

DESCRIPTION

TITLE OF INVENTION: POSITIONING TERMINAL

5 CROSS REFERENCE TO RELATED APPLICATION

[0001]

The present application is based on Japanese Patent Application No. 2014-21630 filed on February 6, 2014, the disclosure of which is incorporated herein by reference.

10

TECHNICAL FIELD

[0002]

The present disclosure relates to a positioning terminal that measures its position based on signals received from man-made satellites used in a satellite positioning system.

15

BACKGROUND ART

[0003]

There is conventionally known a positioning terminal that measures its position by receiving signals from man-made satellites used in a satellite positioning system.

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[0004]

Recent development of a simulator capable of generating a man-made satellite signal in a pseudo manner undesirably allows a malicious person to use such a simulator to let the positioning terminal calculate an incorrect position.

25

[0005]

Patent Literature 1 proposes a technique authenticating whether a signal received by a positioning terminal is a legitimate signal from a man-made satellite used in a satellite positioning system. Such technology permits a positioning terminal to access a database in an authentication center and acquire data for authenticating a target man-made satellite based on a satellite number and satellite

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time included in the signal received from the man-made satellite by the positioning terminal. The positioning terminal then uses the data from the authentication center to authenticate whether the received signal is a legitimate signal from the man-made satellite used in the satellite positioning system. Such authentication involves
5 complicated arithmetic processing.

PRIOR ART LITERATURES

PATENT LITERATURE

[0006]

10 Patent Literature 1: JP 2013-130395 A

SUMMARY OF INVENTION

[0007]

Each time the signal is received by the positioning terminal, the technique in
15 Patent Literature 1 performs an authentication process of determining whether the received signal is a legitimate signal from the man-made satellite used in the satellite positioning system.

[0008]

An application of the technique enables the positioning terminal to determine
20 whether a source transmitting the signal received by the positioning terminal is a man-made satellite used in the satellite positioning system (hereinafter referred to as an application example). If the positioning terminal receives a legitimate signal from a man-made satellite used in the satellite positioning system, the source transmitting the signal is determined to be a man-made satellite used in the satellite positioning
25 system.

[0009]

The application example regards the signal from the source determined to be
the man-made satellite used in the satellite positioning system (i.e., the signal from the authenticated source) as a signal that is transmitted from a man-made satellite
30 and not generated by a simulator, thereby using the signal for positioning. The result of positioning based on a signal from an authenticated source is supposed to be more

reliable than the result of positioning based on a signal from an unauthenticated source from the viewpoint of a position indicated by the former positioning result being, at least, not falsified by a malicious person.

[0010]

5 The authentication process involves (i) an access to an authentication center to acquire data and (ii) complicated arithmetic, needing a time for awaiting a certain period of time for the completion of authentication of even a single transmitting source. The positioning terminal needs to authenticate each of a plurality of man-made satellites acting as the sources that transmit signals received by the
10 positioning terminal. The authentication process for all the sources transmitting the signals received by the positioning terminal requires an increased amount of time. A legitimate man-made satellite could therefore be left unauthenticated.

[0011]

15 When the authentication process is not completed for all the transmitting sources, signals from authenticated transmitting sources are preferentially measured for positioning purposes. This can reduce the possibility of positioning results being falsified.

[0012]

20 The quality of a signal from an authenticated transmitting source is, however, not always high. If the signal from an authenticated transmitting source has a relatively significant error due to multipath interference or ionospheric disturbance, the result of positioning based on such an erroneous signal is inaccurate.

[0013]

25 In contrast, some of the unauthenticated transmitting sources may be a man-made satellite used in the satellite positioning system. Such an unauthenticated man-made satellite may incidentally provide a signal that is less affected by multipath interference or ionospheric disturbance than the signals from authenticated transmitting sources. Namely, the accuracy of positioning could increase when the signal from an unauthenticated man-made satellite is used for
30 positioning purposes.

[0014]

Suppose a billing system that uses position data of a positioning terminal to charge a parking fee or a toll road toll. Such system requires a high legitimacy reliability of the position data from the viewpoint of whether the position data is based on a signal transmitted from a legitimate man-made satellite, simultaneously
5 preferring a high accuracy of positioning. That is, the positioning is demanded to provide more accuracy while assuring the legitimacy reliability in its results.

[0015]

It is an object of the present disclosure to provide a positioning terminal that achieves positioning more accurately while assuring the legitimacy reliability of
10 positioning results.

[0016]

To achieve the above object, according to an example of the present disclosure, a positioning terminal is provided to include the following constituent elements. A satellite receiver is to receive signals from a plurality of man-made
15 satellites used in a satellite positioning system. An authentication data acquisition section is to acquire, from an authentication center, an authentication data required to authenticate whether a transmitting source of a signal received by the satellite receiver is one of the man-made satellites. A transmitting source authentication
20 acquisition section is to use the authentication data acquired by the authentication data acquisition section to authenticate whether the transmitting source of the signal received by the satellite receiver is the one of the man-made satellites. An authentication-prioritizing positioning section is to measure a position of the positioning terminal itself by preferentially using, among signals received by the
25 satellite receiver from the transmitting sources, a signal that is received from the transmitting source authenticated by the transmitting source authentication section. A signal quality evaluation section is to evaluate a signal quality relative to each of the transmitting sources, the signal quality indicating an unlikelihood making a positioning result erroneous when a signal transmitted from each of the transmitting sources is used in positioning. A signal-quality-prioritizing positioning section is to measure a
30 position of the positioning terminal itself by preferentially using, among signals received by the satellite receiver from the transmitting sources, a signal received from

the transmitting source that provides the signal quality estimated to be higher relative to the other of the transmitting sources. A positioning result selection section is to adopt, as a current position, a position indicated by either a signal-quality-prioritizing positioning result that is a result of positioning by the signal-quality-prioritizing positioning section, or an authentication-prioritizing positioning result that is a result of positioning by the authentication-prioritizing positioning section. Herein, the positioning result selection section adopts the position indicated by the signal-quality-prioritizing positioning result as the current position when the signal-quality-prioritizing positioning result satisfies an admissibility condition, while adopting the position indicated by the authentication-prioritizing positioning result as the current position when the signal-quality-prioritizing positioning result fails to satisfy the admissibility condition. The admissibility condition is a condition determining an estimation that the transmitting source of the signal used in positioning by the signal-quality-prioritizing positioning section is one of the man-made satellites.

[0017]

When the signal-quality-prioritizing positioning result satisfies predetermined admissibility condition relative to the authentication-prioritizing positioning result, the above configuration adopts the position data indicated by the signal-quality-prioritizing positioning result as the current position. The admissibility condition is used to determine whether a source transmitting a signal used for signal-quality-prioritizing positioning can be estimated as a man-made satellite.

[0018]

When the admissibility condition is satisfied by the signal-quality-prioritizing positioning result, the signal-quality-prioritizing positioning result is a positioning result based on a signal transmitted from a source estimated as a man-made satellite.

[0019]

Even if a signal used for positioning purposes is transmitted from a source that is still not authenticated as a man-made satellite used in the satellite positioning system, the above configuration reduces the possibility of a positioning result indicating falsified position data.

[0020]

The signal-quality-prioritizing positioning section provides a result of positioning based on a signal transmitted from a transmitting source having relatively high signal quality as compared to other transmitting sources of signals received by the satellite receiver. The signal-quality-prioritizing positioning result satisfying the admissibility condition therefore represents the current position of the positioning terminal more accurately than the authentication-prioritizing positioning result.

[0021]

The signal-quality-prioritizing positioning result satisfying the admissibility condition achieves higher accuracy while assuring the legitimacy and reliability of positioning results.

BRIEF DESCRIPTION OF DRAWINGS

[0022]

The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. 1 is a diagram illustrating an exemplary outline configuration of an authentication type positioning system according to an embodiment of the present disclosure;

FIG. 2 is a block diagram illustrating an exemplary outline configuration of an authentication center;

FIG. 3 is a block diagram illustrating an exemplary outline configuration of an in-vehicle apparatus;

FIG. 4 is a diagram illustrating an example of data for managing authentication and signal quality data of each acquired GPS satellite 2;

FIG. 5 is a flowchart illustrating an example of an authentication-related process in the in-vehicle apparatus;

FIG. 6 is a flowchart illustrating an example of a positioning-related process in the in-vehicle apparatus; and

FIG. 7 is a flowchart illustrating an example of a position data transmission

process in the in-vehicle apparatus.

EMBODIMENTS FOR CARRYING OUT INVENTION

[0023]

5 An embodiment of the present disclosure will be described with reference to the accompanying drawings. FIG. 1 is a diagram illustrating an exemplary outline configuration of an authentication type positioning system 1 according to the present embodiment. As in FIG. 1, the authentication type positioning system 1 includes a monitor station 110, an authentication center 120, a master control station 130, an
10 in-vehicle apparatus 200 in a vehicle, and a service center 300. The in-vehicle apparatus 200 may be referred to as a positioning terminal. A portable positioning terminal that can be carried into the vehicle may be used in place of the in-vehicle apparatus 200.

[0024]

15 <Outline Configuration of Authentication Type Positioning System 1>

The monitor station 110 receives GPS radio waves (signals) transmitted from GPS satellites 2a-2f included in a GPS (Global Positioning System), which is a satellite positioning system. The GPS satellites 2a-2f are some of many GPS satellites in the GPS and acquired by the monitor station 110. The GPS satellites 2a-2f are not to be
20 distinguished from each other are hereinafter referred to as GPS satellites 2.

[0025]

As is well known, the GPS radio waves transmitted from the GPS satellites 2 each include a navigation message M. The navigation message M transmitted from a GPS satellite 2 includes satellite clock correction parameters, detailed orbit data
25 (ephemeris data) on the GPS satellite 2, ionization layer correction parameters, and general orbit data (almanac data) on all GPS satellites. Further, the GPS radio waves also include data (GPS time) indicative of a transmission time of a GPS satellite 2. As the GPS satellites 2 differ in the ephemeris data, the data included in the navigation messages transmitted from the GPS satellites 2a-2f are obviously different from each
30 other.

[0026]

The monitor station 110 demodulates the received GPS radio waves to extract the navigation messages M. The monitor station 110 then successively transmits the extracted navigation messages M to the authentication center 120.

[0027]

5 The authentication center 120 generates an RAND (Reference Authentication Navigation Data) message from a navigation message M. The authentication center 120 then creates parity data, which is associated with the navigation message M and the RAND message, from the generated RAND message and an H-matrix, which is an encryption key.

10 [0028]

The authentication center 120 communicates with the monitor station 110, the master control station 130, and the in-vehicle apparatus 200. The authentication center 120 transmits a signal including the created parity data to the master control station 130. The authentication center 120 will be described in detail later with
15 reference to FIG. 2.

[0029]

The master control station 130 transmits the parity data, which is received from the authentication center 120, to a quasi-zenith satellite (QZS) 3. The QZS 3 broadcasts a navigation message N including the parity data to the ground.

20 [0030]

The in-vehicle apparatus 200 is of employing a navigation message authentication (NMA). The in-vehicle apparatus 200 communicates with the authentication center 120 and performs an authentication process to authenticate whether the navigation message M received from a GPS satellite 2 is legitimate. The
25 in-vehicle apparatus 200 then determines that the GPS satellite 2, which has transmitted the navigation message M determined to be legitimate, is a legitimate GPS satellite 2. Subsequently, a GPS satellite 2 determined to be legitimate may be referred to as an authenticated GPS satellite 2. A state where authentication is not complete will be referred to as unsuccessfully authenticated or incompletely
30 authenticated.

[0031]

The authentication process is successively performed on all sources that have transmitted received navigation messages M. However, the authentication process requires a considerable amount of time. Only some GPS satellites 2 may therefore be authenticated before all the GPS satellites 2 used for positioning are completely
5 authenticated. Even if having transmitted a legitimate navigation message M, a GPS satellite 2 remains unsuccessfully authenticated until successfully authenticated as a result of the authentication process. The authentication process will be described in detail later with reference to FIG. 5.

[0032]

10 The in-vehicle apparatus 200 measures its current position by using GPS radio waves received from a plurality of GPS satellites 2. The in-vehicle apparatus 200 measures its current position by using the GPS radio waves received from at least four GPS satellites 2. The number of GPS satellites 2 required for positioning is hereinafter referred to as the required number of positioning satellites. The required
15 number of positioning satellites in the present embodiment is supposed to be four, but may be three without limited to four.

[0033]

The in-vehicle apparatus 200 calculates an authentication level, namely, the ratio of the number of authenticated GPS satellites 2 used for positioning to the total
20 number of GPS satellites 2 used for the positioning. The in-vehicle apparatus 200 then attaches the calculated authentication level to position data indicative of the measured current position (the position data may be referred to as the position information), and wirelessly transmits the resulting combination to an external source. The in-vehicle apparatus 200 will be described in detail later with reference to FIG. 3.

25 [0034]

The service center 300 is located externally separate from the vehicle and managed by a service provider who provides a service by using the position data transmitted from the in-vehicle apparatus 200. When the vehicle in which the in-vehicle apparatus 200 is mounted is determined to have been parked in a pay
30 parking lot or have traveled on a toll road, the service center 300 uses the position data to automatically bill a user of the vehicle.

[0035]

Based on the authentication level attached to the position data transmitted from the in-vehicle apparatus 200, the service center 300 determines whether to use the position data during a relevant process. If the authentication level is not lower than a predetermined threshold value, the service center 300 uses the position data to provide a service. By contrast, if the authentication level is lower than the predetermined threshold value, the service center 300 neither uses the position data nor provides the service.

[0036]

As an example, a billing process performed to bill the user of the vehicle for parking in a roadside pay parking lot or traveling on a toll road is described below. When the authentication level attached to the position data is lower than the predetermined threshold value so that the position data is not determined to be a billing target, the position data is not targeted for automatic billing even if corresponding to a region targeted for billing. By contrast, when the authentication level attached to the position data is not lower than the predetermined threshold value so that the position data is determined to be a billing target, the position data is targeted for billing and subjected to automatic billing if corresponding to a region targeted for billing. Automatic billing is a process performed to deduct a parking fee or a toll road toll from a preregistered account or credit card of a bill payer.

[0037]

<Detailed Configuration of Authentication Center 120>

As in FIG. 2, the authentication center 120 includes a control circuit 122, a data storage unit 124, and a communication unit 126.

[0038]

The control circuit 122 is a computer that includes a CPU, a ROM, and a RAM and controls the data storage unit 124 and the communication unit 126. The control circuit 122 implements various functions by permitting the CPU to use a temporary storage function of the RAM and execute programs stored in the ROM. Specifically, the control circuit 122 includes various functional blocks, namely, an RAND message generation section 1221, a SEED value generation section 1222, an H-matrix

generation section 1223, a parity generation section 1224, and a signal processing section 1225. The functions of sections 1221-1225 may be the same as those disclosed in Patent Literature 1.

[0039]

5 The RAND message generation section 1221 generates an RAND message from a navigation message M acquired from the monitor station 110. TOW (Time Of Week), TOC, AF0, and AF1, which are extracted from a bit string of the navigation message M, are sequentially arranged in the RAND message. TOW indicates the elapsed time within a week. TOC, AF0, and AF1 are clock correction parameters.

10 [0040]

 The RAND message additionally includes an AS Flag and a PRN (Pseudo Random Noise) ID, which follow AF1. The AS Flag is an anti-spoof flag. The PRN ID is a satellite number. In the subsequent description, it is assumed that the PRN IDs of the GPS satellites 2a, 2b, 2c, 2d, 2e, 2f are 12, 13, 14, 15, 16, and 17, respectively.

15

[0041]

 As the RAND message includes a TOW and a PRN ID, the RAND message is a set of data indicating a transmission from which GPS satellite 2 and the time of transmission. The TOW changes at intervals of 6 seconds. The RAND message generation section 1221 therefore generates the RAND message at 6-second intervals for every GPS satellite 2 whose navigation message M is received by the monitor station 110.

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[0042]

 The SEED value generation section 1222 generates a SEED value by generating a random number in response to the input of a PC clock.

25

[0043]

 The H-matrix generation section 1223 generates an H-matrix by using the SEED value generated by the SEED value generation section 1222. The H-matrix is used to generate a parity bit that is uniquely determined from input data. The H-matrix is a matrix whose number of columns and rows are based on the number of bits of input data and the number of parity bits. A well-known hash function may be

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used as the H-matrix. For example, a parity check matrix for LDPC (Low Density Parity Check) encoding may be used.

[0044]

5 The parity generation section 1224 calculates parity data from the RAND message generated by the RAND message generation section 1221 and the H-matrix calculated by the H-matrix generation section 1223. The parity data is calculated by multiplying the RAND message by the H-matrix.

[0045]

10 The signal processing section 1225 associates the parity data calculated by the parity generation section 1224 with the RAND message used to calculate the parity data, and inserts the resulting association into the navigation message N, which is to be transmitted from the QZS 3. The signal processing section 1225 then transmits the resulting navigation message N to the master control station 130.

[0046]

15 The present embodiment assumes that the navigation message N transmitted from the QZS 3 includes the parity data and RAND message associated with each GPS satellite 2. Namely, the signal processing section 1225 inserts the parity data and RAND message associated with each GPS satellite 2 into the navigation message N.

[0047]

20 At the time of signal insertion, the signal processing section 1225 associates the parity data calculated by the parity generation section 1224 with the RAND message used to calculate the parity data, the H-matrix, and the SEED value used to calculate the H-matrix, and stores the resulting association in the data storage unit 124.

25 [0048]

Each time the RAND message is generated by the RAND message generation section 1221, the signal processing section 1225 inserts the RAND message and parity data into the navigation message N that is to be transmitted from the QZS 3. Therefore, the RAND message generation section 1221, the SEED value generation section 1222, the H-matrix generation section 1223, and the parity generation section 1224 also perform a process each time the RAND message is generated by the RAND

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message generation section 1221.

[0049]

When the H-matrix selection section 1226 receives the PRN ID and TOW transmitted from the in-vehicle apparatus 200, an H-matrix selection section 1226
5 checks H-matrices stored in the data storage unit 124 and selects an H-matrix associated with the received PRN ID and TOW. The H-matrix selection section 1226 then returns the selected H-matrix to the in-vehicle apparatus 200.

[0050]

H-matrix exchanges between the authentication center 120 and the in-vehicle
10 apparatus 200 are made by using secure encrypted communications. For example, a public key cryptosystem may be used. The authentication center 120 may transmit an encrypted H-matrix to the in-vehicle apparatus 200 by using a public key distributed from the in-vehicle apparatus 200. The in-vehicle apparatus 200 decrypts the encrypted H-matrix naturally by using a secret key associated with the public key
15 used by the authentication center 120.

[0051]

<Detailed Configuration of In-Vehicle Apparatus 200>

A configuration of the in-vehicle apparatus 200 will be described with reference to FIG. 3. As in FIG. 3, the in-vehicle apparatus 200 includes a
20 communication unit 210, a control circuit 220, and a satellite receiver 230.

[0052]

The communication unit 210 includes a reception unit 211 and a transmission unit 212. The communication unit 210 has a narrow-area communication function and a wide-area communication function. For example, the narrow-area
25 communication function has a communication range of several hundred meters, and the wide-area communication function has a communication range of several kilometers. The wide-area communication function permits the communication unit 210 to establish communication with a base station of a public communication network to communicate with a remote communication instrument within the
30 communication range of the public communication network. The wide-area communication function enables the communication unit 210 to communicate with

the authentication center 120 and the service center 300. The narrow-area communication function may be used to let the communication unit 210 communicate with the authentication center 120 and the service center 300 through a roadside instrument (unshown).

5 [0053]

The satellite receiver 230 receives, at predetermined time intervals, radio waves transmitted from the GPS satellites 2 and the QZS 3. The received radio waves are demodulated and outputted to the control circuit 220. The satellite receiver 230 successively receives the navigation messages M transmitted from the GPS satellites 2 and the navigation messages N transmitted from the QZS 3, and
10 outputs them to the control circuit 220.

[0054]

The control circuit 220 is a computer that includes a CPU, a ROM, and a RAM and controls the communication unit 210 and the satellite receiver 230. The control circuit 220 performs an authentication-related process in FIG. 5, a positioning-related process in FIG. 6, and a position data transmission process in FIG. 7 by permitting the CPU to use a temporary storage function of the RAM and execute programs stored in the ROM.
15

[0055]

A memory 221 is a rewritable storage medium that is implemented by an EEPROM or RAM included in the control circuit 220. The memory 221 stores position data indicative of a current position and data on GPS satellites 2 whose radio waves are received (information and received satellite data (or received satellite information)).
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25 [0056]

The current position is indicated by the well-known geodetic coordinate system or ECEF coordinate system. The geodetic coordinate system expresses the current position by (latitude, longitude, altitude). The ECEF coordinate system has its origin at the center of gravity of the earth, a Z-axis that is the axis of rotation of the earth in the North Pole direction, an X-axis that is the Greenwich meridian direction perpendicular to the Z-axis, and a right-handed Y-axis that is orthogonal to the X- and
30

Z-axes. For example, the WGS84 coordinate system may be used. An arbitrary point P in the ECEF coordinate system is expressed by (X, Y, Z). The current position calculated in terms of the ECEF coordinate system is converted as needed to the counterpart according to the geodetic coordinate system before use.

5 [0057]

For each acquired GPS satellite 2, authentication state data (referred to also as the authentication state information) and signal quality data (referred to also as the signal quality information) are stored as the received satellite data (see FIG. 4). The authentication state data indicates whether a GPS satellite 2 is authenticated.

10 The signal quality data indicates the quality of a signal received from the GPS satellite 2. The higher the signal quality, the lower the possibility of obtaining an erroneous positioning result from a signal transmitted from a source. An S/N ratio, an angle of elevation, and a pseudo-distance residual Δd are used as indices indicative of the quality of a signal received from a GPS satellite 2. Namely, these index values are
15 stored as the signal quality data.

[0058]

As is well known, the S/N ratio is a logarithmic expression of the ratio of signal to noise. The higher the S/N ratio, the higher the signal quality. The angle of elevation is an angle formed between a straight line connecting a GPS satellite 2 to
20 the current position and a horizontal plane referenced to the current position. It is known that the smaller the angle of elevation, the greater the error in the measurement of distance (that is, the later-described pseudo-distance residual Δd). Namely, the pseudo-distance residual Δd tends to decrease with an increase in the angle of elevation. The pseudo-distance residual Δd is variously affected by
25 multipath interference. Even when the angle of elevation is large, a distance error is more likely to occur than in the case of a GPS satellite 2 having a smaller angle of elevation. Further, the position of a GPS satellite 2 can be determined from data included in the navigation message M. The current position may use a value calculated in the later-described positioning-related process.

30 [0059]

The pseudo-distance residual Δd represents the magnitude of difference

between (i) a straight-line distance D from the current position to a relevant GPS satellite 2 and (ii) a pseudo-distance d . The pseudo-distance is a distance calculated based on (i) a time lag between the transmission of a GPS radio wave and its reception and (ii) a propagation speed of the radio wave. In short, the
5 pseudo-distance residual Δd is calculated as being equal to $|D - d|$. The straight-line distance D may be determined by regarding the current position in the ECEF coordinate system as $P_0 (X_0, Y_0, Z_0)$, regarding the position P_G of the GPS satellite 2 as (X_G, Y_G, Z_G) , and calculating the distance between these positions.

[0060]

10 The authentication state data represents the reliability of a transmitting source (referred to the transmitting source reliability) from the viewpoint of whether the transmitting source is a legitimate GPS satellite 2. The transmitting source reliability contributes to the reliability (legitimateness reliability) of a positioning result from the viewpoint of whether the position data eventually indicated by the
15 positioning result is falsified. The signal quality data represents the reliability (positioning accuracy reliability) from the viewpoint of whether the accuracy of a positioning result based on a relevant signal is reliable.

[0061]

The memory 221 stores the above authentication state data and signal quality
20 data in association with the PRN ID of a transmitting GPS satellite 2 in a manner in FIG. 4.

[0062]

In FIG. 4, the GPS satellite 2a (PRN ID = 12) is authenticated, its S/N ratio is 20 dB, its angle of elevation is 60 degrees, and its pseudo-distance residual Δd is 300
25 m. The signal quality data on the GPS satellite 2d (PRN ID = 15), which is authenticated as is the case with the GPS satellite 2a, is such that the S/N ratio is 39 dB, and that the angle of elevation is 55 degrees, and further that the pseudo-distance residual Δd is 8 m. The comparison in signal quality between the GPS satellite 2a and the GPS satellite 2d indicates that the GPS satellite 2d is far better
30 than the GPS satellite 2a in the S/N ratio and pseudo-distance residual Δd , and that the GPS satellite 2d is comprehensively superior in signal quality to the GPS satellite

2a.

[0063]

Although the GPS satellite 2b (PRN ID = 13) is not authenticated, its S/N ratio is 40 dB, its angle of elevation is 60 degrees, and its pseudo-distance residual Δd is 5 m. Thus, the GPS satellite 2b is also superior in signal quality to the GPS satellite 2a. However, as the GPS satellite 2b is not authenticated, it is inferior to the GPS satellite 2a in transmitting source reliability.

[0064]

The authentication state data and signal quality data on each acquired GPS satellite 2 are stored in the memory 221 and successively updated in the later-described positioning-related process.

[0065]

The processes performed by the control circuit 220 in the in-vehicle apparatus 200 will be described with reference to the flowcharts of FIGS. 5, 6, and 7. The processes in the flowcharts of FIGS. 5, 6, and 7 are performed independently of each other.

[0066]

<Authentication-Related Process>

The authentication-related process will be described with reference to the flowchart of FIG. 5. The authentication-related process is performed by the control circuit 220 in the in-vehicle apparatus 200 to authenticate that a signal received by the satellite receiver 230 is a legitimate navigation message received from a GPS satellite 2. The process in the flowchart of FIG. 5 may be performed each time the navigation message M transmitted from a GPS satellite 2 is inputted from the satellite receiver 230.

[0067]

In addition to a signal transmitted from a legitimate GPS satellite 2, the in-vehicle apparatus 200 might receive a radio wave transmitted from a simulator that generates, in a pseudo manner, a signal transmitted from a GPS satellite 2. If the in-vehicle apparatus 200 performs positioning by using a radio wave transmitted from a transmitting source mimicking a GPS satellite 2 (i.e., non-legitimate transmitting

source), the position indicated by the result of such positioning might greatly differ from the actual position. If a radio wave transmitted from a non-legitimate transmitting source is used as mentioned, failure to perform proper billing occurs when the service center 300 provides a service based on position data. In view of the above circumstances, the authentication-related process is performed to determine whether a source from which a signal received by the in-vehicle apparatus 200 is transmitted is a legitimate GPS satellite 2. A non-legitimate transmitting source is assumed to be included in the GPS satellites 2.

[0068]

It is noted that a flowchart or the processing of the flowchart in the present application includes sections (also referred to as steps), each of which is represented, for instance, as S1. Further, each section can be divided into several sub-sections while several sections can be combined into a single section. Furthermore, each of thus configured sections can be also referred to as a device, module, or means.

Each or any combination of sections explained in the above can be achieved as (i) a software section in combination with a hardware unit (e.g., computer) or (ii) a hardware section (e.g., integrated circuit, hard-wired logic circuit), including or not including a function of a related apparatus; furthermore, the hardware section may be constructed inside of a microcomputer.

[0069]

In S1, the satellite receiver 230 acquires the navigation message N received from the QZS 3. In S2, a RAND message and parity data associated with the RAND message are extracted from the navigation message N acquired in S1, and these two types of data are stored in association with each other. All bits of the RAND message need not be stored. The parity data needs to be associated with at least the PRN ID and TOW, which are included in the RAND message.

[0070]

The navigation message N includes the RAND message of each GPS satellite 2 and the parity data associated with the RAND message. In S2, therefore, the parity data of each GPS satellite 2 is acquired. The parity data derived from the navigation message N is referred to as the received parity data to differentiate it from

later-described comparative parity data.

[0071]

In S3, the satellite receiver 230 acquires the navigation message M received from the GPS satellite 2. In S4, a check is performed to determine whether the transmitting source from which the navigation message M was received in S3 is authenticated. Whether the transmitting source is authenticated can be determined by accessing the memory 221 and referencing the authentication state data associated with the PRN ID of the navigation message M. If the transmitting source is not authenticated, the query in S4 is answered "NO" and processing proceeds to S5. By contrast, if the transmitting source of the navigation message M received in S3 is authenticated, the query in S4 is answered "YES" and processing proceeds to S13.

[0072]

In S5, the PRN ID and TOW in the navigation message M received in S3 and the public key for use in confidential communication are transmitted from the transmission unit 212 to the authentication center 120. As mentioned, the authentication center 120 encrypts the H-matrix, which is defined by the PRN ID and TOW, by using the public key and transmits the encrypted H-matrix to the in-vehicle apparatus 200.

[0073]

In S6, the H-matrix transmitted from the authentication center 120 is acquired from the reception unit 211. In S7, the encrypted H-matrix acquired in S5 is decrypted by using the secret key. S5, S6, and S7 are referred to also as the authentication data acquisition section.

[0074]

In S8, the RAND message is created from the navigation message M acquired in S3. In S9, the parity data (referred to as the comparative parity data) is created from the RAND message created in S8 and the H-matrix decrypted in S7, by the same process as the process performed by the parity generation section 1224.

[0075]

In S10, a check is performed to determine whether the comparative parity data created in S9 agrees with the received parity data that is acquired in S2 and

associated with the PRN ID in the navigation message M received in S3.

[0076]

The H-matrix decrypted in S6 is the same as the H-matrix that was used by the authentication center 120 to create the parity data. The parity generation
5 section 1224 in the authentication center 120 calculates the parity data from the H-matrix and the RAND message.

[0077]

When the comparative parity data created in S9 agrees with the received parity data stored in S2, the RAND message created in S8 is identical with the RAND
10 message created by the authentication center 120. The fact that the RAND messages are identical with each other signifies that the navigation message M serving as a base for the RAND message created in S8 agrees with the navigation message M serving as a base for the RAND message generated by the RAND message generation section 1221 in the authentication center 120.

15 [0078]

If the comparative parity data created in S9 agrees with the received parity data stored in S2, the navigation message M acquired in S3 is a legitimate navigation message M acquired by the authentication center 120 as well.

[0079]

20 If the comparative parity data created in S9 agrees with the received parity data stored in S2 (S10: YES), it is determined that authentication is successful in S11. When authentication is determined in S11 to be successful, the authentication state data on the relevant GPS satellite 2, which is stored in the memory 221, is set as authenticated, and processing proceeds to S13. S10 and S11 are referred to also as
25 the transmitting source authentication section.

[0080]

If the comparative parity data and the received parity data do not agree with each other (S10: NO), it is determined that authentication is unsuccessful in S12. When authentication is determined to be unsuccessful, the authentication state data
30 on the relevant GPS satellite 2 is left unauthenticated, and processing proceeds to S13.

[0081]

In S13, a check is performed to determine whether all the acquired GPS satellites 2 are authenticated. If all the acquired GPS satellites 2 are authenticated (S13: YES), the process in FIG. 5 terminates. By contrast, if any of the acquired GPS
5 satellites 2 is unauthenticated (S13: NO), processing returns to S2 to repeat the process.

[0082]

The above authentication-related process can determine whether a transmitting source from which a signal is received by the satellite receiver 230 is a
10 legitimate GPS satellite 2. The sequence of the authentication-related process in FIG. 5 is merely an example and may be changed as appropriate.

[0083]

<Positioning-Related Process>

The following describes a sequence of processing by the control circuit 220 in
15 the in-vehicle apparatus 200 to perform positioning based on the navigation message M received by the satellite receiver 230 (hereinafter referred to as the positioning-related process) with reference to the flowchart of FIG. 6. The process in the flowchart of FIG. 6 may be performed successively (for example, at 100 ms intervals) when the satellite receiver 230 receives signals from the GPS satellites 2,
20 the number of which is not smaller than the required number of positioning satellites (four in the present example).

[0084]

In S21, an authentication-prioritizing positioning satellite selection process is performed, and then processing proceeds to S22. In the authentication-prioritizing
25 positioning satellite selection process, which is performed in S21, authenticated GPS satellites 2 are preferentially selected as transmitting sources of signals used for positioning. The GPS satellites 2 are referred to as the authentication-prioritizing positioning satellites.

[0085]

30 Authenticated GPS satellites 2 are selected based on the authentication state data on each GPS satellite 2 stored in the memory 221. If there are four or more

authenticated GPS satellites 2, they are selected before proceeding to S22. In the example of FIG. 4, the GPS satellite 2a (PRN ID = 12), the GPS satellite 2d (PRN ID = 15), the GPS satellite 2e (PRN ID = 16), and the GPS satellite 2f (PRN ID = 17) are selected.

5 [0086]

Any authenticated GPS satellite 2 whose signal quality is determined to be lower than a predetermined level may be excluded from the authentication-prioritizing positioning satellites as far as the resulting total number of authenticated GPS satellites 2 is four or more. A threshold value used to determine whether to exclude
10 GPS satellites having low signal quality from the authentication-prioritizing positioning satellites may be designed as appropriate for each index indicative of signal quality. If the pseudo-distance residual Δd is not smaller than a predetermined value (for example, 200 m), the signal level may be determined to be lower than the predetermined level.

15 [0087]

If the number of authenticated GPS satellites 2 is smaller than four, all the authenticated GPS satellites 2 are selected. In addition, unauthenticated GPS satellites 2 are selected as needed to compensate for a shortfall in the required number of positioning satellites. If only three GPS satellites 2 are authenticated, one
20 of unauthenticated GPS satellites 2 is selected. An unauthenticated GPS satellite 2 having relatively high signal quality should be selected from the unauthenticated GPS satellites 2 to compensate for the shortfall in the required number of positioning satellites.

[0088]

25 In S22, signals transmitted from the GPS satellites 2 selected in S21 are used to compute the current position by a well-known method. Positioning computation based on the signals transmitted from the authentication-prioritizing positioning satellites is referred to as authentication-prioritizing positioning computation. The result of computation in S22 is referred to as the authentication-prioritizing
30 positioning result to differentiate it from a later-described result of computation in S24. A timestamp indicative of positioning time is attached to the computed

authentication-prioritizing positioning result, and the resulting combination is stored in the memory 221. S22 is referred to also as the authentication-prioritizing positioning section.

[0089]

5 In S23, a signal-quality-prioritizing positioning satellite selection process is performed, and then processing proceeds to S24. In the signal-quality-prioritizing positioning satellite selection process, which is performed in S23, GPS satellites 2 having high signal quality are preferentially selected as the GPS satellites for positioning by referencing the signal quality data on each GPS satellite 2 stored in the
10 memory 221, no matter whether the GPS satellites 2 are authenticated.

[0090]

In the present embodiment, signal quality comparison is made by checking the pseudo-distance residual Δd . Values indicative of the pseudo-distance residual Δd may be sorted in increasing order to select GPS satellites 2 having relatively small
15 values. If having the same pseudo-distance residual Δd , some GPS satellites 2 are compared against each other in terms of the S/N ratio to determine that a GPS satellite 2 having a relatively high S/N ratio has relatively high signal quality. If a plurality of GPS satellites 2 are equal in both the pseudo-distance residual Δd and the S/N ratio, a GPS satellite 2 having a relatively large angle of elevation is determined to
20 have relatively high signal quality.

[0091]

In FIG. 4, the GPS satellite 2b (PRN ID = 13), the GPS satellite 2c (PRN ID = 14), the GPS satellite 2d (PRN ID = 15), and the GPS satellite 2e (PRN ID = 16) are selected. The GPS satellite 2a (PRN ID = 12) and the GPS satellite 2f (PRN ID = 17)
25 are not selected because their signal quality is determined to be lower than the predetermined level.

[0092]

The highest priority is given to the pseudo-distance residual Δd . However, the highest priority may be given to the S/N ratio. A second alternative is to
30 variously weight the pseudo-distance residual Δd , the S/N ratio, the angle of elevation, and other indices indicative of signal quality and use, for example, a function for

evaluating the overall signal quality from individual parameters. Specifically, the second alternative is to handle the pseudo-distance residual Δd , the S/N ratio, and the angle of elevation as variables, design a function for generating an output value that increases with a decrease in the pseudo-distance residual Δd , with an increase in the S/N ratio and the angle of elevation, and preferentially select a GPS satellite 2 having a relatively great output value of the function.

[0093]

In S24, the current position is determined by performing well-known positioning computation on the signals transmitted from the GPS satellites 2 selected in S23. Positioning computation performed in S24 on the signals transmitted from the signal-quality-prioritizing satellites is referred to as signal-quality-prioritizing positioning computation. A positioning result obtained from the signal-quality-prioritizing positioning computation is referred to as the signal-quality-prioritizing positioning result to differentiate it from the authentication-prioritizing positioning result. A timestamp is attached to the computed signal-quality-prioritizing positioning result, and the resulting combination is stored in the memory 221 as distinguished from the authentication-prioritizing positioning result. S24 is referred to also as the signal-quality-prioritizing positioning section.

[0094]

In S25, the authentication-prioritizing positioning result calculated in S22 is compared against the signal-quality-prioritizing positioning result calculated in S25. If the signal-quality-prioritizing positioning result satisfies a predetermined admissibility condition when compared against the authentication-prioritizing positioning result, the signal-quality-prioritizing positioning result is adopted as the current position. S25 is referred to also as the positioning result selection section.

[0095]

The admissibility condition permits the signal-quality-prioritizing positioning result to be adopted as the current position and is used to estimate whether the transmitting sources of signals used in a signal-quality-prioritizing positioning computation process are legitimate GPS satellites 2. Namely, the admissibility

condition assures a predetermined level of legitimacy reliability of the signal-quality-prioritizing positioning result obtained by using the GPS satellites 2. The background for setting the admissibility condition will be described below.

[0096]

5 The transmitting sources selected in the signal-quality-prioritizing positioning satellite selection process include an unauthenticated transmitting source. The unauthenticated transmitting source may be either a legitimate GPS satellite 2 or a non-legitimate transmitting source.

[0097]

10 In general, a positioning result, which uses a signal transmitted from a non-legitimate transmitting source so as to disguise the current position, is presumed to represent a position significantly displaced from the actual current position. In contrast, even though a positioning result using a signal transmitted from a legitimate GPS satellite 2 includes an error due to multipath interference or ionospheric
15 disturbance, such position result represents a position relatively close to an actual position.

[0098]

 An unauthenticated legitimate GPS satellite 2 might have higher positioning accuracy reliability than authenticated GPS satellites 2. Once authenticated, the
20 unauthenticated legitimate GPS satellite 2 having high positioning accuracy reliability is selected in the authentication-prioritizing positioning satellite selection process. Before completely authenticated, such unauthenticated legitimate GPS satellite 2 having high positioning accuracy reliability will naturally remain unselected in the authentication-prioritizing positioning satellite selection process.

25 [0099]

 Suppose that the unauthenticated transmitting sources include several legitimate GPS satellites 2 having higher positioning accuracy reliability than authenticated GPS satellites 2 while the transmitting sources selected in the signal-quality-prioritizing positioning satellite selection process do not include any
30 non-legitimate transmitting source. In such instance, the signal-quality-prioritizing positioning result is more likely to indicate a point close to an actual position than the

authentication-prioritizing positioning result. Further, the point indicated by the signal-quality-prioritizing positioning result in the above instance is presumed to be relatively close to a point indicated by the authentication-prioritizing positioning result.

5 [0100]

The admissibility condition is defined in view of the above situation. If the point indicated by the signal-quality-prioritizing positioning result is close to a point indicated by the authentication-prioritizing positioning result, it is paradoxically estimated that the transmitting sources selected in the signal-quality-prioritizing positioning satellite selection process are all legitimate GPS satellites 2. This assures a certain level of legitimacy reliability of the positioning result (i.e., the signal-quality-prioritizing positioning result).

[0101]

15 If the point indicated by the signal-quality-prioritizing positioning result is within a predetermined distance, e.g., 100 m, from the point indicated by the authentication-prioritizing positioning result, the admissibility condition may be considered satisfied. In addition to the distance to a point indicated by each positioning result, the admissibility condition may include a condition that GPS satellites 2 selected in the signal-quality-prioritizing positioning satellite selection process of S23 must be equal in satellite time (for instance, TOW).

20 [0102]

In S26, the positioning result adopted in S25, either the authentication-prioritizing positioning result or the signal-quality-prioritizing positioning result, is stored in the memory 221 as the current position, and then processing proceeds to S27. Data on the time at which the current position was measured (i.e., a timestamp) is attached to the calculated current position, and the resulting combination is stored in the memory 221.

25 [0103]

In S27, the signal quality data on each acquired GPS satellite 2 is updated to terminate the positioning-related process indicated in the flowchart of FIG. 6. Specifically, the current position stored in S26 is used to calculate and update the

pseudo-distance residual Δd and the angle of elevation of each GPS satellite 2. The S/N ratio may be updated each time a signal is received from a transmitting source. S27 is referred to also as the signal quality evaluation section.

[0104]

5 The sequence of the positioning-related process in FIG. 6 is merely an example and may be changed as appropriate.

[0105]

<Position Data Transmission Process>

10 The following describes a sequence of processing by the control circuit 220 in the in-vehicle apparatus 200 to perform a process related to position data transmission to the service center 300 (hereinafter referred to as the position data transmission process) with reference to the flowchart of FIG. 7. The position data transmission process is performed to transmit not only the position data on the current position calculated in the earlier-described positioning-related process, but
15 also the authentication level, which indicates the number of authenticated GPS satellites 2 used for positioning and the ratio of the number of such authenticated GPS satellites 2 to the total number of GPS satellites 2 used for the positioning. The process in the flowchart of FIG. 7 may be initiated when a position data request signal is received from the service center 300 or at predetermined time intervals.

20 [0106]

 In S31, the current position of the in-vehicle apparatus 200 itself which is selected in S26 of the flowchart of FIG. 6 is read from the memory 221, and then processing proceeds to S32.

[0107]

25 In S32, the authentication level is calculated. The authentication level indicates the ratio of the number of authenticated GPS satellites 2 used for the measurement of the current position acquired in S31 to the total number of GPS satellites 2 used for the same measurement. If four GPS satellites 2 are used for positioning and one of them is authenticated, the authentication level is 25%. S32 is
30 referred to also as the authentication level calculation section. The authentication level may be the number of authenticated GPS satellites 2 used for the measurement

of the current position. The higher the authentication level, the lower the possibility of a positioning result representing a falsified position, and thus the higher the legitimacy reliability.

[0108]

5 In S33, transmission data is generated. The transmission data includes position data indicative of the read current position, a timestamp, and the authentication level calculated in S32. The format of the transmission data may be designed as appropriate. The transmission data may additionally include the traveling direction and speed of a vehicle in which the in-vehicle apparatus 200 is
10 mounted. The speed of the vehicle may be based on a value detected by a wheel speed sensor or determined by calculating the distance traveled by the vehicle per unit time from position data on a plurality of chronologically arranged points. The traveling direction of the vehicle may be determined from the result of detection by a gyroscope or based on the extension direction of an approximate line determined by
15 the least square method from the position data on a plurality of chronologically arranged points.

[0109]

In S34, the transmission data generated in S33 is transmitted through the transmission unit 212, and then the process in the flowchart terminates. The
20 sequence of the positioning-related process in FIG. 7 is merely an example and may be changed as appropriate.

[0110]

(Summary of Embodiment)

25 If a point indicated by the signal-quality-prioritizing positioning result is within a predetermined distance from a point indicated by the authentication-prioritizing positioning result, the embodiment of the present disclosure adopts the point data represented by the signal-quality-prioritizing positioning result as the current position (S25). The admissibility condition is used to determine whether the transmitting source of a signal used for signal-quality-prioritizing positioning can be estimated as a
30 man-made satellite.

[0111]

When satisfying the admissibility condition, the signal-quality-prioritizing positioning result can be regarded as a positioning result based on a signal transmitted from a transmitting source that is estimated as a man-made satellite.

[0112]

5 Even if an adopted signal is received from a transmitting source that is not yet authenticated as a man-made satellite used in a satellite positioning system, the above configuration reduces the possibility of a positioning result representing falsified position data.

[0113]

10 The signal-quality-prioritizing positioning section provides a result of positioning based on a signal transmitted from a transmitting source having relatively high signal quality as compared to other transmitting sources of signals received by the satellite receiver. The signal-quality-prioritizing positioning result satisfying the admissibility condition therefore represents the current position of the positioning
15 terminal more accurately than the authentication-prioritizing positioning result.

[0114]

The signal-quality-prioritizing positioning result satisfying the admissibility condition achieves higher accuracy while assuring the legitimacy reliability of positioning results.

20 [0115]

The service center 300, which performs a process that uses the position data transmitted from the in-vehicle apparatus 200, can determine based on the authentication level attached to the position data whether to perform the process that uses the position data. For example, a billing process in which the required reliability
25 of the position data is high is executed only when the authentication level is high. Meanwhile, a game, a route guidance, and other processes in which the required reliability of the position data is low can be executed even if the authentication level is low.

[0116]

30 In an application and a system that use positioning results based on signals transmitted from GPS satellites 2 in a satellite positioning system, the positioning

results can be flexibly utilized depending on positioning result reliability required for the application and the system.

[0117]

While the embodiment of the present disclosure has been described, it should
5 be understood that the present disclosure is not limited to the above embodiment.
The following modified embodiments, which will be referred to as the modifications,
are also included in the technical scope of the present disclosure. Further, in addition
to the following modifications, various other modifications may be made without
departing from the spirit of the present disclosure.

10 [0118]

<First Modification>

The foregoing embodiment has been described on the assumption that the
authentication level represents the ratio of the number of authenticated GPS satellites
used for positioning to the total number of GPS satellites 2 used for the positioning.
15 However, the authentication level is not limited to the above one. The authentication
level may be determined as described below when a signal-quality-prioritizing
positioning result is transmitted as the current position.

[0119]

In S25, the authentication level of an authentication-prioritizing positioning
20 result is determined in comparison with a signal-quality-prioritizing positioning result.
As mentioned, the authentication level of the authentication-prioritizing positioning
result may represent the ratio of the number of authenticated GPS satellites 2 used for
an authentication-prioritizing positioning computation process to the total number of
GPS satellites 2 used for the same process. Further, the authentication level of the
25 signal-quality-prioritizing positioning result may be determined by multiplying the
authentication level of the authentication-prioritizing positioning result by a
predetermined authentication level coefficient α . The authentication level coefficient
 α may be a value from 0 to 1. Thus, the authentication level coefficient α may be 0.5.
If the authentication level of the authentication-prioritizing positioning result is 100%,
30 the authentication level of the signal-quality-prioritizing positioning result is obtained
by multiplying a value of 100% by α ($= 0.5$), namely, 50%.

[0120]

Alternatively, the authentication level of the signal-quality-prioritizing positioning result may be the average between the ratio of the number of authenticated GPS satellites 2 used for the signal-quality-prioritizing positioning computation process to the total number of GPS satellites 2 used for the same process and the ratio of the number of authenticated GPS satellites 2 used for the authentication-prioritizing positioning computation process to the total number of GPS satellites 2 used for the same process.

[0121]

10 <Second Modification>

In the foregoing embodiment, current position, namely, the positioning result selected in S25, is transmitted to the service center 300. The present disclosure is not limited to the above configuration. Whether priority should be given to the authentication level or to the positioning accuracy may vary with the type of service provided by the service center 300. It is preferred that the service center 300, which receives the position data, be provided with a choice between the use of the authentication-prioritizing positioning result and the use of the signal-quality-prioritizing positioning result. Consequently, the in-vehicle apparatus 200 may transmit both the authentication-prioritizing positioning result and the signal-quality-prioritizing positioning result together with the authentication level.

[0122]

While the present disclosure has been described with reference to embodiments thereof, it is to be understood that the disclosure is not limited to the embodiments and constructions. The present disclosure is intended to cover various modification and equivalent arrangements. In addition, while the various combinations and configurations, other combinations and configurations, including more, less or only a single element, are also within the spirit and scope of the present disclosure.

CLAIMS

1. A positioning terminal comprising:

a satellite receiver that receives signals from a plurality of man-made satellites used in a satellite positioning system;

an authentication data acquisition section that acquires, from an authentication center, an authentication data required to authenticate whether a transmitting source of a signal received by the satellite receiver is one of the man-made satellites;

a transmitting source authentication section that uses the authentication data acquired by the authentication data acquisition section to authenticate whether the transmitting source of the signal received by the satellite receiver is the one of the man-made satellites;

an authentication-prioritizing positioning section that measures a position of the positioning terminal itself by preferentially using, among signals received by the satellite receiver from the transmitting sources, a signal that is received from the transmitting source authenticated by the transmitting source authentication section;

a signal quality evaluation section that evaluates a signal quality relative to each of the transmitting sources, the signal quality indicating an unlikelihood making a positioning result erroneous when a signal transmitted from each of the transmitting sources is used in positioning;

a signal-quality-prioritizing positioning section that measures a position of the positioning terminal itself by preferentially using, among signals received by the satellite receiver from the transmitting sources, a signal received from the transmitting source that provides a relatively high signal quality; and

a positioning result selection section that adopts, as a current position, a position indicated by either a signal-quality-prioritizing positioning result that is a result of positioning by the signal-quality-prioritizing positioning section, or an authentication-prioritizing positioning result that is a result of positioning by the authentication-prioritizing positioning section,

wherein

the positioning result selection section

adopts the position indicated by the signal-quality-prioritizing positioning result as the current position when the signal-quality-prioritizing positioning result satisfies an admissibility condition, and

adopts the position indicated by the authentication-prioritizing positioning result as the current position when the signal-quality-prioritizing positioning result fails to satisfy the admissibility condition,

the admissibility condition being a condition determining an estimation that the transmitting source of the signal used in positioning by the signal-quality-prioritizing positioning section is one of the man-made satellites.

2. The positioning terminal according to claim 1, wherein

the signal quality evaluation section uses at least either an S/N ratio or a pseudo-distance residual, as an index indicative of the signal quality,

the S/N ratio representing the ratio of the signals to noise,
the pseudo-distance residual representing a magnitude of difference between a straight-line distance that is from the current position to the transmitting source and a pseudo-distance that is calculated based on a propagation speed of a radio wave and a time lag from time when the signal is transmitted from the transmitting source to time when the transmitted signal is received.

3. The positioning terminal according to claim 1 or 2, further comprising:

an authentication level calculation section that calculates an authentication level indicative of a level of reliability of a result of positioning based on

a total number of transmitting sources of signals used in positioning and

a total number of transmitting sources that are authenticated by the transmitting source authentication section among the transmitting sources of

the signals used in positioning; and

a positioning result transmission processing section that transmits to an external source at least a positioning result selected by the positioning result selection section together with the authentication level calculated by the authentication level calculation section with respect to the positioning result.

4. The positioning terminal according to any one of claims 1 to 3, wherein the admissibility condition is that a position indicated by the signal-quality-prioritizing positioning result is within a predetermined distance from a position indicated by the authentication-prioritizing positioning result.

5. The positioning terminal according to any one of claims 1 to 4, wherein the admissibility condition is that a satellite time of the transmitting source used in positioning by the signal-quality-prioritizing positioning section is within a predetermined period of time from a satellite time of the transmitting source used in positioning by the authentication-prioritizing positioning section.