时间)。GPS 服务器 26 可通过接线 27 耦接至陆基电话系统/网络 28，也可通过接线 25 有选择地耦接至蜂窝交换中心 24，还可通过接线 25b 选接到中心 24b。显然，接线 25 和 27 一般是导线接线，当然也可以是无线连接。如图所示，系统 10 的一种选用元件是询问终端 29，它可以包括通过网络 28 而耦接到 GPS 服务器 26 的另一个计算机系统。该询问终端 29 可向 GPS 服务器 26 发出请求，询问某一小区中特定 GPS 接收机的位置和/或速度，于是服务器 26 通过蜂窝交换中心与特定的 GPS 接收机通话，以确定该 GPS 接收机的位置和/或速度，并向询问终端 29 报告要询问的信息。在另一实施例中，可由移动 GPS 接收机用户对 GPS 接收机提出位置确定；例如，移动 GPS 接收机用户可在小区电话上按 911，表示该移动 GPS 接收机地点的某种紧急状态，这就启动了以本文描述的方法所执行的定位处理。

应该指出，蜂窝或小区通信系统是一种具有一个以上发射机的通信系统，

每个发射机都服务于按实时即时预定的不同地域。一般而言，每个发射机都是一种服务于一个小区的无线发射机，小区的地域半径小于 20 英里，尽管覆盖的区域取决于特定的蜂窝系统。蜂窝通信系统有多种类别，诸如蜂窝电话、PCS(个人通信系统)、SMR(专用移动电话)、单向与双向寻呼系统、RAM、ARDIS 和无线信息包数据系统。一般而言，把预定的地域称为小区，多个小区合在一起称为蜂窝服务区，如图 1 所示的蜂窝服务区 11，并把这类多个小区耦接到一个或多个蜂窝交换中心，再由这些中心连接到陆基电话系统和/或网络。服务区经常用于记帐。因此，可以将一个以上服务区的小区连接至一个交换中心。如图 1 中，小区 1 与 2 位于服务区 11，小区 3 位于服务区 13，但这三个小区都接至交换中心 24。或在有些场合中，可将一个服务区内的诸小区接到不同的交换中心。在人口稠密区尤其如此。通常，一个服务区被定义为邻近地区内诸小区的集合。符合上述情况的另一类蜂窝系统则以卫星为基础，蜂窝基站或区站就是通常绕地球轨道运行的诸卫星。在这类系统中，小区扇区与服务区的移动是时间的函数。这类系统包括 Ividium、Globalstar、Orbcomm、Odyssey 等。

图 2 示出一例 GPS 服务器 50，可用作图 1 的 GPS 服务器 26，它包括一个数据处理单元 51，可以是一种容错数字计算机系统，还包括调制解调器或其它通信接口 52、调制解调器或其它通信接口 53 和 54。这些通信接口为图 2 所示的定位服务器在三个不同网络 60、62 和 64 之间的信息交换提供接续。网络 60 包括蜂窝交换中心和/或陆基电话系统或区站。在图 1 的这种网络例子中，GPS 服务器 26 代表图 6 的服务器 50。因此，可以认为网络 60 包括蜂窝交换中心 24 与 24b、陆基电话系统/网络 28、网络服务区 11 以及小区 18 与 20。可以认为网络 64 包括图 1 的询问终端 29 或“PSAP”，它是公共安全应答点，通常是应答 911 电话紧急呼叫的控制中心。在询问终端 29 的情况下。该终端可用来询问服务器 26，以从位于小区通信系统中各小区内的某指定移动 SPS 接收机获得状态(如位置)信息。此时，定位操作由移动 GPS 接收机用户以外的人启动。在包括蜂窝电话的移动 GPS 接收机发出 911 电话呼叫的情况下，定位处理由蜂窝电话用户启动。代表图 1 中 GPS 参照网络 32 的网络 62 是一种 GPS 接收机网络，它是 GPS 参照接收机，用于向数据处理单元提供差分 GPS 校正信息，还提供 GPS 信号数据，包括至少一部分卫星星历表数据等卫星导航信息。当服务器 50 对极大的地区服务时，本地选择的 GPS 接收机如

选用的 GPS 接收机 56，可能无法观察在整个该地区看得到诸移动 SPS 接收机的所有 GPS 卫星。因此，在根据本发明一实施例的广阔范围内，网络 62 至少收集并提供部分卫星导航信息，如卫星星历表数据与差分 GPS 校正数据。

如图 6 所示，海量存储器 55 耦接至数据处理单元 51。一般情况下，海量存储器 55 将包括用于存贮软件与数据的存储器，以便在接收来自移动 GPS 接收机(如图 1 的接收机 16)的伪距离后执行 GPS 位置计算。这些伪距离通常通过区站、蜂窝交换中心和调制解调器或其它接口 53 接收。至少在一个实施例中，海量存储器 55 还包括了软件，用于接收和利用 GPS 参照网络 32 经调制解调器或另一接口 54 提供的卫星星历表数据。

在本发明一典型实施例中，选用的 GPS 接收机不必像图 1 中 GPS 参照网络 32(图 2 中的网络 62)那样提供差分 GPS 信息，而是从看得见 GPS 参照网络中各种参照接收机的诸卫星提供原始的卫星导航信息。显然，可以用常规方法将通过调制解调器或另一接口 54 从该网络获得的卫星星历表数据，同从移动 GPS 接收机获得的伪距离一起用于计算该移动 GPS 接收机的位置信息。接口 52、53 和 54 可以是调制解调器或其它合适的通信接口，用于将数据处理单元耦接到其它计算机系统(网络 64 的情况)，耦接到蜂窝通信系统(网络 60 的情况)，和耦接到发射装置，如网络 62 中的计算机系统。在一实施例中，网络 62 显然包括散布在某地域内的分散集中的 GPS 参照接收机。

图 3A 示出一种包括 GPS 接收机和通信系统收发机的一般组合系统。在一个例子中，通信系统收发机是一种蜂窝电话。系统 75 包括带 GPS 天线 77 的 GPS 接收机 76 和带通信天线 79 的通信收发机 78。GPS 接收机 76 经图 3A 的接线 80 耦接至通信收发机 78。在一种工作模式中，通信系统收发机 78 经天线 79 接收近似多普勒信息，并将该信息经链路 80 提供给 GPS 接收机 76，后者经 GPS 天线 77 从 GPS 卫星接收 GPS 信号而作伪距离确定。然后，通过通信系统收发机 78 将该伪距离发射给如图 1 所示 GPS 服务器的定位服务器(location server)。一般是通信系统发收机 78 通过天线 79 向区站发一信号，再由该区站将此信息传回如图 1 的 GPS 服务器 26 的 GPS 服务器。系统 75 各种实施例是本领域所共知的，如美国专利 5,663,734 描述了一例组合式 GPS 接收机与通信系统，它应用了一种改进的 GPS 接收机系统。另一例组合式 GPS 与通信系统已在 1996 年 5 月 23 日提出的共同待批专利申请 No.08/652,833 中作了描述。图 3A 的系统 75 及另一些具有 SPS 接收机的通信系统，都可应用本发

明方法与本发明的 GPS 参照网络一起工作。

图 3B 示出 GPS 参照台的一个实施例。很显然，每个参照台都能以这种方式构制并耦接至通信网络或媒体。一般而言，每个 GPS 参照台(如图 3B 的 GPS 参照台 90)将包括一种耦接至 GPS 天线 91 的单频或双频 GPS 参照接收机 92，而天线 91 从看得见天线 91 的诸 GPS 卫星接收 GPS 信号。在本领域，GPS 参照接收机是众所周知的。根据本发明一实施例，GPS 参照接收机至少提供两类作为其输出的信息。将伪距离输出 93 提供给处理器与网络接口 95，用于以常规方式对看得见 GPS 天线 91 的那些卫星计算伪距离校正值。在本领域中，处理器与网络接口 95 可以是一种常规数字计算计系统，具有用于从 GPS 参照接收机接收数据的接口，这是众所周知的。处理器 95 通常包括设计成处理为距离数据的软件，以对每颗看得见 GPS 天线 91 的卫星确定合适的伪距离校正值。然后，通过网络接口将这些伪距离校正值(和/或伪距离数据输出)发送给通信网络或媒体 96，而该通信网络或媒体 96 还与其它 GPS 参照台耦接。在一个实施例中，GPS 参照接收机 92 还包括至少一部分卫星导航信息(如卫星星历表数据输出 94)的表示，并将该数据提供给处理器与网络接口 95，再由后者将该数据发射到通信网络 96 上。

在一个实施例中，每台参照接收机以高于正常速率将整个导航信息发送入网。有些常规 GPS 接收机可以每隔 6 秒钟(可以认为是正常速率)输出原始(数字)导航信息数据；如某些 NovAtel GPS 接收机具有这种能力。这类接收机将一个子帧的导航信息数字数据(在标准 GPS 信号中为 300 位)汇集于缓冲器，然后每隔 6 秒移出该缓冲器的数据(缓冲全子帧 300 位后)，在接收机输出端提供这一数据。然而，在本发明一实施例中，至少一部分数字导航信息的表示是以每隔 600 毫秒的速率发送入网的。这种高数据速率可以执行测量时间的方法。如 1997 年 2 月 3 日提出的共同待批美国专利申请 No.08/794,649 中描述的方法。在本发明该实施例中，通过只将一部分子帧(如 30 位)汇集在缓冲器里并在该部分汇集后移出，可以每隔 600 毫秒将一部分导航信息发射入网。因此，处理器 95 发射入网的数据包所含的导航信息部分，要小于一个全子帧(300 位)缓冲器所建立的包能提供的信息部分。显然，一旦缓冲汇集了该部分子帧(如 30 位)，就可将该数据移出而成为通过本发明网络以极高数据速率(如 512Kbps)发射的包。然后在接收数字处理系统中从若干包中提取数据并将数据连在一起重建完整的子帧，就重新组装好这些包(少于全子帧)。

在本发明一实施例中，每个 GPS 参照台发射至少一部分卫星导航信息与伪距离数据(不是伪距离校正数据)的表示。伪距离校正数据可以从特定卫星的伪距离与星历表信息中导出。因此，GPS 参照台可将伪距离校正数据或星历表(或二者)发射入网。然而，在一较佳实施例中，伪距离数据(代替伪距离校正数据)由每个 GPS 参照台发射入网，因为来自不同接收机的校正值可从不同组的星历表数据导出，造出不同接收机的校正值有差异。根据该较佳实施例，中央校正处理器(如图 4 的网络校正处理器 110)使用一组一致的从任一 GPS 参照接收机收到的最新星历表数据，因而避免了这些差异。该组数据由于包括一批来自多颗卫星的星历表、距离测量结果(如伪距离)和/或校正值，因此是一致的，适用于实时的特定瞬间。只要每组的适用时间重叠，就可把该组与其它组的数据合并起来。

回过来参照图 3B，卫星星历表数据输出 94 一般至少提供部分整个原始 50 波特导航二进制数据，这类数据已在从每颗 GPS 卫星收到的实际 GPS 信号里作了编码。卫星星历表数据是作为来自 GPS 卫星的 GPS 信号中每秒 50 位的数据流而广播的部分导航信息，在 GPSICD－200 文件中有详述。处理器与网络接口 95 接收这一卫星星历表数据输出 94，并实时或接近实时的将它发送给通信网络 96。如下面要描述的，根据本发明的诸方面，这一发射入通信网的卫星星历数据以后通过该网络被各定位服务器接收。

在本发明某些实施例中，为了对网络接口和通信网减低带宽要求，对定位服务器只发送某几段卫星导航信息。而且，不要求连续提供这种数据。例如，可将包含星历表信息的仅仅前三个子帧而不是所有 5 个子帧发送入通信网 96，若这三个子帧包含更新信息的话。显然，在本发明一实施例中，定位服务器可用一个或多个 GPS 参照接收机发射的导航信息数据执行有关卫星数据信息的时间的测量方法，如共同待批的美国专利申请 No.08/794,649 中描述的方法，该申请由 Norman F.Krasner 于 1997 年 2 月 3 日提交。还可以理解，GPS 参照接收机 92 对来自看得见该接收机 92 的不同 GPS 卫星的不同 GPS 信号作译码，以提供包含该卫星星历表数据的二进制数据输出 94。

一般该数据包不提供给特定的定位服务器，且包括部分导航信息和从某颗卫星收到数据的标识符；在有些实施例中，该包还可以规定一个发射参照台的标识符。在有些实施例中，选用的 GPS 接收机 56 可能是主要的导航信息数据源，被当地的定位服务器所用，而本发明的网络可以按要求提供信息。

图 4 示出一例 GPS 参照接收机网络，整个系统 101 包括耦接到通信网或媒体 103 的两个定位服务器 115 和 117，对应于图 3B 的通信网 96。网络校正处理器 110 和 112 也耦接至通信网 103。图 4 示出了五个 GPS 参照台 104、105、106、107 和 108，全都耦接至通信网 103。每个 GPS 参照台如台 104 对应于图 3B 中的示例性 GPS 参照台 90，而通信网 103 对应于图 3B 的通信网 96。显然，诸 GPS 参照台(如 104－108)散布于某一地域，以便对同样可被移动 GPS 接收机接收的 GPS 信号提供接收机覆盖。相邻参照台间的这种覆盖一般相重叠，从而完全覆盖了整个地域。整个参照台网的地域可以扩展到全世界或其任一子集，如城市、州、图家或大陆。每个 GPS 参照台(如台 104)都将伪距离校正数据提供给通信网 103，而且还提供被定位服务器(如服务器 115)使用的原始导航数据信息。如下面要描述的，定位服务器的数量可能少于参照台，所以将要处理来自广泛分布的移动 GPS 接收机的伪距离数据。例如，一个定位服务器可能正在处理来自加州的一台移动 GPS 接收机和加州的一台参照台的伪距离数据，而同一个定位服务器可能正在处理来自纽约的一台移动 GPS 接收机和纽约的一台参照台的伪距离数据，因而单个定位服务器可能正在接收来自分布广泛的两个或多个参照台的导航信息。如图 4 所示，通信网可以是诸如帧中继的数据网或 ATM 网，或是其它高速数据通信网。

图 4 还示出两个网络校正处理器 110 和 112；在一实施例中，这些处理器对多个参照台提供并网校正值，也可对定位服务器提供电离层数据。下面再描述一个网络校正处理器实施例的工作情况。这些处理器通常根据具有同一适用时间的伪距离与星成表确定合适的伪距离校正值，并把相关的各组校正值与星历表数据合并成具有同一或重叠适用时间的一组，然后在网上再次发送该合并值，以供耦接于该网的诸定位服务器接收。

图 5A 与 5B 以流程图形式示出本发明一实施例的方法。在该方法 200 中，每个 GPS 参照接收机接收来自看得到特定参照接收机的卫星的卫星星历表数据，并将该数据(导航信息)发射入通信网，诸如图 4 所示的分组数据网 103。在这一步骤 201 的典型实施例中，对来自看得见该特定参照接收机的 GPS 卫星的每个 GPS 信号译码，以便提供该 GPS 信号中存在的每秒 50 位二进制数据流，并以实时或接近实时的方式将它发射入通信网。在另一实施例中，如上述那样，只将部分这种数据流发射入网。在步骤 203 中，每个 GPS 参照接收机对看得见该参照接收机的诸 GPS 卫星确定伪距离的校正值；执行这一操作

可以常规方式应用控制器计算机，诸如图 3B 的处理器与网络接口 95。然后，将这些来自每个 GPS 参照接收机的伪距离校正值发射入通信网，如图 4 的通信网 96 或 103。在步骤 205 中，耦接至通信网(如图 103)的处理器(如网络校正处理器 110)接收卫星星历表数据和伪距离校正值。网络校正处理器可按下述那样产生一组合并的伪距离校正值并执行其它操作。然后将这些合并的伪距离校正值发射入通信网(如网 103)，以便让同样耦接至该通信网的各种定位服务器接收。

该方法继续到步骤 207，其中第一定位服务器至少接收一部分来自该网络的导航信息(如卫星星历表数据)和合并的伪距离校正值。这样，例如定位服务器 115 可以接收各个 GPS 参照台已经发射入网的导航信息数据。这种数据通常以接近实时的方式提供，而每个定位服务器一般将至少接收来自两个和往往更多个参照台的卫星星历表数据。一般定位服务器对收到的卫星导航信息数据作译码，以提供卫星时钟与星历表数据并存贮在该服务器里，让定位服务器根据要求计算卫星位置和时钟状态。这种星历表数据用来计算某移动 GPS 接收机的位置，之后接收机向看得见该移动 GPS 接收机的诸卫星提供伪距离。这样，在步骤 209，第一定位服务器接收来自第一移动 GPS 接收机的伪距离，并根据自该网格收到的卫星星历表数据和源于第一移动 GPS 接收机的伪距离，确定第一移动 GPS 接收机的位置。应用参照台网络能让定位服务器计算散布于相当 GPS 参照接收机网络覆盖区的区域内诸移动 GPS 接收机的位置。因此，不是拥有位于定位服务器的单个 GPS 接收机和向某个定位服务器提供星历表数据，图 4 所示的分散的 GPS 参照台网可以让定位服务器为广泛分布的诸移动 GPS 接收机提供位置计算。如图 4 所示，第二定位服务器也可耦接到通信网 103 而对诸移动 GPS 接收机提供位置求解运算。显然，在一实施例中，在定位服务器 115 故障时，服务器 117 可以是该服务器 115 的冗余/备用服务器。一般而言，每个定位服务器都应是一个容错计算机系统。在因定位服务器覆盖区内人口稠密而对特定的该定位服务器提供高数据处理需求的情况下，除了冗余的定位服务器以外，还可将若干定位服务器布署在该地区。步骤 211 和 213 示出在本发明方法中应用的第二定位服务器。在步骤 211，第二定位服务器从通信网接收卫星星历表数据和经校正的伪距离校正值。显然，从该网接收的卫星星历表数据，对于看得见定位服务器 117 服务的相应区域内诸参照台那些卫星而言，可能是卫星专用的。通过将首部分组(header packet)

或其它寻址数据与某一参照台发射的卫星星历表数据和经校正的伪距离校正值放在一起而将该数据提交给特定的定位服务器，就能实现这一目的。在步骤 213，第二定位服务器从第二移动 GPS 接收机接收伪距离，并根据从该网接收的卫星导航信息数据和第二移动 GPS 接收机始发的伪距离，确定第二移动 GPS 接收机的状态(如位置)。

图 6 示出一例数据流，它与网络校正处理器(如图 4 的处理器 110)有关。每个网络校正处理器都将来自多个参照台的校正值合并成一组校正值(和调节值)，对定位服务器应用具有基本上同样的适用时间。在一实施例中，若一个特定的定位服务器无法从一特定网络校正处理器接收校正数据，它可向不同地点的备用网络处理器请求同样的信息。一旦到达某个网络校正处理器，每个校正组就在存储器中缓存供查找。需要时可使用。大气误差消除后，请校正值合并起来对卫星时钟与位置误差(包括 SA 抖动)引起的测距误差作最佳评估。然后将这些合并的网络校正值与关键的电离层数据和最新的导航信息一起发射给有关观察的卫星。在一特定实施例中，将该信息发送给所有指定的定位服务器(已被指定为来自网络校正处理器的诸校正值的地址)。由于每个卫星载体在一实施例中由一台以上参照接收机跟踪，所以可以检查每组网络校正值来保证内部一致性。这样，可将来自第一参照台的伪距离校正值对同一颗卫星对比来自邻近参照台的伪距离校正值而保证内部一致性。如图 6 所示，参照台 301 代表在地域上分散的参照台，如图 4 的台 104－108。在一实施例中，将伪距离校正数据 303 和至少包括一部分包含在 GPS 信号里的 50 位数据流发送给网络校正数据器，后者提出电离参数 310 并对单信号出现时间(single epoch)309 建立一校正组。消除大气延迟，建立合并校正值 316。这里描述的各种操作的数据流还示于图 6。

图 7 示出一侧有关定位服务器的数据流，它示出相对该定位服务器位于远地的系统的至少三个不同部分。参照接收机网 401 对应于图 4 的参照台 104－108。这些参照台经通信网(如图 4 的网 103)耦接至该定位服务器。参照接收机网 401 经数据网 403 提供校正值和/或伪距离数据，还经该数据网提供至少一部分导航信息 405。该导航信息一般包括所谓的卫星星历表数据，在一实施例中为来自每颗 GPS 卫星的 GPS 信号里的 50 波特数据流。校正值在校正处理器中经合并和内部一致性检查，作为校正值 408 或选用的地域校正值，经通信网传到定位服务器。导航信息数据 407 用于提取星历表数据，以对移动 GPS

接收机作状态(如位置)计算。可用来自地域海拔数据库 411 的高度估算帮助状态(如位置)计算 410。定位服务器通常以连续为基础经通信网(如网 103)接收校正数据和导航信息数据。因此，卫星星历表数据源既非来自与定位服务器一同定位的地方 GPS 接收机，也非来自图 4 中参照台 104—108 的 GPS 参照接收机网。在此方法中，定位服务器服务于很大一块地域，这是与该定位服务器一同定位的参照 GPS 接收机做不到的。

定位服务器在不断从 GPS 参照接收机网接收至少一部分卫星导航信息数据和校正数据的同时，还接受对移动 GPS 接收机(示为客户 424)位置的请求。与移动 GPS 接收机的联系通常始于数据交换。一般而言，多谱勒数据 423 提供给移动 GPS 接收机 424(基于来自该移动接收机或蜂窝元件的近似位置数据)，然后移动 GPS 接收机将伪距离数据 425 提供给定位服务器上的客户接口 420。如上所述，这种定位处理可以由移动 GPS 接收机通过按 911 而启动(在蜂窝电话情况下)，或可由被认为对应于图 1 的访问终端 29 的远地操作员 422 启动。如图 7 所示，通过客户接口 420 将多普勒测算 414 从定位服务器提供给移动 GPS 接收机 424。而后者一般以伪距离数据 425 作出响应，并与星历表数据一起确定其位置。可用普通 GPS 接收机中任一种常规位置算法作位置计算，然后将示为导航求解 414 的这一位置提供给客户接口 420，而后者可通过执行模块 421(通常为软件模块)再把这一信息传递给远地操作员 422。在一实施例中，远地操作员 422 是 PSAP(公共安全应答点)，它是应答 911 电话呼叫的控制中心。

客户接口 420 管理定位服务器与客户(如移动 GPS 接收机)间的通信链路。在一实施例中，执行接口把一个客户接口目标分配给每个移动 GPS 接收机。客户接口一般可在地方服务上由软件操作实现。通常也在定位服务器上软件操作的执行模块 421，分配诸接口解决远地操作请求，还控制与外部数据库的接口，执行网络管理和其它必需的外部交互作用。特定的定位服务器通常提供多个远地操作员接口，例如可以提供标准帧中继、x.25 和 TCP/IP 网接续，以满足远地操作员的要求。

虽然上述已经设想了一种特定的结构(其中移动 SPS 接收机从 SPS 卫星接收 SPS 信号，并对这些卫星确定伪距离，再将伪距离连同时间标记发送给定位服务器，由后者确定该移动接收机的位置)，但是本发明显然可以采用其它结构。例如，移动 SPS 接收机可通过接收 SPS 信号并确定伪距离，而且接收

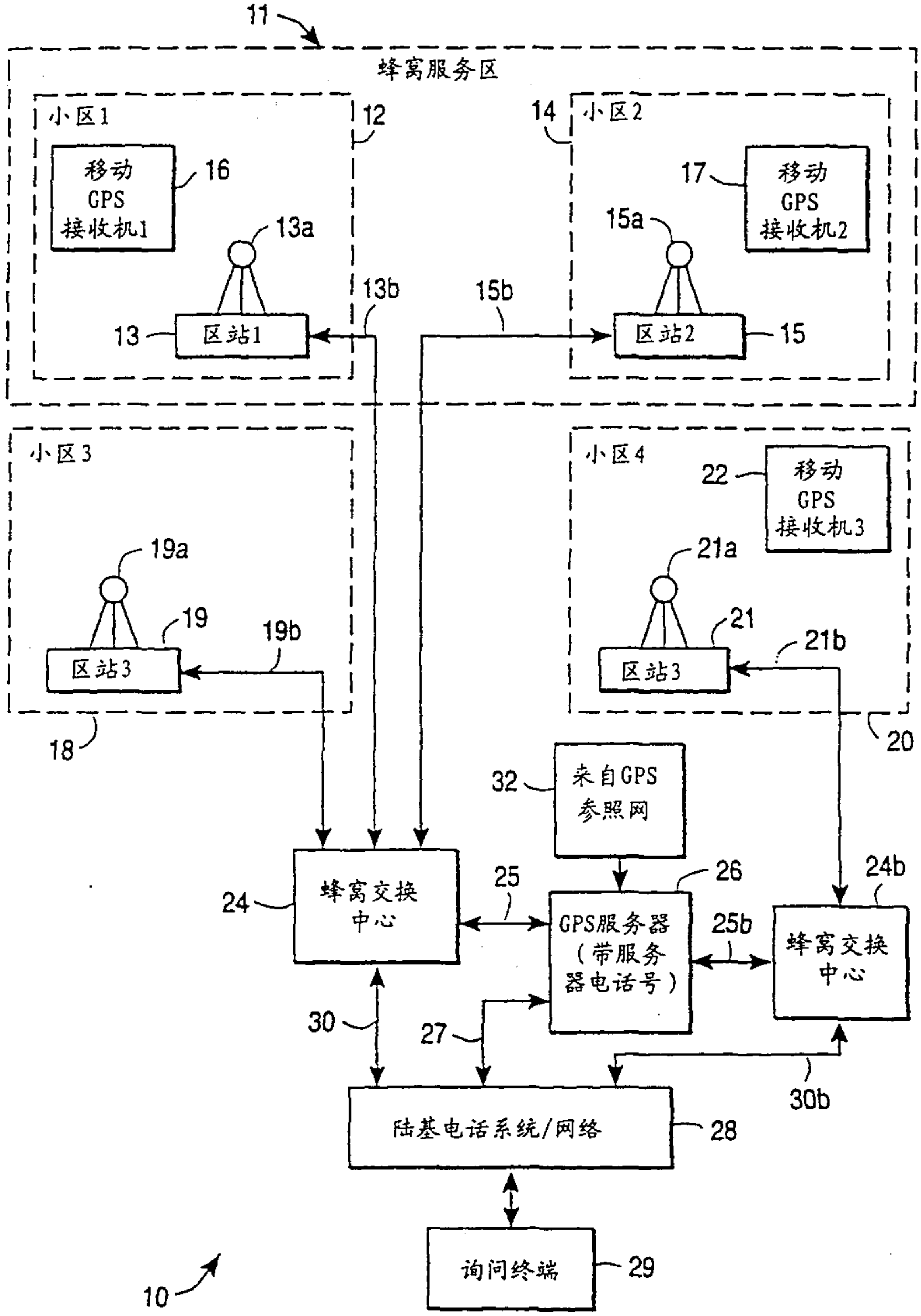
和应用卫星星历表数据(如来自定位服务器的数据，该服务器根据由与该移动SPS 接收机通信的区站所确定的该接收机的近似位置，发送有关的卫星星历表数据)，可以确定其自己的位置。在本例中，定位服务器从参照网的诸接收机接收卫星星历表数据，根据对移动接收机定位的请求，通过小区通信系统(如蜂窝电话系统)向该移动接收机发射有关的卫星星历表数据。有关的卫星星历表数据一般根据该移动接收机的近似位置确定；该近似地点可由与该移动接收机建立了小区无线通信链路的区站的地点确定。定位服务器可用区站提供的标识符确定近似地点；在 Norman F.Krasner 于 1997 年 4 月 15 日提交的共同待批美国专利申请 No.08/842,559 中，描述了各种确定和应用该近似定位的技术，该申请包括在此作参照。近似定位将确定在观察范围内的诸卫星，然后定位服务器通过移动交换中心与区站向该移动接收机发射这些卫星的卫星星历表数据。本例中，定位服务器还可向移动 SPS 接收机发射多普勒测算数据和/或卫星年历和/或伪距离校正值。

虽然已参照 GPS 卫星描述了本发明的方法和设备，但是它们显然同样适用于利用准卫星或卫星与准卫星(pseudolites)组合的定位系统。准卫星是广播以 L 波段载波信号调制的 PN 码(类似于 GPS 信号)的地面发射机，通常与 GPS 时间同步，每台发射机可分配一种独特的 PN 码而被远地接收机识别。在无法得到绕地球轨道运行的卫星的 GPS 信号的场合中，如隧道、矿井、大数或其它封闭区，Pseudolites 是有用的。这里的术语“卫星”试图包括准卫星或其等效物，而 GPS 信号试图包括来自准卫星或其等效的 GPS 类信号。

在上述讨论中，已参照专利申请“美国全球定位卫星(GPS)”系统描述了本发明。然而很清楚，这些方法同样适用于类似的卫星定位系统，特别是俄国的 Glonass 系统。Glonass 系统与 GPS 系统的主要差异在于，通过应用略微不同的载频而不是应用不同的伪随机码，使不同卫星的发射相互区分开来。在此情况下，基本上上述所有的电路与算法都适用，只是在处理新的卫星的发射时，要用对应于不同载频的不同指数乘法器对数据作预处理。这里的术语“GPS”包括此类卫星定位系统，其中包括俄国的 Glonass 系统。

在上述说明书中，已参照特定的示例性实施例描述了本发明，显然，在不背离权利要求书所限定的本发明的广义精神与范围的情况下，可对本发明作各种修正和变化。因此，本说明书和附图被视作示例而并非有限制的意义。

说　明　书　附　图



11
蜂窝服务区
小区1
12
14
小区2
移动
GPS
接收机1
16
17
移动
GPS
接收机2
13a
15a
13b
15b
13
区站1
区站2
15
小区3
小区4
22
移动
GPS
接收机3
19a
21a
19
21
19b
21b
区站3
区站3
18
20
32
来自GPS
参照网
26
24b
24
蜂窝交换
中心
25
GPS服务器
(带服务
器电话号)
25b
蜂窝交换
中心
30
27
30b
陆基电话系统/网络
28
询问终端
29
10

图　1

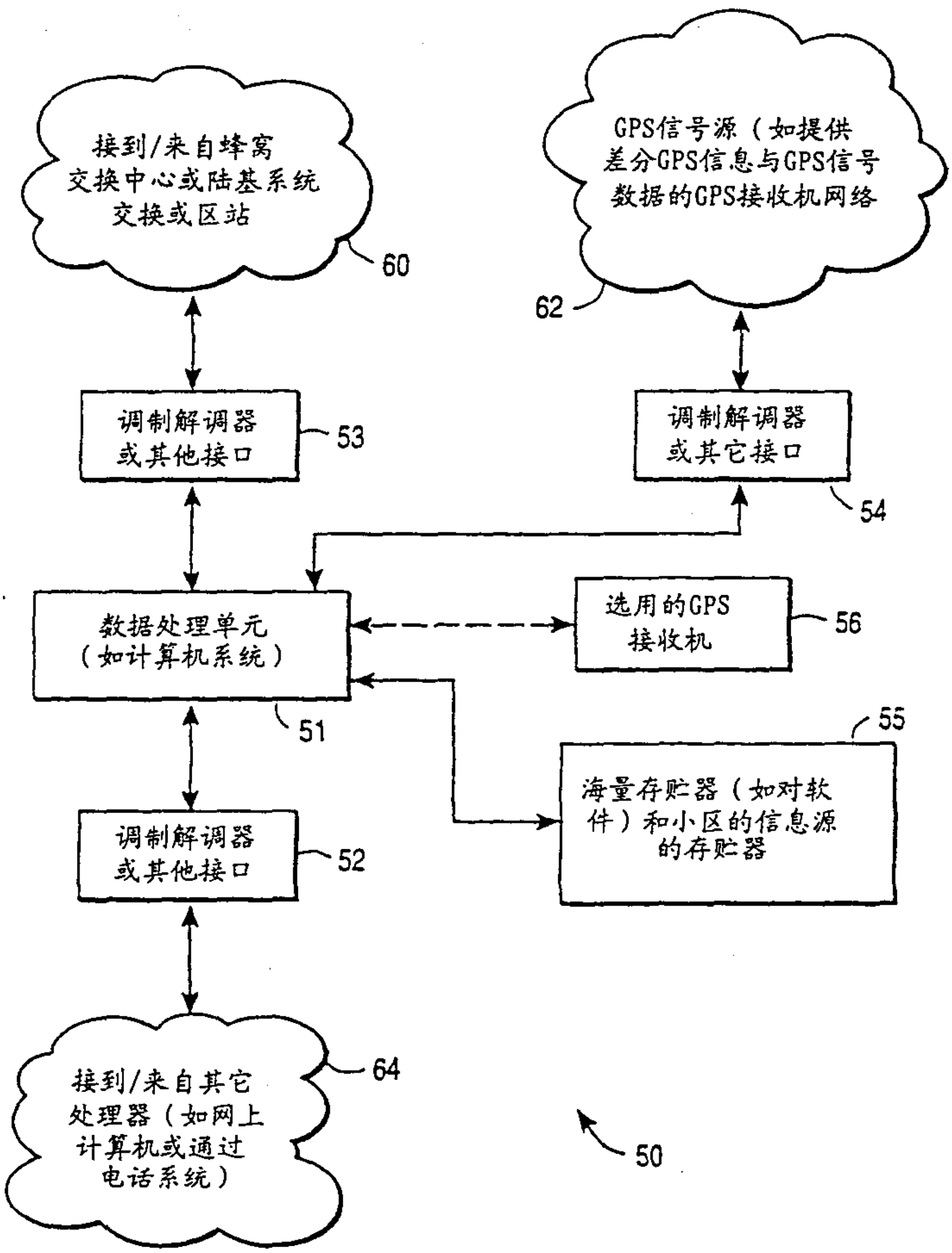

接到/来自蜂窝
交换中心或陆基系统
交换或区站
60
GPS信号源（如提供
差分GPS信息与GPS信号
数据的GPS接收机网络
62
调制解调器
或其他接口
53
调制解调器
或其它接口
54
数据处理单元
（如计算机系统）
51
选用的GPS
接收机
56
55
海量存贮器（如对软
件）和小区的信息源
的存贮器
调制解调器
或其他接口
52
接到/来自其它
处理器（如网上
计算机或通过
电话系统）
64
50

图 2

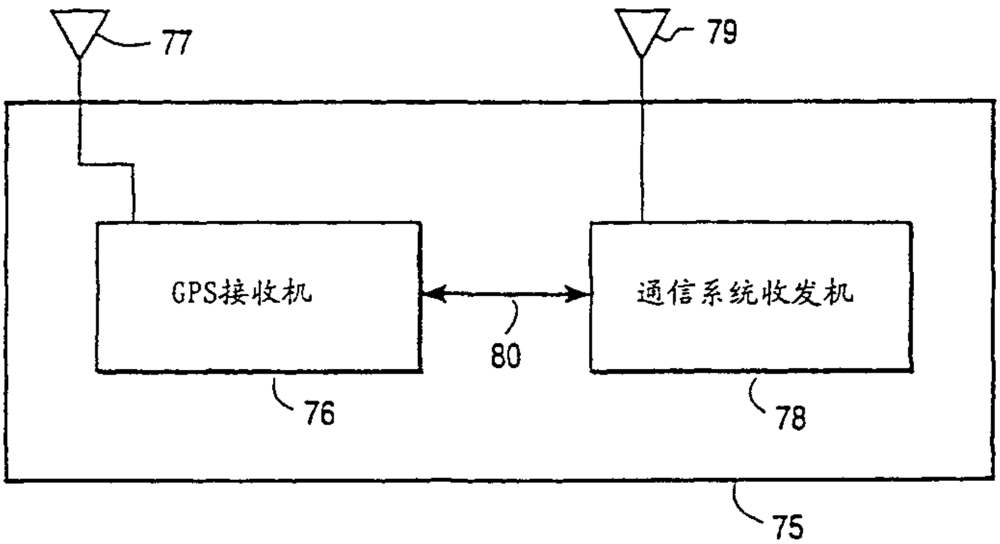


图 3A

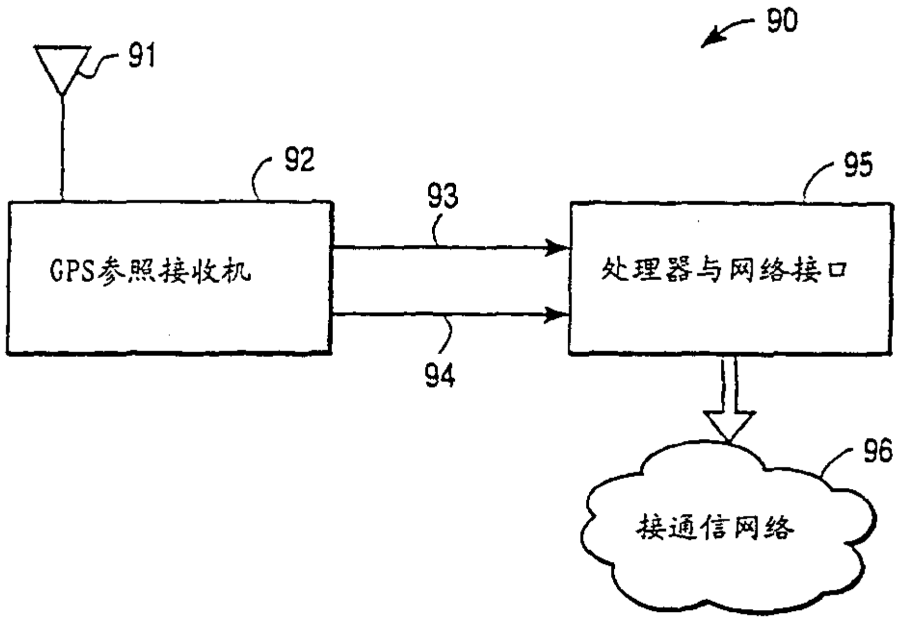


图 3B

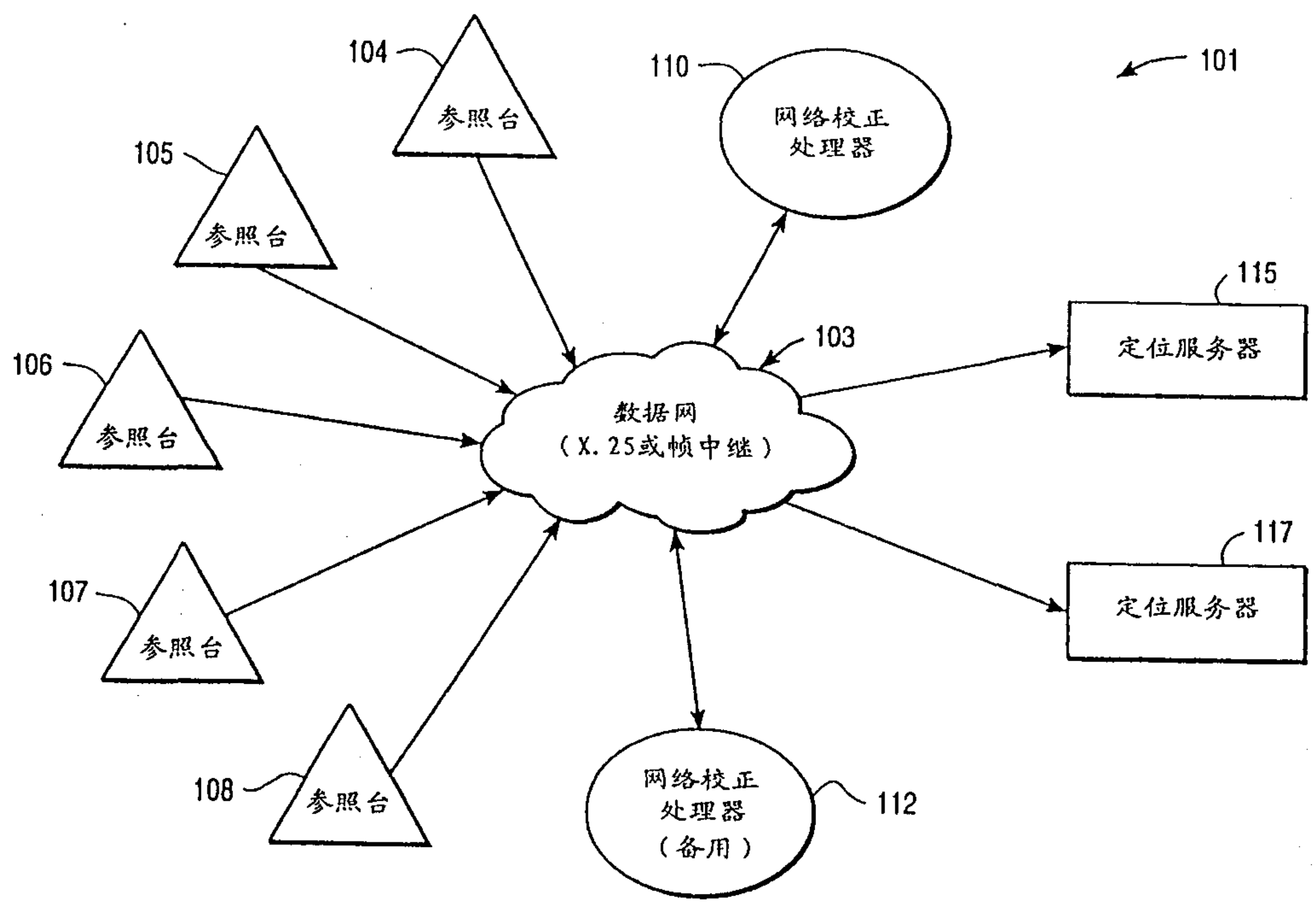

101
104
105
106
107
108
参照台
参照台
参照台
参照台
参照台
110
网络校正
处理器
103
数据网
（X.25或帧中继）
115
定位服务器
117
定位服务器
网络校正
处理器
（备用）
112

图 4

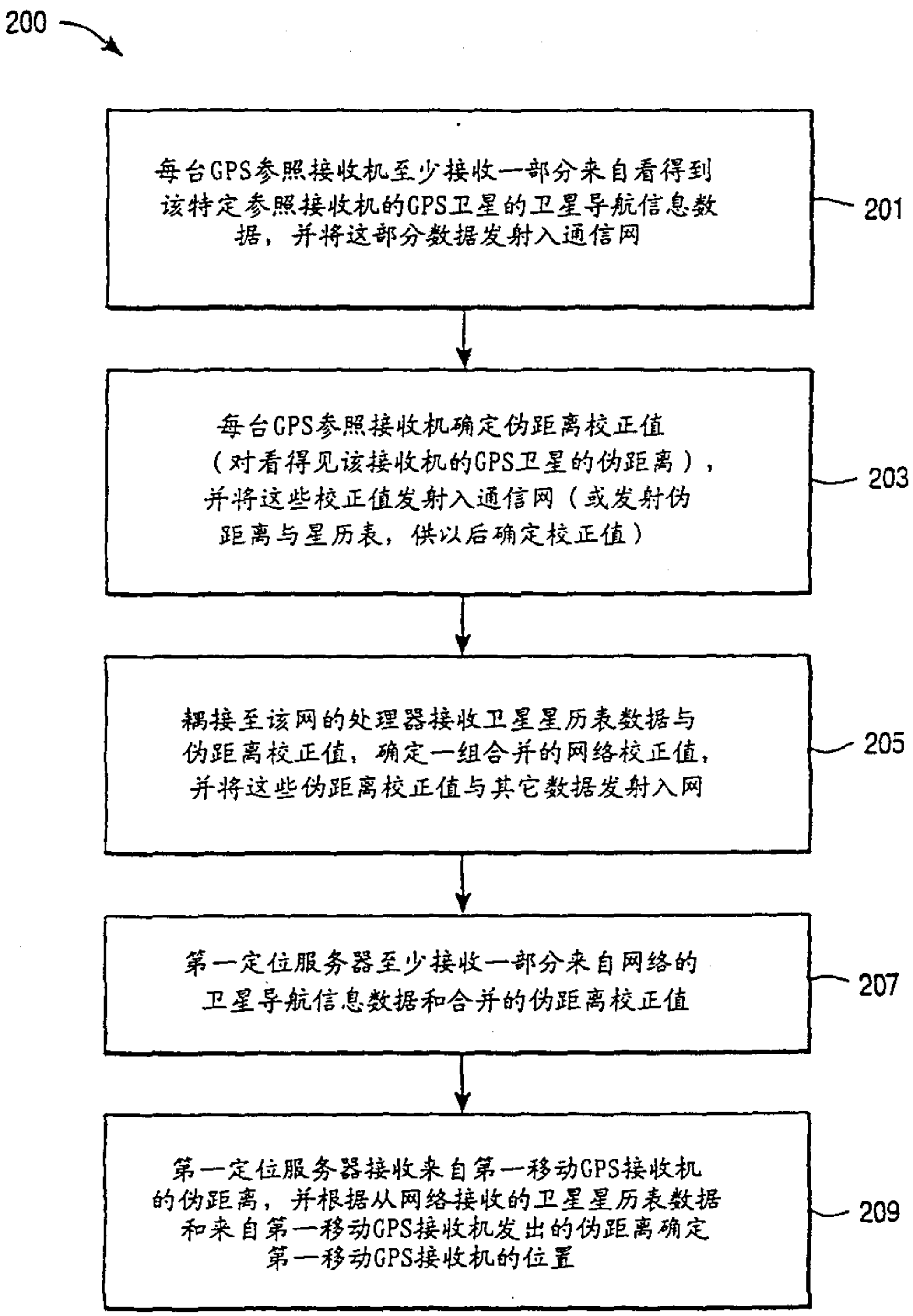

200
每台GPS参照接收机至少接收一部分来自看得到该特定参照接收机的GPS卫星的卫星导航信息数据，并将这部分数据发射入通信网
201
每台GPS参照接收机确定伪距离校正值（对看得见该接收机的GPS卫星的伪距离），并将这些校正值发射入通信网（或发射伪距离与星历表，供以后确定校正值）
203
耦接至该网的处理器接收卫星星历表数据与伪距离校正值，确定一组合并的网络校正值，并将这些伪距离校正值与其它数据发射入网
205
第一定位服务器至少接收一部分来自网络的卫星导航信息数据和合并的伪距离校正值
207
第一定位服务器接收来自第一移动GPS接收机的伪距离，并根据从网络接收的卫星星历表数据和来自第一移动GPS接收机发出的伪距离确定第一移动GPS接收机的位置
209

图　5A

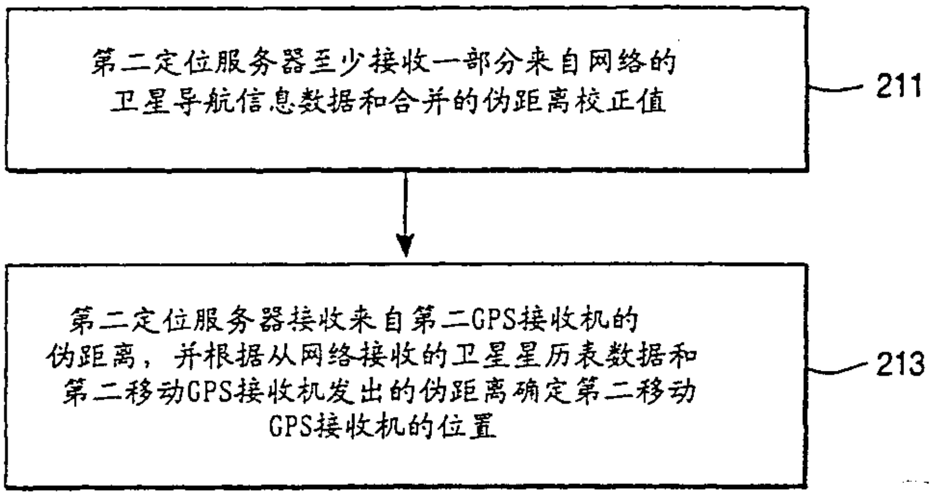

第二定位服务器至少接收一部分来自网络的
卫星导航信息数据和合并的伪距离校正值
211
第二定位服务器接收来自第二GPS接收机的
伪距离，并根据从网络接收的卫星星历表数据和
第二移动GPS接收机发出的伪距离确定第二移动
GPS接收机的位置
213

图 5B

网络校正处理器数据流

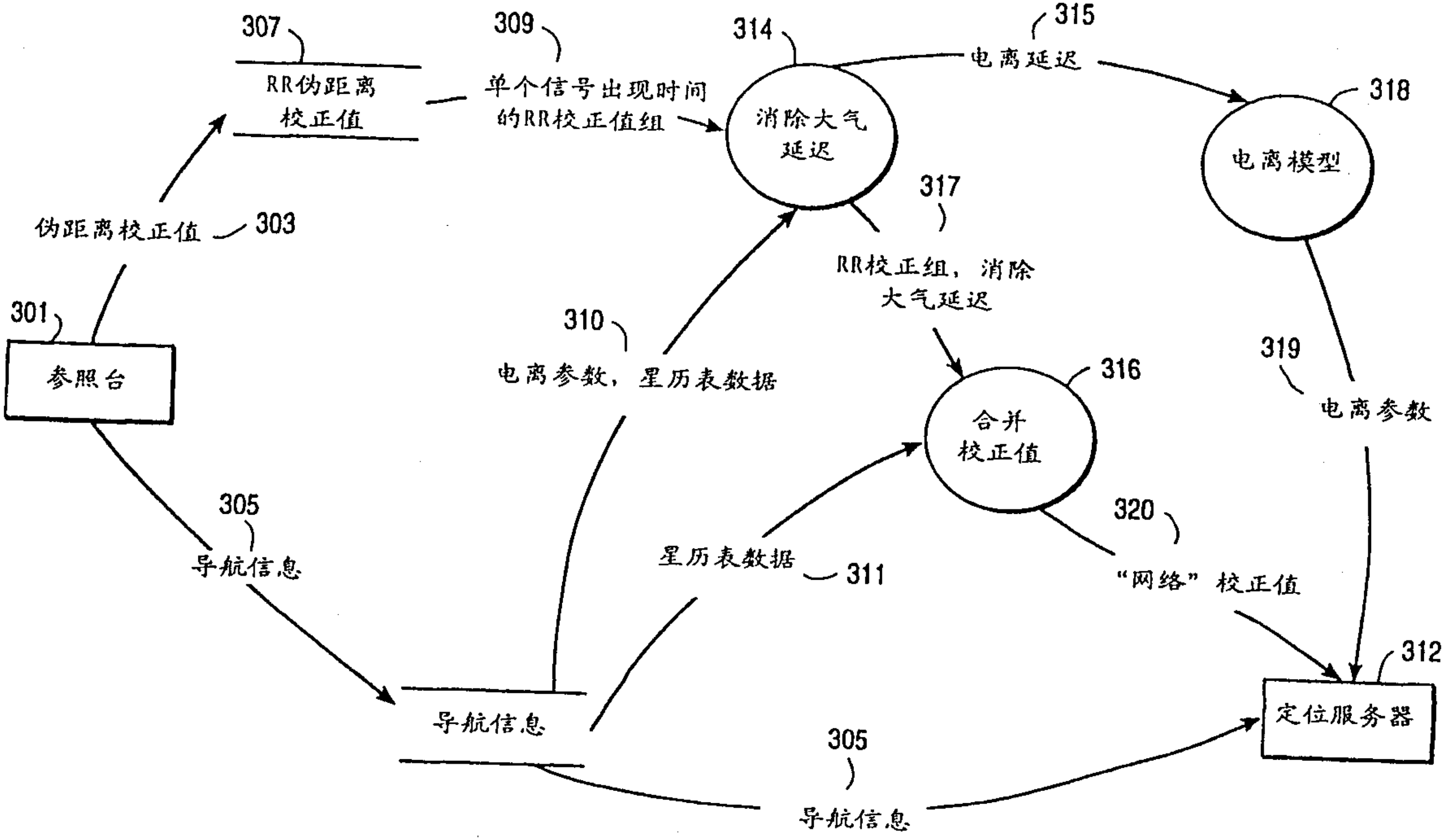


图 6

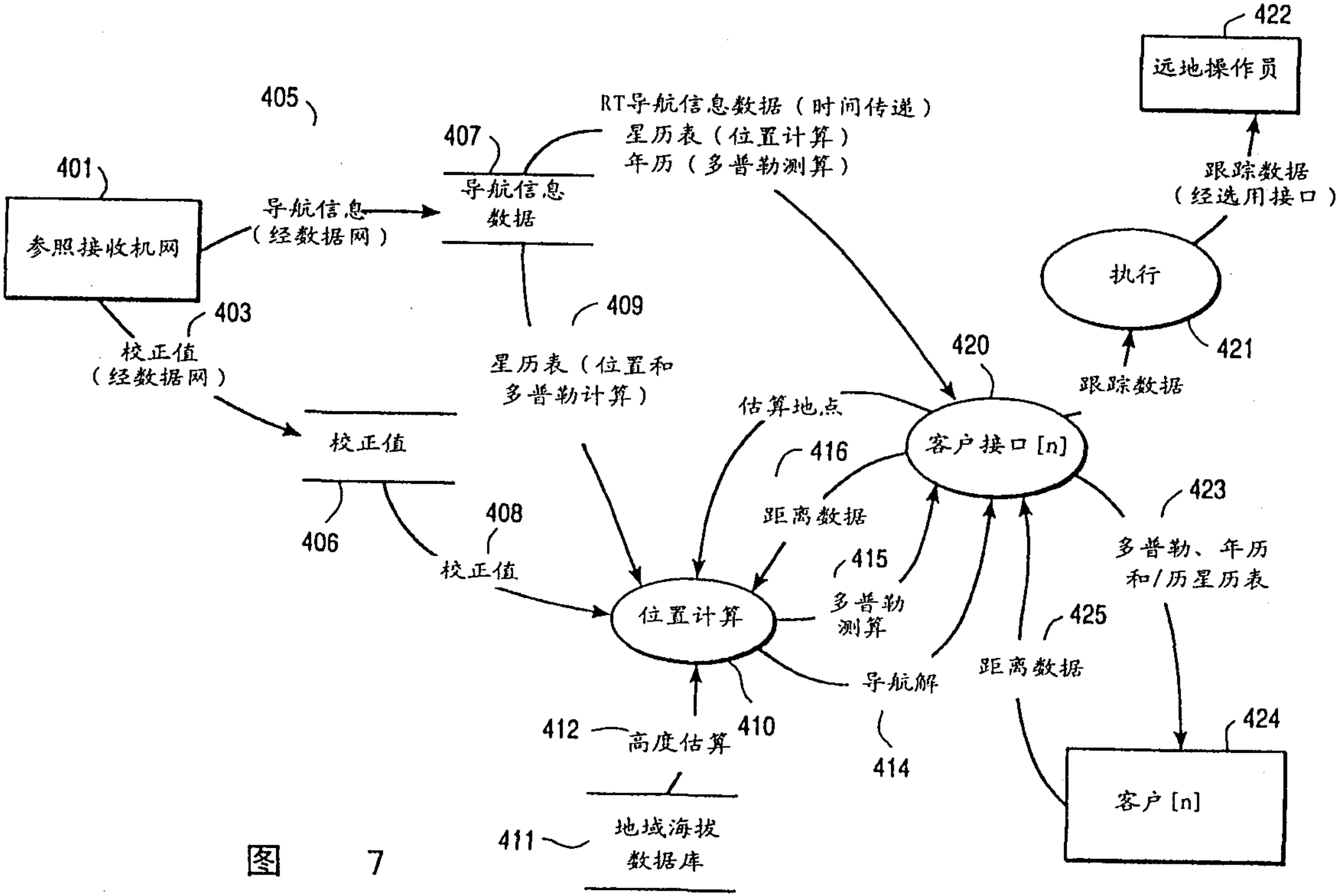

405
401
参照接收机网
导航信息
(经数据网)
407
导航信息
数据
RT导航信息数据(时间传递)
星历表(位置计算)
年历(多普勒测算)
403
校正值
(经数据网)
409
星历表(位置和
多普勒计算)
校正值
406
408
校正值
位置计算
410
412
高度估算
411
地域海拔
数据库
估算地点
416
距离数据
415
多普勒
测算
导航解
414
420
客户接口[n]
跟踪数据
执行
421
跟踪数据
(经选用接口)
422
远地操作员
423
多普勒、年历
和/历星历表
425
距离数据
424
客户[n]

图 7