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(54) **SYSTEM AND METHOD FOR POSITION CALCULATION OF A MOBILE DEVICE**

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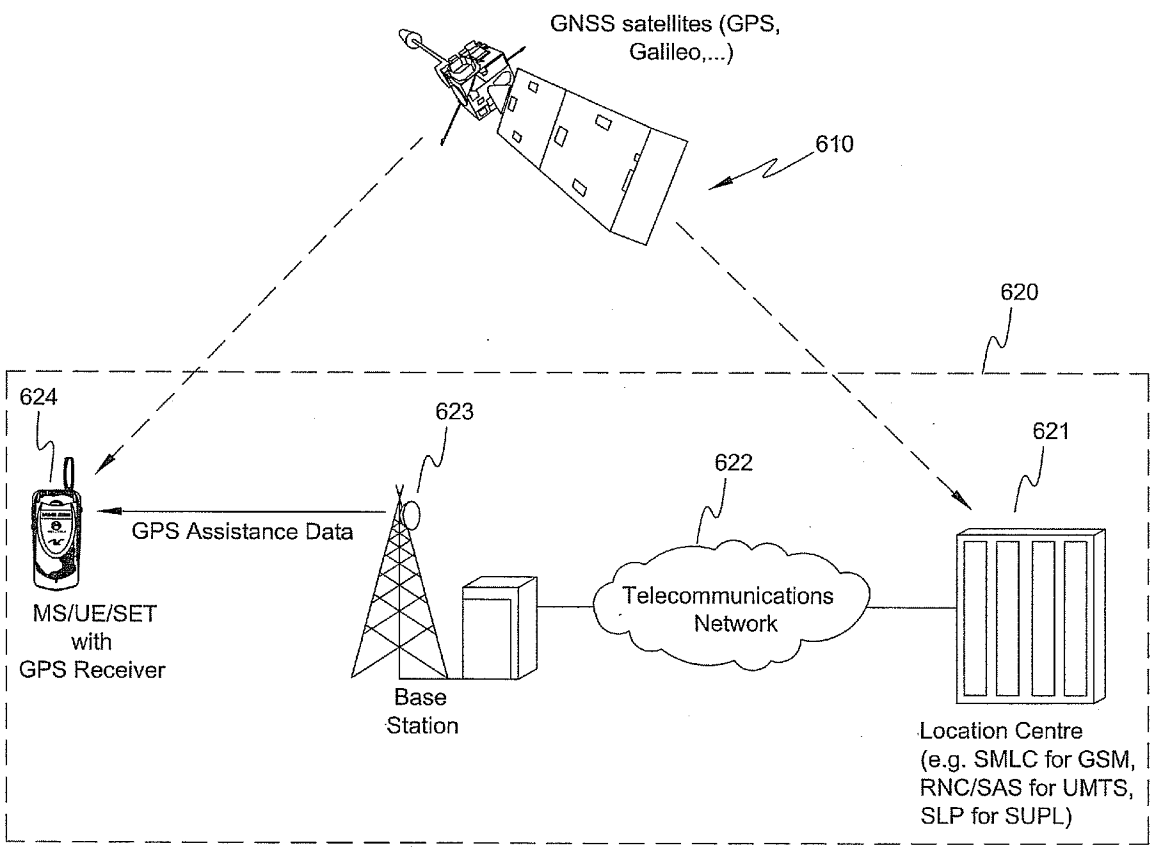
(57) **ABSTRACT**

A system and method for determining a location of a device. Plural signals from a first plurality of satellites may be received a the device where an estimated location of the device is determined as a function of frequency information from the signals. A location of the device may then be determined as a function of the estimated location and/or as a function of phase information from the signals. A second plurality of satellites may also be determined as a function of any one of the determined locations. In such embodiments, assistance data may be transmitted to the device that includes information from the second plurality of satellites. Another location of the device may then be determined from this information.



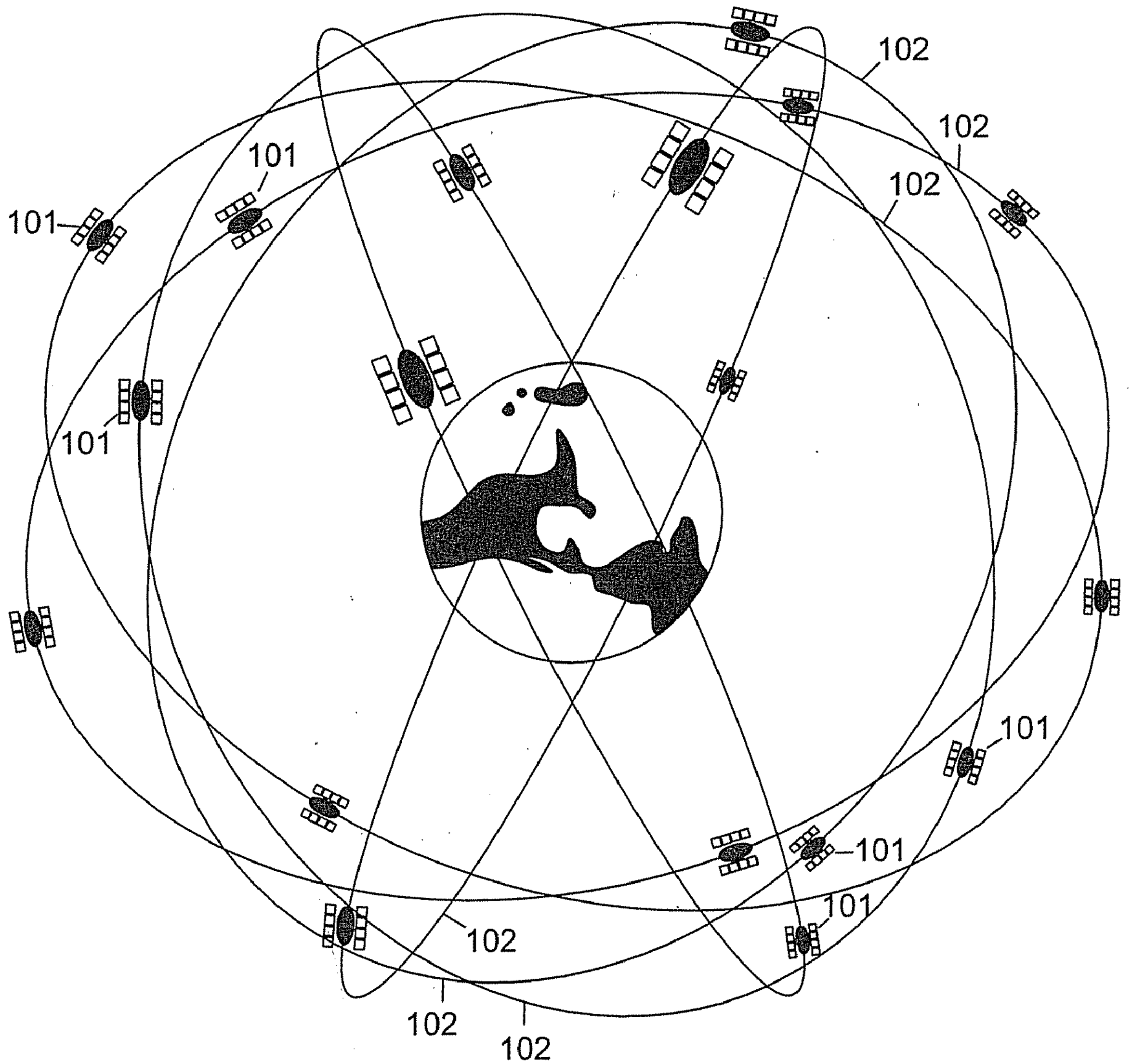


FIG. 1

PRIOR ART

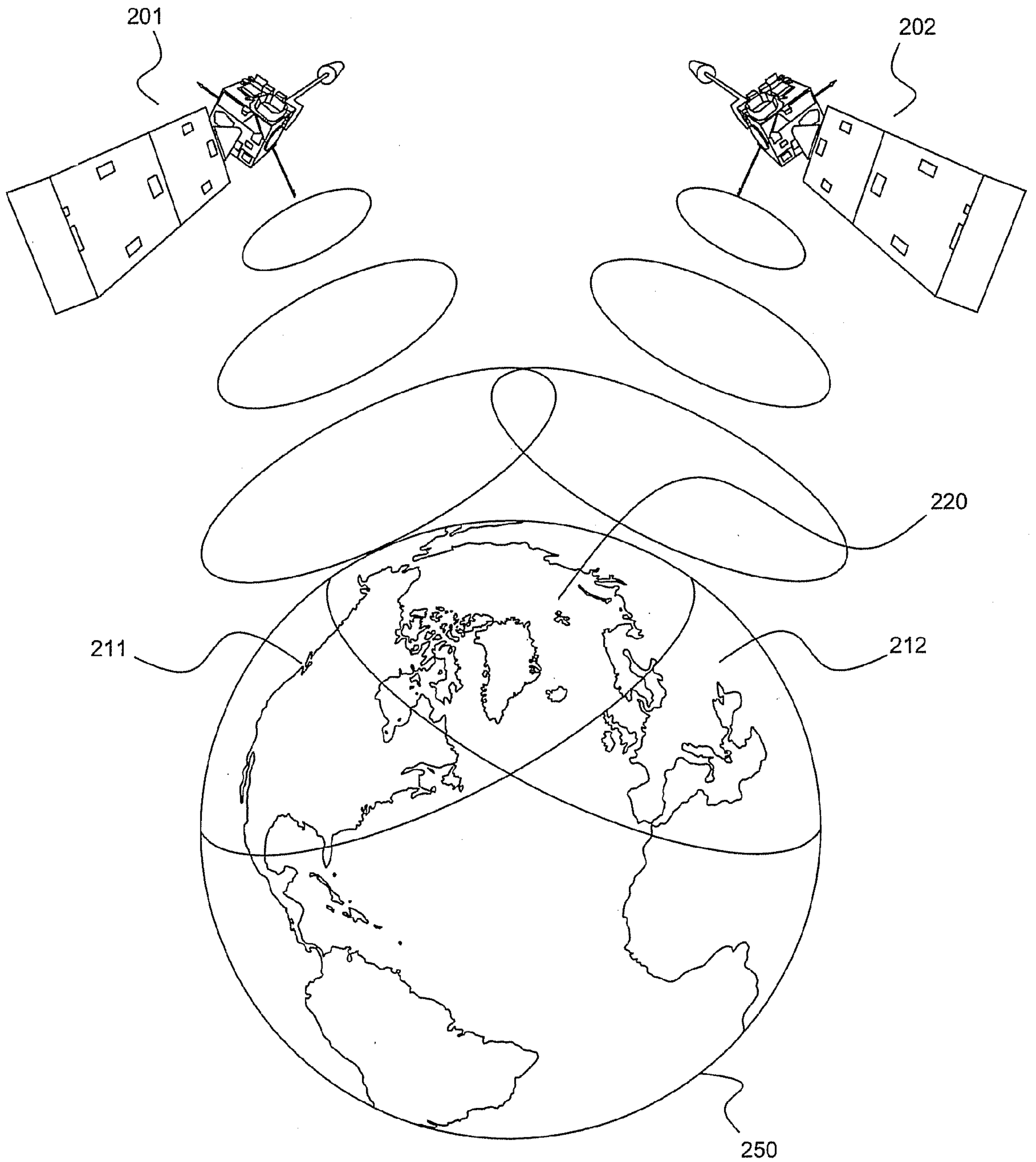


FIG. 2

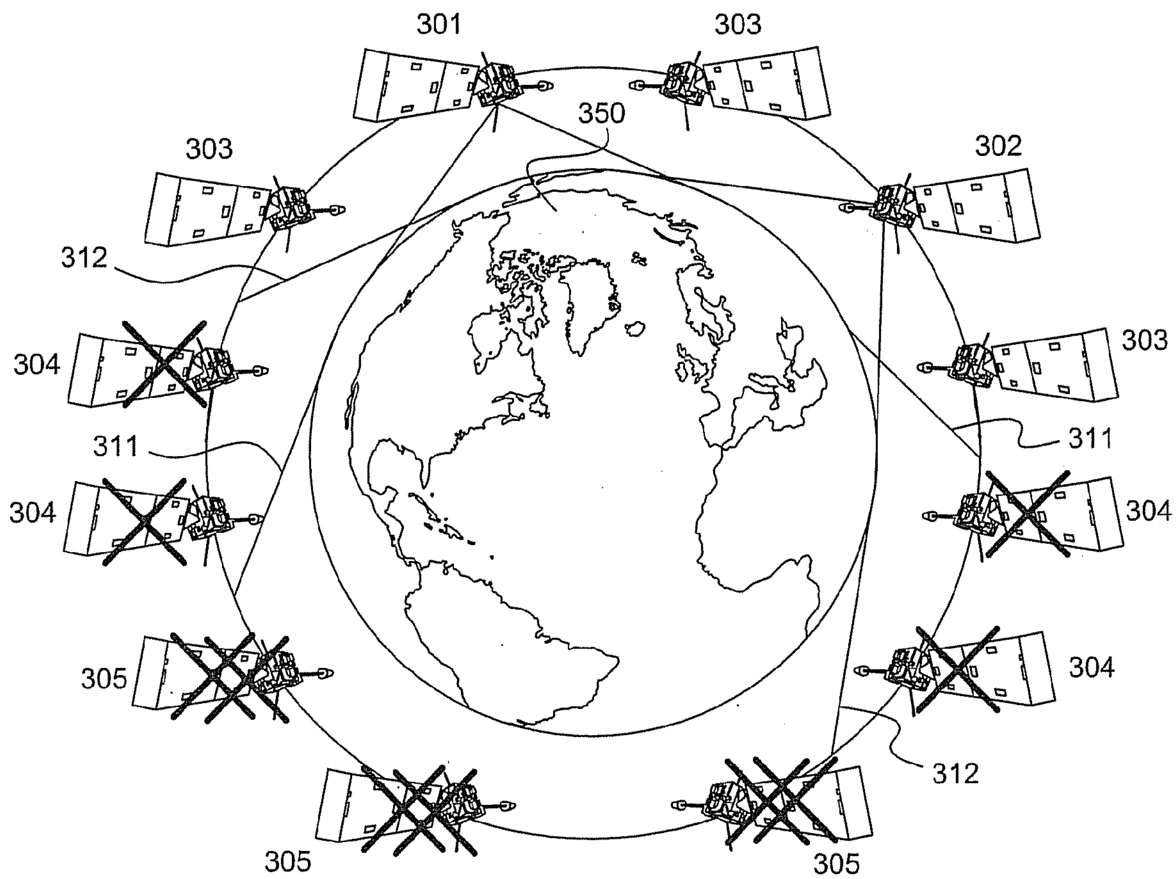

301
303
350
303
302
312
304
303
311
311
304
304
305
304
312
305
305

FIG. 3

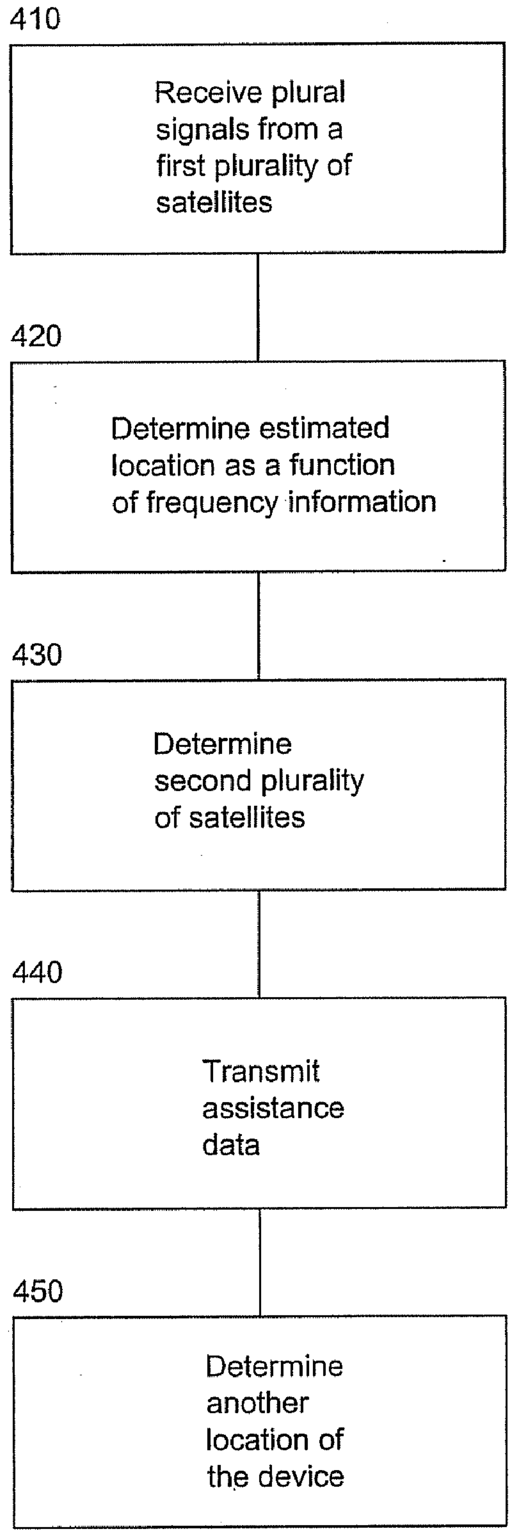

410
Receive plural signals from a first plurality of satellites
420
Determine estimated location as a function of frequency information
430
Determine second plurality of satellites
440
Transmit assistance data
450
Determine another location of the device

FIG. 4

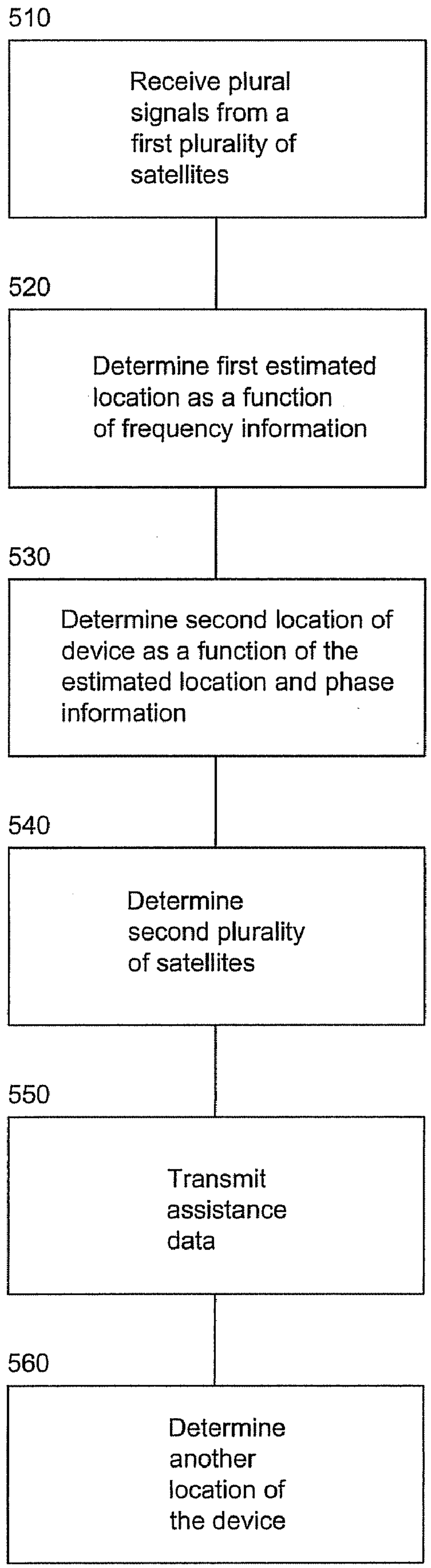
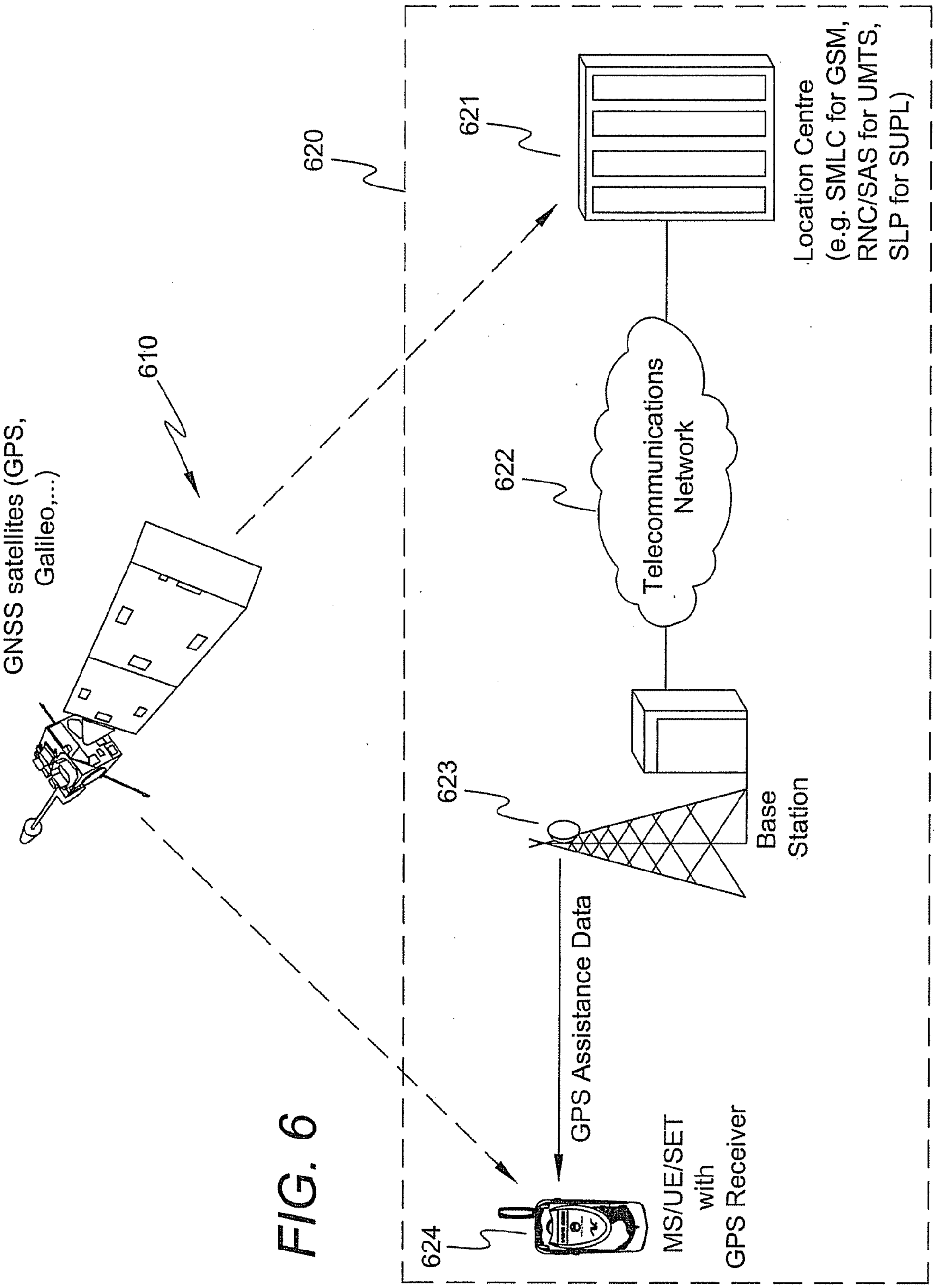

510
Receive plural signals from a first plurality of satellites
520
Determine first estimated location as a function of frequency information
530
Determine second location of device as a function of the estimated location and phase information
540
Determine second plurality of satellites
550
Transmit assistance data
560
Determine another location of the device

FIG. 5



GNSS satellites (GPS, Galileo,...)
610
620
621
Location Centre (e.g. SMLC for GSM, RNC/SAS for UMTS, SLP for SUPL)
622
Telecommunications Network
623
Base Station
GPS Assistance Data
624
MS/UE/SET with GPS Receiver

FIG. 6

SYSTEM AND METHOD FOR POSITION CALCULATION OF A MOBILE DEVICE

RELATED APPLICATIONS

[0001] The instant application claims the priority benefit of U.S. Provisional Application No. 61/012,319, filed Dec. 7, 2007, the entirety of which is incorporated herein by reference. The instant application is related to U.S. Application Ser. No. 12/099,694, filed Apr. 8, 2008 and U.S. Application Ser. No. 12/050,794, filed Mar. 18, 2008, the entirety of each incorporated herein by reference.

BACKGROUND

[0002] Radio communication systems generally provide two-way voice and data communication between remote locations. Examples of such systems are cellular and personal communication system ("PCS") radio systems, trunked radio systems, dispatch radio networks, and global mobile personal communication systems ("GMPCS") such as satellite-based systems. Communication in these systems is conducted according to a pre-defined standard. Mobile devices or stations, also known as handsets, portables or radiotelephones, conform to the system standard to communicate with one or more fixed base stations. It is important to determine the location of such a device capable of radio communication especially in an emergency situation. In addition, in 2001 the United States Federal Communications Commission ("FCC") required that cellular handsets must be geographically locatable. This capability is desirable for emergency systems such as Enhanced 911 ("E-911"). The FCC requires stringent accuracy and availability performance objectives and demands that cellular handsets be locatable within 100 meters 67% of the time for network based solutions and within 50 meters 67% of the time for handset based solutions.

[0003] Current generations of radio communication generally possess limited mobile device location determination capability. In one technique, the position of the mobile device is determined by monitoring mobile device transmissions at several base stations. From time of arrival or comparable measurements, the mobile device's position may be calculated. However, the precision of this technique may be limited and, at times, may be insufficient to meet FCC requirements. In another technique, a mobile device may be equipped with a receiver suitable for use with a Global Navigation Satellite System ("GNSS") such as the Global Positioning System ("GPS"). GPS is a radio positioning system providing subscribers with highly accurate position, velocity, and time ("PVT") information.

[0004] FIG. **1** is a schematic representation of a constellation **100** of GPS satellites **101**. With reference to FIG. **1**, GPS may include a constellation of GPS satellites **101** in non-geosynchronous orbits around the earth. The GPS satellites **101** travel in six orbital planes **102** with four of the GPS satellites **101** in each plane. Of course, a multitude of on-orbit spare satellites may also exist. Each orbital plane has an inclination of 55 degrees relative to the equator. In addition, each orbital plane has an altitude of approximately 20,200 km (10,900 miles). The time required to travel the entire orbit is just under 12 hours. Thus, at any given location on the surface of the earth with clear view of the sky, at least five GPS satellites are generally visible at any given time.

[0005] With GPS, signals from the satellites arrive at a GPS receiver and are utilized to determine the position of the receiver. GPS position determination is made based on the time of arrival ("TOA") of various satellite signals. Each of the orbiting GPS satellites **101** broadcasts spread spectrum microwave signals encoded with satellite ephemeris information and other information that allows a position to be calculated by the receiver. Presently, two types of GPS measurements corresponding to each correlator channel with a locked GPS satellite signal are available for GPS receivers. The two carrier signals, L**1** and L**2**, possess frequencies of 1.5754 GHz and 1.2276 GHz, or wavelengths of 0.1903 m and 0.2442 m, respectively. The L**1** frequency carries the navigation data as well as the standard positioning code, while the L**2** frequency carries the P code and is used for precision positioning code for military applications. The signals are modulated using bi-phase shift keying techniques. The signals are broadcast at precisely known times and at precisely known intervals and each signal is encoded with its precise transmission time.

[0006] GPS receivers measure and analyze signals from the satellites, and estimate the corresponding coordinates of the receiver position, as well as the instantaneous receiver clock bias. GPS receivers may also measure the velocity of the receiver. The quality of these estimates depends upon the number and the geometry of satellites in view, measurement error and residual biases. Residual biases generally include satellite ephemeris bias, satellite and receiver clock errors, and ionospheric and tropospheric delays. If receiver clocks were perfectly synchronized with the satellite clocks, only three range measurements would be needed to allow a user to compute a three-dimensional position. This process is known as multilateration. However, given the engineering difficulties and the expense of providing a receiver clock whose time is exactly synchronized, conventional systems generally account for the amount by which the receiver clock time differs from the satellite clock time when computing a receiver's position. This clock bias is determined by computing a measurement from a fourth satellite using a processor in the receiver that correlates the ranges measured from each satellite. This process requires four or more satellites from which four or more measurements can be obtained to estimate four unknowns x, y, z, b. The unknowns are latitude, longitude, altitude and receiver clock offset. The amount b, by which the processor has added or subtracted time, is the instantaneous bias between the receiver clock and the satellite clock. It is possible to calculate a location with only three satellites when additional information is available. For example, if the altitude of the handset or mobile device is well known, then an arbitrary satellite measurement may be included that is centered at the center of the earth and possesses a range defined as the distance from the center of the earth to the known altitude of the handset or mobile device. The altitude of the handset may be known from another sensor or from information from the cell location in the case where the handset is in a cellular network.

[0007] Traditionally, satellite coordinates and velocities have been computed inside the GPS receiver. The receiver obtains satellite ephemeris and clock correction data by demodulating the satellite broadcast message stream. The satellite transmission contains more than 400 bits of data transmitted at 50 bits per second. The constants contained in the ephemeris data coincide with Kepler orbit constants requiring many mathematical operations to turn the data into position and velocity data for each satellite. In one implementation, this conversion requires 90 multiplies, 58 adds and 21 transcendental function cells (sin, cos, tan) to translate the ephemeris into a satellite position and velocity vector at a single point, for one satellite. Most of the computations also require double precision, floating point processing.

[0008] Thus, the computational load for performing the traditional calculation is significant. The mobile device generally must therefore include a high-level processor capable of the necessary calculations, and such processors are relatively expensive and consume large amounts of power. Portable devices for consumer use, e.g., a cellular phone or comparable device, are preferably inexpensive and operate at very low power. These design goals are inconsistent with the high computational load required for GPS processing.

[0009] Further, the slow data rate from the GPS satellites is a limitation. GPS acquisition at a GPS receiver may take many seconds or several minutes, during which time the receiver circuit and processor of the mobile device must be continuously energized. Preferably, to maintain battery life in portable receivers and transceivers such as mobile cellular handsets, circuits are de-energized as much as possible. The long GPS acquisition time can rapidly deplete the battery of a mobile device. In any situation and particularly in emergency situations, the long GPS acquisition time is inconvenient.

[0010] Assisted-GPS ("A-GPS") has gained significant popularity recently in light of stringent time to first fix ("TTFF"), i.e., first position determination and sensitivity, requirements of the FCC E-911 regulations. In A-GPS, a communications network and associated infrastructure may be utilized to assist the mobile GPS receiver, either as a standalone device or integrated with a mobile station or device. The general concept of A-GPS is to establish a GPS reference network (and/or a wide-area D-GPS network) including receivers with clear views of the sky that may operate continuously. This reference network may also be connected with the cellular infrastructure, may continuously monitor the real-time constellation status, and may provide data for each satellite at a particular epoch time. For example, the reference network may provide the ephemeris and the other broadcast information to the cellular infrastructure. In the case of D-GPS, the reference network may provide corrections that can be applied to the pseudoranges within a particular vicinity. As one skilled in the art would recognize, the GPS reference receiver and its server (or position determination entity) may be located at any surveyed location with an open view of the sky. Typical A-GPS information may include data for determining a GPS receiver's approximate position, time synchronization mark, satellite ephemerides, and satellite dopplers. Different A-GPS services may omit some of these parameters; however, another component of the supplied information is the identification of the satellites for which a device or GPS receiver should search.

[0011] However, the signal received from each of the satellites may not necessarily result in an accurate position estimation of the handset or mobile device. The quality of a position estimate largely depends upon two factors: satellite geometry, particularly, the number of satellites in view and their spatial distribution relative to the user; and the quality of the measurements obtained from satellite signals. For example, the larger the number of satellites in view and the greater the distances therebetween, the better the geometry of the satellite constellation. Further, the quality of measurements may be affected by errors in the predicted ephemeris of the satellites, instabilities in the satellite and receiver clocks, ionospheric and tropospheric propagation delays, multipath interference, receiver noise and RF interference. A-GPS implementations generally rely upon provided assistance data to indicate which satellites are visible. Assistance data may generally be provided to a mobile device as a function of an estimated or initial location of the mobile device. From such assistance data, a mobile device will attempt to search for and acquire satellite signals for the satellites included in the assistance data. If, however, satellites are included in the assistance data that are not measurable by the mobile device (e.g., the satellite is no longer visible, etc.), then the mobile device will waste time and considerable power attempting to acquire measurements for the satellite.

[0012] In embodiments where an initial location of the handset or mobile device is determined as a function of the base station, cell, etc., situations may exist where this location is incorrectly known or is unknown (e.g., when a Mobile Location Center ("MLC") is employed as a service bureau for multiple network operators). Thus, if the respective code phase position calculation does not know the initial location to within 100 km, the position calculation for the mobile device may fail thereby having a significant impact on yield and accuracy for the MLC.

[0013] Accordingly, there is a need for a method and apparatus for geographic location determination of a device that would overcome the deficiencies of the prior art. Therefore, an embodiment of the present subject matter provides a method for determining the location of a device. The method comprises the steps of receiving at a device plural signals from a first plurality of satellites, determining an initial location of the device as a function of frequency information from the signals. A second plurality of satellites may be determined as function of this initial location. Assistance data may then be transmitted to the device which includes information from the second plurality of satellites, and a second estimated location of the device may be determined from the information from the second plurality of satellites. In another embodiment, another estimated location of the device may be determined as a function of phase information from the signals. In another embodiment of the present subject matter, the location of the mobile device may be determined in an exemplary two-step process by utilizing frequency shift (Doppler) information to calculate a coarse location from such information, and then taking the coarse location as an input and performing a more accurate location determination utilizing the code phase information.

[0014] In a further embodiment of the present subject matter, a system is provided for determining the location of a device from signals received from a plurality of GNSS satellites. The system comprises a receiver for receiving plural signals from a first plurality of satellites, circuitry for determining an coarse or initial location of the device as a function of frequency information from the signals, and circuitry for determining a second plurality of satellites as a function of the coarse location. The system may also include a transmitter for transmitting assistance data to the device where the assistance data includes information from the second plurality of satellites and circuitry for determining another location of the device from the information from the second plurality of satellites. In another embodiment, the system may include circuitry for determining a third estimated location of the device as a function of phase information from the signals. In yet another embodiment of the present subject matter, the system may comprise circuitry for determining the location of the mobile device in an exemplary two-step process by utilizing frequency shift (Doppler) information to calculate a coarse location from such information, and then taking the coarse location as an input and performing a more accurate location determination utilizing the code phase information.

[0015] In an additional embodiment of the present subject, a method is provided for determining a location of a device. The method may comprise the steps of receiving at the device plural signals from a first plurality of satellites and determining a first estimated location of the device as a function of frequency information from the signals. A second estimated location of the device may be determined as a function of the first estimated location and as a function of phase information from the signals. A second plurality of satellites may then be determined as a function of the first or second estimated location. The method may further include the steps of transmitting assistance data to the device where the assistance data includes information from the second plurality of satellites and determining a third estimated location of the device from the information from the second plurality of satellites.

[0016] These embodiments and many other objects and advantages thereof will be readily apparent to one skilled in the art to which the invention pertains from a perusal of the claims, the appended drawings, and the following detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a schematic representation of a constellation of GPS satellites.

[0018] FIG. **2** is a depiction of one method of selecting a second plurality of satellites according to an embodiment of the present subject matter.

[0019] FIG. **3** is a depiction of another method of selecting a second plurality of satellites according to an embodiment of the present subject matter.

[0020] FIG. **4** is an algorithm according to one embodiment of the present subject matter.

[0021] FIG. **5** is another algorithm according to one embodiment of the present subject matter.

[0022] FIG. **6** is a schematic representation for implementing one embodiment of the present subject matter.

DETAILED DESCRIPTION

[0023] With reference to the figures where like elements have been given like numerical designations to facilitate an understanding of the present subject matter, the various embodiments of a system and method for position calculation of a mobile device are herein described.

[0024] The disclosure relates to methods and apparatuses for determining geolocation using satellite signals and assistance data. The satellites may be considered as part of a Global Navigation Satellite System ("GNSS"), such as, but not limited to, the U.S. Global Positioning System ("GPS"). While the following description references the GPS system, this in no way should be interpreted as limiting the scope of the claims appended herewith. As is known to those of skill in the art, other GNSS systems operate, for the purposes of this disclosure, similarly to the GPS system, such as, but not limited to, the European Satellite project, Galileo; the Russian satellite navigation system, GLONASS; the Japanese Quasi-Zenith Satellite System ("QZSS"), and the Chinese satellite navigation and positioning system called Beidou (or Compass). Therefore, references in the disclosure to GPS and/or GNSS, where applicable, as known to those of skill in the art, apply to the above-listed GNSS systems as well as other GNSS systems not listed above.

[0025] Generally wireless A-GPS devices or handsets have a low time to first fix ("TTFF") as the devices are supplied with assistance data from an exemplary communications network to assist in locking onto or acquiring satellites quickly. Exemplary network elements that supply the assistance data may be a Mobile Location Center ("MLC") or other comparable network element. The MLC may generally be a node in a wireless network that performs an A-GPS position calculation utilizing code phases measured by a mobile device with a GPS receiver in the network. In embodiments of the present subject matter, the respective position calculation function ("PCF") generally may be seeded with an initial location of the mobile device within 100 km of the respective actual location to solve the GPS millisecond ambiguity problem. The millisecond-ambiguity problem is generally a result of the knowledge of the code phase chips only within a predetermined time interval, e.g., the present millisecond. If, however, a GPS receiver's location is known within approximately 100 km, then the millisecond-ambiguity problem may be resolved and an accurate location of a mobile device determined. The MLC may generally determine A-GPS information utilizing an approximate or initial location of the device. Conventionally, this approximate location may be the location of the cell tower serving the device. The MLC may then supply the device with the appropriate A-GPS assistance data for the set of satellites in view from this conventional location.

[0026] This typical process performs well when the approximate location possesses a small uncertainty; however, in the absence of an approximate location or where the approximate location possesses a large uncertainty (e.g., an uncertainty measured in hundreds of kilometers) the possible set of satellites may be quite large, and not all of the satellites in this set may be measurable. As each satellite requires time and resources to provide assistance data therefor and signaling methods often limit the number of satellites for which signals may be provided, assistance data for only a subset of the set satellites may be provided to the mobile device.

[0027] Since A-GPS implementations generally rely upon the provided assistance data to indicate which satellites are visible, the mobile device attempts to acquire only the satellite signals for the satellites included in the assistance data. In the absence of a location estimate, a small number of the satellites included in the assistance data may be measurable for the mobile device resulting in no location fix or a poor quality location fix of the respective device.

[0028] Embodiments of the present subject matter may utilize a staged approach to determine a plurality or set of satellites to select and send to a mobile device. In one embodiment of the present subject matter a wide spread of satellites may be selected to ensure an even coverage over a predetermined location, such as, but not limited to, the entire planet or the entirety of the known area of the location estimate, e.g., cell, communications network, city, county, country, continent, etc.

[0029] After this selection of satellites, generally one of four outcomes may occur: (i) the device may be able to determine its respective location with adequate precision from available satellite measurements; (ii) the device may be able to provide a rough location estimate with a predetermined number of satellite measurements, but the location estimate may not adequately precise or possesses a poor quality. For example, methods utilizing an earth-centered pseudo-measurement may be employed with three satellite measurements, even with an inadequate precision; standard A-GPS methods may then be employed to determine another set of satellites for which signals may be provided to the device. The remaining outcomes may be that (iii) the device may be able to provide one or two satellite measurements (in this instance, a location estimate may not be determined, however, the satellite measurements may be utilized to select another plurality or set of satellites for which assistance data may be provided or that are more likely to produce additional satellite measurements); and (iv) no satellite measurements are obtained, whereby the aforementioned process may be reattempted with a different set of satellites, or abandoned.

[0030] In the scenarios where a second plurality or set of satellites may be determined or selected, embodiments of the present subject matter may provide various methods for such a selection. For example, in one embodiment of the present subject matter, a second plurality or set of satellites may be selected as a function of an intersection of the coverage areas of the first plurality of satellites whereby this intersection may be employed as the new reference location.

[0031] FIG. **2** is a depiction of one method of selecting a second plurality of satellites according to an embodiment of the present subject matter. With reference to FIG. **2**, a first satellite **201** and a second satellite **202** may be present in the first plurality or set of satellites. Of course, any number of satellites may be present in the first plurality or set of satellites and the depiction of two satellites in FIG. **2** should not in any way limit the scope of the claims herewith as this depiction is provided for ease of description. The first satellite **201** provides a first coverage area **211** projected upon the surface of the Earth **250**. The second satellite **202** provides a second coverage area **212** projected upon the surface of the Earth **250**. An intersection area **220** of these two respective coverage areas **211**, **212** may be employed as a reference location or estimated location for which a second set or plurality of satellites is determined. In a further embodiment of the present subject matter, the coverage area may be extended or decreased by a predetermined amount or area to thereby increase or reduce the number of satellites in the second plurality or set of satellites.

[0032] In another embodiment of the present subject matter, a second plurality or set of satellites may be selected as a function of an occlusion mask drawn from each measured satellite. FIG. **3** is a depiction of another method of selecting a second plurality of satellites according to an embodiment of the present subject matter. With reference to FIG. **3**, signals from a first satellite **301** and a second satellite **302** in a first plurality of satellites may be measured by a device. The first plurality of satellites may be any number or all of the satellites **301**, **302**, **303**, **304**, **305** in a satellite constellation. In the scenario depicted by FIG. **3**, an occlusion mask **311**, **312** may be drawn from any one or more measured satellites **301**, **302** (it should be noted that in three-dimensions, the occlusion masks **311**, **312** are conical). Satellites **304**, **305** may then be removed from a second plurality or set of satellites provided in future assistance data if any one or more of the satellites are occluded by the Earth **350** from any one or more measured satellites **301**, **302**. As illustrated, three satellites **305** are occluded by the Earth **350** from both measured satellites **301**, **302**, and four satellites **304** are occluded by the Earth **350** from one of the measured satellites **301** or **302**. This illustration is exemplary only and should not in any way limit the scope of the claims appended herewith. Any set or subset of the remaining satellites **301**, **302**, **303** may then be selected for the second plurality of satellites.

[0033] In a further embodiment of the present subject matter, the respective occlusion masks **311**, **312** may be extended or decreased by a predetermined amount or angle to thereby alter the conical mask to increase or reduce the number of satellites in the second plurality or set of satellites. For example, an exemplary occlusion mask may be extended if the mobile device is unable to measure satellites below a certain angle above the horizontal. Additionally, an exemplary occlusion mask may be decreased if the mobile device is able to measure satellites at a certain angle below the horizontal.

[0034] In yet another embodiment of the present subject matter, a second plurality or set of satellites may be determined as a function of Doppler measurements and/or the approximate or initial location of the mobile device (e.g., within 1 to 2 km) calculated therefrom. In a further embodiment, this location may also be utilized as an input to the respective code phase position calculation to determine a more accurate location of the mobile device.

[0035] In these embodiments, the first and second plurality of satellites may be mutually exclusive, that is, there may not be a satellite of the first plurality of satellites that is a member of the second plurality of satellites; therefore, the associated assistance data would also be mutually exclusive. Of course, embodiments of the present subject matter may include one or more common satellites in each of the first and second plurality or sets of satellites, especially in the instance where the mobile device was able to provide a measurement for the common satellite.

[0036] In one embodiment of the present subject matter, an initial location of a mobile device may be calculated using Doppler measurements. In another embodiment, an exemplary method may also seed any one or all of the position calculation functions with (0, 0, 0), that is, the center of the Earth in Earth-Centered Earth-Fixed ("ECEF") coordinates. An exemplary Doppler location calculation may then calculate the location of a device within a predetermined distance (e.g., 5 to 10 km, less than or equal to 100 km, etc.) to solve the millisecond ambiguity problem described above. The Doppler location calculation may then be utilized as the initial location for an exemplary code phase-based position calculation according to embodiments of the present subject matter. One non-limiting example of a Doppler position calculation is outlined in Hill, J., "The Principle of a Snapshot Navigation Solution Based on Doppler Shift," ION GPS 2001, 14th International Technical Meeting of the Satellite Division of the Institute of Navigation, Sep. 11-14, 2001, the entirety of which is incorporated herein by reference.

[0037] Generally, Doppler shift occurs since a GPS signal travels at the speed of light. The rate of change of the range between a satellite and a respective receiver may expand or compress the wavelength effectively measured by a receiver. For example, when a satellite approaches the receiver, frequency may increase slightly and when the satellite recedes, the frequency may decrease. Assuming a stationary receiver and utilizing Doppler measurements from one or more satellites, an approximate or initial location of a mobile device may thus be determined. For example, the coarse acquisition ("C/A") code is 1023 bits long and repeats every millisecond.

As an exemplary mobile device may measure the distance offset within the 1023 bits, the measurements may be ambiguous at the millisecond level. The number that the mobile device measures is the remainder part of the respective pseudorange or the pseudorange modulo one millisecond.

[0038] The whole part of the pseudorange may then be determined in units of 1023 bits and summed with the measured values. Generally, this is in the range of 70 as the travel time of the signal is in the order of 70 milliseconds. The GPS chipping rate in seconds is generally $1.023 \cdot 10^6$. The resolution of a 1023 bit C/A code in meters may be represented by the following relationship:

$$\frac{codelength}{GPSchippingrate} \cdot c = 299792.458 \tag{1}$$

[0039] It follows that the resolution of one chip in meters may be represented by the following relationship:

$$\frac{resolutionof1023bitcode}{1023} = 293.05226 \tag{2}$$

Therefore, the whole and part chips may be utilized to determine the pseudorange that represents the measured range modulo one millisecond.

[0040] To calculate the true pseudorange between the satellite and the receiver the following steps may be utilized for each satellite: determine the location of the satellite using the time of receipt of the signals, determine the satellite clock correction using the time of receipt of the signals, and determine the distance between the estimated mobile device location and the location of the satellite and subtract the satellite clock correction. If the mobile device clock correction is known, then this value should also be subtracted as represented by the following relationship:

$$\text{range} = \sqrt{(x_s - x_r)^2 + (y_s - y_r)^2 + (z_s - z_r)^2} - \text{satelliteclockcorr.} - \text{receiverclockcorr.} \tag{3}$$

[0041] A fractional range from the whole and part GPS chips may be determined utilizing the following relationship:

$$\text{frange} = (\text{wholechips} \cdot \text{resolutionofonechip}) + (\text{partchips} \cdot \text{resolutionofonechip}) \tag{4}$$

[0042] The number of whole units of 1023 bits in the range may now be determined utilizing the following relationship:

$$N = \text{int}\left(\frac{(\text{range} - frange)}{resolutionof1023bitcode} + 0.5\right) \tag{5}$$

[0043] The pseudorange may then be determined:

$$\text{pseudorange} = (\text{N} \cdot \text{resolutionof1023bitcode}) + \text{frange} \tag{6}$$

[0044] In further embodiments of the present subject matter, to formulate a least squares solution for a Doppler location estimate, the following relationship may be utilized:

$$Ax = b \tag{7}$$

[0045] The matrix A in Equation (7) may be represented by the following relationship:

$$A = \begin{vmatrix} V_{0x} & V_{0y} & V_{0z} & \|S_{0c}\| \\ V_{1x} & V_{1y} & V_{1z} & \|S_{1c}\| \\ \vdots & \vdots & \vdots & \vdots \\ V_{mx} & V_{my} & V_{0mz} & \|S_{mc}\| \end{vmatrix} \tag{8}$$

[0046] Each row in the above matrix A corresponds to each measured satellite. With reference to Equation (8), the first three terms for each row represent the respective velocity of a satellite in the x, y and z directions. The satellite velocity at time t may be determined using the ephemeris. The final term in each row represents the matrix norm of a satellite location, e.g., the square root of the sum of the squares of the satellite location vector.

[0047] The x matrix in Equation (7) may be represented by the following relationship:

$$x_n = \begin{vmatrix} U_{cxn} \\ U_{cyn} \\ U_{czn} \\ \Delta W_n \end{vmatrix} \tag{9}$$

[0048] The vector represented by x_n is generally the unknown for which a solution should be found. With reference to Equation (9), the results of a least squares process may generally provide a location in ECEF coordinates, and ΔW_n represents any clock error in the respective solution. In one embodiment of the subject matter, x_n may be provided as the initial location estimate of a mobile device. However, in another embodiment, the ECEF coordinates (0, 0, 0) may also suffice.

[0049] With continued reference to Equation (7), the b matrix may be represented by the following relationship:

$$B_i(x_n) = W_i\|S_i - U_{cn}\| + S_{ic} \cdot V_i + \Delta W_n(\|S_{ic}\| - \|S_{ic} - U_{cn}\|) \tag{10}$$

[0050] Wi may be determined by the following relationship:

$$Wi = \frac{\Delta F_r}{F_t} c \tag{11}$$

where ΔF_r represents the measured Doppler and F_t represents the transmitted frequency of carrier signal L**1** (e.g., 1.5754 GHz).

[0051] Upon construction of the A, x and b matrices, a least squares iterative procedure may be invoked by the following relationship:

$$x_{n+1} = (A^t A)^{-1} A^t B(x_n) \tag{12}$$

The resultant location determination may then be utilized as an input or seed for a second position calculation utilizing phase information such as, but not limited to, C/A code phase information. The resultant location determination may also be utilized to determine a second set or plurality of satellites from which appropriate AGPS information may be provided to an exemplary mobile device.

[0052] In one exemplary embodiment of the present subject matter, tests were conducted over a full day of data from a stationary GPS receiver in open sky conditions. The following statistics show the horizontal error for the respective GPS data:

TABLE 1

Horizontal Error Statistics for All Satellites	
Total Records	155,043
Average	796.8 m
Stdev	255.2 m
Minimum	174.6 m
Maximum	5691.4 m
67%	827.9 m
95%	1136.6 m
Yield For All Satellites	100.0

[0053] As shown above in the statistical data, the average error of the Doppler calculated location was 796.8 m with a maximum error of 5691.4 m. Thus, the average error was considerably well within the 100 km required to provide an input or seed a subsequent code phase position determination.

[0054] FIG. **4** is an algorithm **400** according to one embodiment of the present subject matter. With reference to FIG. **4**, at step **410**, plural signals may be received at a mobile device from a first plurality of satellites. In one embodiment of the present subject matter, the first plurality of satellites may be at least four. Of course, any appropriate number of satellites may comprise the first plurality, and such an example should not limit the scope of the claims appended herewith. Exemplary satellites may be a part of a Global Navigation Satellite System ("GNSS") such as, but not limited to, Global Positioning System ("GPS"), Galileo, Global Navigation Satellite System ("GLONASS"), Quasi-Zenith Satellite System ("QZSS"), and combinations thereof. An exemplary device may be, but is not limited to, a cellular device, text messaging device, computer, portable computer, vehicle locating device, vehicle security device, communication device, and wireless transceiver.

[0055] An estimated location of the device may be determined as a function of frequency information from the signals at step **420**. In one embodiment of the present subject matter, the estimated location may be determined as a function of coordinates for origin in an ECEF coordinate system. In yet another embodiment, the frequency information may include Doppler shift information. At step **430**, a second plurality of satellites may be determined as a function of the estimated location. Assistance data may then be transmitted to the device where the assistance data includes information from the second plurality of satellites at step **440**. At step **450**, another location of the device may then be determined from this information. In one exemplary embodiment, the first and second plurality of satellites may be mutually exclusive. Of course, any number of satellites in the first and second plurality of satellites may be common therebetween. In another embodiment, a third location of the device may be determined as a function of phase information from the signals. Exemplary phase information may include C/A code phase information.

[0056] FIG. **5** is another algorithm **500** according to one embodiment of the present subject matter. With reference to FIG. **5**, at step **510**, plural signals may be received at a mobile device from a first plurality of satellites. An estimated location of the device may be determined as a function of frequency information from the signals at step **520**, and at step **530** a second estimated location determined as a function of the first estimated location and phase information from the signals. At step **540**, a second plurality of satellites may be determined as a function of any one of the first or second estimated locations. Assistance data may then be transmitted to the device where the assistance data includes information from the second plurality of satellites at step **550**. At step **560**, another location of the device may then be determined from this information. In one exemplary embodiment, the first and second plurality of satellites may be mutually exclusive. Of course, any number of satellites in the first and second plurality of satellites may be common therebetween.

[0057] FIG. **6** is a schematic representation for implementing one embodiment of the present subject matter. With reference to FIG. **6**, a satellite system **610** may communicate with a ground system **620**. An exemplary satellite system **610** may be a GNSS such as, but not limited to, GPS, Galileo, GLONASS, QZSS, and combinations thereof. The ground system **620** may include a cellular network having a location center **621**. The location center **621** may be a Mobile Location Center (MLC) or another network component such as a central office configured to communicate with a telecommunication network **622** and at least one base station **623**. In one embodiment of the present subject matter, a device **624** may communicate with the base station **623** to acquire GPS assistance data. For example, the location center **621** may or may not receive a preliminary estimate of the device's location or boundary thereof on the basis of the device's serving or neighboring cell site, sector, network boundary, or other area. Further the preliminary estimate may be a function of frequency information as discussed above. The location center **621** may also determine a plurality of satellites as a function of this boundary or region and determine whether any one or more of these plural satellites, while operational, are not visible by the device **624** for some reason. The location center **621** may also receive satellite information from GPS satellites. The satellite information may include the satellite's broadcast ephemeris information of the broadcasting satellite, that of all satellites, or that of selected satellites. Further, the location center **621** may manipulate the assistance data to prevent the device **624** from searching and attempting to acquire signals from one or more satellites. This information may then be transmitted or relayed to the device **624** and utilized for location determination. The location center **621** may relay the information back to the device **624** or use the information, either singularly or along with some preliminary estimation of the device's location, to assist the device **624** in a geographic location determination. In another embodiment, any one or plural steps illustrated in FIGS. **4** and **5** may be implemented at the location center **621** and communicated to the device **624**. Of course, the estimated location of the device **624** may be determined as a function of additional signals provided by the network **622**. Exemplary devices may be, but are not limited to, a cellular device, text messaging device, computer, portable computer, vehicle locating device, vehicle security device, communication device, and wireless transceiver.

[0058] In another embodiment, the device **624** may acquire GPS information directly from plural satellites in the satellite system **610**. For example, the device **624** may include a receiver for receiving plural signals from a first plurality of satellites and respective circuitry for determining an estimated location thereof as a function of frequency information from the signals. Exemplary frequency information may be, but is not limited to, Doppler shift information. The device **624** may also include circuitry for determining a location thereof as a function of the estimated location and as a function of phase information from the signals. Exemplary phase information may include C/A code phase information. The determined location may also be a function of coordinates for origin in an ECEF coordinate system. Of course, the device **624** may receive assistance data from the location center **621** that may include information from a second plurality of satellites. The device **624** may also comprise circuitry for determining another location thereof from this information. Of course, the first and second plurality of satellites may be mutually exclusive, or any number of satellites in the first and second plurality of satellites may be common therebetween.

[0059] As shown by the various configurations and embodiments illustrated in FIGS. **1-6**, a method and system for position calculation of a mobile device have been described.

[0060] While preferred embodiments of the present subject matter have been described, it is to be understood that the embodiments described are illustrative only and that the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occurring to those of skill in the art from a perusal hereof.

What we claim is:

1. A method for determining a location of a device, the method comprising:

(a) receiving at said device plural signals from a first plurality of satellites;

(b) determining a first estimated location of said device as a function of frequency information from said signals;

(c) determining a second plurality of satellites as a function of said first estimated location;

(d) transmitting assistance data to said device, said assistance data including information from said second plurality of satellites; and

(e) determining a second estimated location of said device from said information from said second plurality of satellites.

2. The method of claim **1** further comprising the step of determining a third estimated location of said device as a function of phase information from said signals.

3. The method of claim **1** wherein said first plurality of satellites is at least four.

4. The method of claim **1** wherein the satellites are part of a Global Navigation Satellite System ("GNSS").

5. The method of claim **4** wherein the GNSS is selected from the group consisting of: Global Positioning System ("GPS"), Galileo, Global Navigation Satellite System ("GLONASS"), and Quasi-Zenith Satellite System ("QZSS").

6. The method of claim **1** wherein the device is selected from the group consisting of: cellular device, text messaging device, computer, portable computer, vehicle locating device, vehicle security device, communication device, and wireless transceiver.

7. The method of claim **1** wherein said first estimated location is determined as a function of coordinates for origin in an Earth-Centered Earth-fixed ("ECEF") coordinate system.

8. The method of claim **1** wherein said first and second plurality of satellites are mutually exclusive.

9. The method of claim **1** wherein said frequency information includes Doppler shift information.

10. The method of claim **2** wherein said phase information includes coarse acquisition ("C/A") code phase information.

11. A system for determining the location of a device from signals received from a plurality of Global Navigation Satellite System ("GNSS") satellites comprising:

(a) a receiver for receiving plural signals from a first plurality of satellites;

(b) circuitry for determining a first estimated location of said device as a function of frequency information from said signals;

(c) circuitry for determining a second plurality of satellites as a function of said first estimated location;

(d) a transmitter for transmitting assistance data to said device, said assistance data including information from said second plurality of satellites; and

(e) circuitry for determining a second estimated location of said device from said information from said second plurality of satellites.

12. The system of claim **11** further comprising circuitry for determining a third estimated location of said device as a function of phase information from said signals.

13. The system of claim **11** wherein said first plurality of satellites is at least four.

14. The system of claim **11** wherein the GNSS is selected from the group consisting of: Global Positioning System ("GPS"), Galileo, Global Navigation Satellite System ("GLONASS"), and Quasi-Zenith Satellite System ("QZSS").

15. The system of claim **11** wherein the device is selected from the group consisting of: cellular device, text messaging device, computer, portable computer, vehicle locating device, vehicle security device, communication device, and wireless transceiver.

16. The system of claim **11** wherein said first estimated location is a function of coordinates for origin in an Earth-Centered Earth-fixed ("ECEF") coordinate system.

17. The system of claim **11** wherein said first and second plurality of satellites are mutually exclusive.

18. The system of claim **11** wherein said frequency information includes Doppler shift information.

19. The system of claim **12** wherein said phase information includes coarse acquisition ("C/A") code phase information.

20. A method for determining a location of a device, the method comprising:

(a) receiving at said device plural signals from a first plurality of satellites;

(b) determining a first estimated location of said device as a function of frequency information from said signals;

(c) determining a second estimated location of said device as a function of said first estimated location and as a function of phase information from said signals;

(d) determining a second plurality of satellites as a function of said first or second estimated location;

(e) transmitting assistance data to said device, said assistance data including information from said second plurality of satellites; and

(f) determining a third estimated location of said device from said information from said second plurality of satellites.

21. The method of claim **20** wherein said first plurality of satellites is at least four.

22. The method of claim **20** wherein the satellites are part of a Global Navigation Satellite System ("GNSS").

23. The method of claim **22** wherein the GNSS is selected from the group consisting of: Global Positioning System ("GPS"), Galileo, Global Navigation Satellite System ("GLONASS"), and Quasi-Zenith Satellite System ("QZSS").

24. The method of claim **20** wherein the device is selected from the group consisting of: cellular device, text messaging device, computer, portable computer, vehicle locating device, vehicle security device, communication device, and wireless transceiver.

25. The method of claim **20** wherein said first estimated location is determined as a function of coordinates for origin in an Earth-Centered Earth-fixed ("ECEF") coordinate system.

26. The method of claim **20** wherein said first and second plurality of satellites are mutually exclusive.

27. The method of claim **20** wherein said frequency information includes Doppler shift information.

28. The method of claim **20** wherein said phase information includes coarse acquisition ("C/A") code phase information.

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