

TITLE OF THE INVENTION

SATELLITE POSITIONING SYSTEM AND POSITIONING SIGNAL RECEIVER

5 TECHNICAL FIELD

[0001]

The present invention relates to a technique for determining a position through positioning signals transmitted from a satellite positioning system as generally represented by a global positioning system and, more specifically, to a technique for
10 shortening a time period from activation to position determination in a positioning signal receiver.

BACKGROUND ART

[0002]

15 A satellite positioning system specifies a position by measuring positioning signals transmitted from a plurality of satellites. For example, an on-board clock is used for generation of a regular, generally sequential, series of events, often called "epoch", and a clock time of occurrence of the epoch is coded to a random number code or a pseudo random number code (hereinafter, referred to as a spreading code). The
20 spreading coded radio wave is received by a receiver, and a phase difference between a spreading code generated at a timing based on a clock time of the receiver and the spreading code of the received signal is measured to thereby determine a distance between the positioning satellite and the receiver.

[0003]

25 One example of such a satellite positioning system includes a global positioning system (GPS). The GPS typically operates by using a plurality of frequency bands such as L1, L2 and L5, each having a center frequency at 1575.42 MHz, 1227.6 MHz and 1176.45 MHz, respectively. Each signal in these frequency bands is modulated by a respective spreading signal. As can be readily understood by
30 those having ordinary skill in the art, a CA (Coarse Acquisition) code signal emitted by

a GPS satellite navigation system is broadcasted in the 1575.42 MHz L1 band, and has a spreading code rate (chip rate) of 1.023 MHz. The signal is superimposed with data, called "navigation message", and a data transmission rate thereof is 50 bps. Among them, a signal having a spreading code rate of 1.023 MHz and a data transmission rate of 50 bps is generally called "L1C/A signal".

[0004]

Further, other instance of the satellite positioning system includes a Quasi-Zenith Satellite System (QZSS) that is being developed in Japan (Non-Patent Document 1). As with the GPS, the QZSS also operates by using a plurality of frequency bands such as L1, L2 and L5, each having a center frequency at 1575.42 MHz, 1227.6 MHz and 1176.45 MHz, respectively. In addition to the same spreading code rate of 1.023 MHz and data transmission rate of 50 bps as those of the GPS, the 1575.42 MHz L1 band includes a signal having a spreading code rate of 1.023 MHz and a data transmission rate of 250 bps, called "L1-SAIF signal", which is faster than the L1C/A signal.

[0005]

In the position determination performed by the satellite positioning system including the GPS, a radio wave transmitted from a positioning satellite is received by a receiver on the ground, and a distance between the satellite and the receiver is measured based on a propagation time of the radio wave from the satellite to the receiver. In this case, the radio wave transmitted from the positioning satellite is superimposed with orbit information indicative of a position of the positioning satellite itself and clock information representing clock time deviation of the satellite itself.

[0006]

The receiver is able to know the position and the clock time of the satellite by demodulating the orbit information and clock information transmitted from the positioning satellite. In this regard, the orbit and clock information transmitted by the positioning satellite is transmitted at a data transmission rate of 50 bps, by which it takes at least 30 seconds for demodulation of the orbit and clock information.

[0007]

The receiver can also determine the position of itself in a manner, for example, of trilateration using a measured value of the distance between a plurality of satellites and the receiver, a position of the satellite, and a clock time.

[0008]

5 Further, a GPS receiver, which is one of the positioning signal receivers, is generally incorporated in recent years in, for example, an electronic device such as a car navigation system, a mobile phone and a digital camera, and is becoming essential in a dairy life.

[0009]

10 Therefore, in the case of an electronic device, such as a mobile phone, which is frequently used by individuals on a dairy base, it is strongly desired, from a viewpoint of improvement in operability and convenience, that a time period from when a positioning function is activated till when it specifies the position is as short as possible.

[0010]

15 One of the methods for shortening such a time period to the position determination is a scheme called A-GPS (Assisted GPS) (Patent Document 1, as one example of A-GPS terminals and positioning methods). The A-GPS scheme generally involves an approach for shortening a time period it takes until the position is determined by externally inputting, as assist information, the orbit information and the
20 clock information of the positioning satellite to the positioning signal receiver using mainly a mobile telephone line, thereby to save the 30 seconds effort of demodulating the orbit and clock information from a radio wave transmitted by the positioning satellite.

[0011]

25 However, the A-GPS scheme has a problem that it requires real-time communication means, such as a mobile telephone line, to be equipped for acquiring assist information from outside the receiver, so that it cannot be applied to receivers having no real-time communication means.

[0012]

30 Then, in the case of applying the A-GPS scheme to the receivers having no

always-on connection capable communication means, there is a possible approach to input assist information, such as an orbit or a clock of the positioning satellite, that would be effective for 24 hours or more (i.e. usable for 24 hours or more) to the receiver, for example once a day. This allows the receiver to save the effort of demodulating the orbit and clock information transmitted by the positioning satellite during the period in which assist information is effective, so that the time for position determination can be shortened. In considering a service providing the assist information effective for such a relatively long time or long period to the receiver, the long effective period improves the convenience for a user of the service because it requires less frequency of input of the assist information. For example, if the assist information effective for one month can be created, a quick position determination becomes possible, by requiring the user of the service to input the assist information to the receiver only once a month, for at least one month after each input.

[0013]

However, even in the above approach, for the orbit information of the satellite among the assist information, it is possible to acquire the information effective for a long period due to the existence of an accurate orbit prediction model, while for the clock information, it is eventually impossible to acquire the information effective for a long period because creation of an accurate orbit prediction model is theoretically impossible.

LIST OF PRIOR ART DOCUMENTS

[PATENT DOCUMENTS]

[0014]

Patent Document 1: JP 2005-083859A

[NON-PATENT DOCUMENTS]

[0015]

Non-Patent Document 1: Japan Aerospace Exploration Agency: "User Interface Specifications for Quasi-Zenith Satellite System (IS-QZSS)" Ver. 1.1, July 31, 2009, Internet <URL: <http://qzss.jaxa.jp/is-qzss/>>

SUMMARY OF THE INVENTION

[OBJECT TO BE ACCOMPLISHED BY THE INVENTION]

[0016]

5 It is therefore an object of the present invention to overcome the forgoing problem and to provide, for example, a satellite positioning system and a positioning signal receiver, the satellite positioning system being capable of shortening a time period from activation to position determination in the positioning signal receiver, in a system, for example, for determining a position based on a positioning signal
10 transmitted from a satellite positioning system as represented by a global positioning system (GPS).

[MEANS TO ACCOMPLISH THE OBJECT]

[0017]

15 The satellite positioning system of the present invention is characterized by comprising: a global positioning system; a positioning signal receiver; a low-frequent assist information providing system for providing satellite orbit information as assist information which is offered low-frequently; a clock information generator for generating clock information; and a QZS for transmitting the clock information to the
20 positioning signal receiver, wherein the clock information generator is operable to superimpose the clock information onto a L1-SAIF signal of the QZS and transmit it to the positioning signal receiver via the QZS, and the positioning signal receiver is operable to determine a position of the positioning signal receiver by using a measured distance value between the GPS and the positioning signal receiver 102, the satellite
25 orbit information, and the clock information.

[0018]

 The clock information is transmitted to the positioning signal receiver over a satellite radio.

[0019]

30 The QZS is a terrestrial radio unit, and the clock information is transmitted to

the positioning signal receiver over a terrestrial radio of the terrestrial radio unit.

[0020]

The clock information comprises clock information for a plurality of satellites in a bit assignment format treated as one message.

5

[EFFECT OF THE INVENTION]

[0021]

The present invention makes it possible to significantly shorten a time period from activation to position determination in a positioning signal receiver even if it has been impossible heretofore, in a system, for example, for determining a position based on a positioning signal transmitted from a satellite positioning system as represented by a global positioning system (GPS).

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BRIEF DESCRIPTION OF THE DRAWINGS

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[0022]

FIG. 1 is an explanatory diagram for explaining an example system configuration in one embodiment of a satellite positioning system according to the present invention.

FIG. 2 is an explanatory diagram for explaining a specific example of a bit assignment format of clock information in one embodiment of the satellite positioning system according to the present invention.

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FIG. 3 illustrates an example of a GPS indicator and a QZS indicator of clock information in one embodiment of the satellite positioning system according to the present invention.

FIG. 4 is an explanatory diagram for explaining past clock offset information of all the GPS satellites.

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FIG. 5 is an explanatory diagram for explaining behaviors of past clock drift parameters of 32 satellites in a GPS.

FIG. 6 is an explanatory diagram for explaining an example system configuration in other embodiment of a satellite positioning system according to the present invention.

30

DESCRIPTION OF EMBODIMENTS

[0023]

An embodiment of a satellite positioning system and a positioning signal receiver according to the present invention will now be described in detail.

5 [0024]

FIG. 1 illustrates an example system configuration in one embodiment of a satellite positioning system according to the present invention.

[0025]

The satellite positioning system 100 comprises a global positioning system (GPS) 101, a positioning signal receiver 102, a low-frequent assist information providing system 103 for providing a satellite orbit as assist information which is offered low-frequently, a clock information generator 104 for generating clock information generated according to the present invention, and a QZS 105 for transmitting the clock information generated according to the present invention.

15 [0026]

The clock information generator 104 superimposes the clock information onto an L1-SAIF signal of the QZS having a data transmission rate of 250 bps, and transmits it to the positioning signal receiver 102 via the QZS 105. Then, the positioning signal receiver 102 determines a position of itself using a measured distance value between the GPS 101 and the positioning signal receiver 102, GPS orbit information having a long effective period provided as assist information, and GPS clock information according to the present invention.

[0027]

FIG. 2 illustrates a specific bit assignment format of the clock information. In the format 200, 250 bits are treated as one message. The one message comprises 8 bits of preamble, 6 bits of message type ID, 2 bits of issue number, 32 bits of GPS indicator, 5 bits of QZSS indicator, clock information for 10 satellites (af_0^{1st} to af_0^{10th}), each consisting of 17 bits, 3 bits of spare area, and 24 bits of check bit.

[0028]

30 In this case, the following three patterns are sequentially repeated for the

preamble, as defined in a section 5.4.3.1.1 of the Non-Patent Document 1 as an example.

[0029]

[Table 1]

Pattern A	01010011
Pattern B	10011010
Pattern C	11000110

5

[0030]

A start of transmission of the first bit of the preamble of pattern A is synchronized with a start of navigation message sub-frame of the 6 seconds long L1C/A signal. Then, the preamble of the message transmitted next to the message having a preamble of pattern A will be pattern B. The pattern B is followed by pattern C, and then it returns to pattern A. The preamble is also subjected to a FEC coding, where it is coded in the same way as other bits in the message block. Therefore, the preamble indicates a start of the message block, but it cannot be used for signal capturing or for bit synchronization prior to FEC decoding process.

10

15 [0031]

As to the message type ID, each message has 6 bits of message type ID which identifies message types of 0 to 63, as defined in a section 5.4.3.1.2 of the Non-Patent Document 1 as an example. The content of data area is defined as described below according to the message type. The following table illustrates a list of the message types (SAIF message types).

20

[0032]

[Table 2]

Type ID	Message Name	Remarks
0	Test mode	
1	PRN mask	
2-5	High-speed correction	

6	Integrity information	
7	(High-speed correction deterioration factor)	
10	Deterioration factor	
18	IGP mask	
24	Composite high-speed/long-term correction	
25	Long-term correction	
26	Ionospheric propagation delay correction	
28	Clock-orbit covariance	
40-51	Reserved for utilization demonstration	LI-SAIF + Message
52	TGP mask	
53	Tropospheric delay correction	
54-55	(Atmosphere delay correction)	TBD
56	Signal bias correction information	
57	(Reserved for orbit information)	TBD
58	QZS ephemeris	Temporary
59	Almanac information	TBD
60	(Wide-area information/Maintenance information)	TBD
62	(Reserved for internal test)	
63	Null message	

[0033]

The issue number is counted up by one when the values of the GPS indicator and the QZSS indicator as described below are modified. It should be noted that

5 11(Bin) is followed by 00(Bin).

[0034]

The GPS indicator and the QZSS indicator indicate, according to ON positions of the bits (e.g., positions where the bits are 1), to what number of satellites of the GPS and of the QZSS the clock information contained in the message belongs. For

10 example, as illustrated in FIG. 3, if 2nd, 5th, 10th, 15th, 19th, 20th, 23rd, 24th and 29th

bits from the most significant bit of the GPS indicator and 2nd bit from the most significant bit of the QZSS indicator are "1", then this means that the message contains clock information for 2nd, 5th, 10th, 15th, 19th, 20th, 23rd, 24th and 29th satellites of the GPS and 2nd satellites of the QZSS. In this case, it is ensured that the clock information for 10 satellites contained in this message is arranged in an order of having the smallest satellite number viewed from the most significant bit of the message.

[0035]

The clock information for one satellite consists of 17 bits, and the information means a clock offset of the satellite. The 17 bits are numerical values of two's complement representation with a scale factor (or an LSB) of 7.43 [ns] (corresponding to 2.23 [m]). In this case, the range which can be represented by 17 bits is +/- 0.5 [ms]. This is a sufficient range for the latest GPS satellite (after the block IIR).

[0036]

FIG. 4 illustrates clock offset information of all the GPS satellites in the past 1.5 years. As illustrated in FIG. 4, there are some clock offsets exceeding the range of +/- 0.5 [ms]. However, these are the GPS satellites of old generation (block IIA), which are scheduled to be expired in a short time and replaced with those of newer generation in view of the time of filing this application. Then, clock offsets for the newer generation satellites (after block IIR) are within the range of +/- 0.5 [ms].

[0037]

While the clock information for one satellite is comprised of 17 bits in the illustration here in order to insert the clock information for ten satellites in a message delimited by 250 bits, if it is comprised of 18 bits alternatively, the scale factor (or the LSB) can be reduced to half the above-mentioned value.

[0038]

The clock offset is generated in the clock information generator 104 according to the following equation:

$$b^k(t) = af_0^k + af_1^k(t - t_{oc})$$

Equation (1)

[0039]

Where

$$b^k(t)$$

is a clock offset of a satellite k at a clock time

$$t$$

$$af_0^k$$

is a bias (zero-order term) message of a latest SV clock transmitted by the satellite k,

$$af_1^k$$

- 5 is a clock drift (first-order term) message of a latest SV clock transmitted by the satellite k, and

$$t_{oc}$$

is a clock epoch of

$$af_0^k$$

and

$$af_1^k$$

.

- 10 [0040]

The check bit protects the message such that 24 bits of CRC parity code is appended to the tail end of the message and the 24 bits of CRC parity has an undetected error probability of 2^{-24} ($= 5.96 \times 10^{-8}$) or less when the bit error rate is 0.5 or less for both of the burst error and random error, as defined in a section 5.4.3.1.3 of the

- 15 Non-Patent Document 1.

[0041]

As a generating polynomial for CRC parity, the following polynomial may be used as an example:

$$g(X) = X^{24} + X^{23} + X^{18} + X^{17} + X^{14} + X^{11} + X^{10} + X^7 + X^6 + X^5 + X^4 + X^3 + X + 1$$

- 20 Equation (2)

[0042]

It should be noted that the receiver performs a CRC parity check on a received message, and in the case of mismatch, it does not use any information contained in the message.

[0043]

5 In the positioning signal receiver 102, when clock information according to the invention is input, the clock offset of the satellite at an arbitrary clock time can be calculated based on the arithmetic processing represented as follows.

[0044]

$$\Delta t^k(t) = b^k(t_{RCV}) + af_1^k \times (t - t_{RCV})$$

10 Equation (3)

[0045]

where

$$\Delta t^k(t)$$

is a clock offset of satellite number k at a time t, and

$$b^k(t_{RCV})$$

is clock information of satellite number k according to the present invention acquired at
15 a time

$$t_{RCV}$$

.

[0046]

Further,

$$af_1^k$$

is a clock drift of satellite number k, which is a newer one of either a clock drift
20 parameter demodulated in the past by the positioning signal receiver from a radio wave transmitted by a GPS or QZS, or a clock drift parameter input from outside the positioning signal receiver as assist information. The clock drift parameter has a long effective period, which may be about one month old from the current clock time.

[0047]

FIG. 5 illustrates behaviors of past clock drift parameters of 32 satellites in a GPS. FIG. 5 shows how much the clock drift parameter af1 changes over time. According to FIG. 5, it can be seen that an amount of change in the clock drift parameters of most satellites are within +/- 0.01pp10¹⁰(10⁻¹²) at a GPS week 1518 which is 5.5 weeks after a GPS week 1512.5 as a beginning of data presentation. The amount of change in the clock drift parameter being 10⁻¹² means that when a clock offset

$$\Delta t^k(t)$$

at an arbitrary clock time t is determined using the Equation (3), if a difference

$$(t - t_{RCV})$$

between a receiving time of the clock information

$$b^k(t_{RCV})$$

according to the present invention and the arbitrary clock time is within several hours

(e.g., four hours = 14400 seconds), the error in the clock offset

$$\Delta t^k(t)$$

due to the variation in

$$af_1^k$$

would merely be 10⁻¹² x 14400 seconds = 1.44 * 10⁻⁸ seconds (= 4.3 m), even if

$$af_1^k$$

is of 5.5 weeks before the clock time

$$t$$

[0048]

A specific example use of the positioning signal receiver and the clock information in one embodiment of the present invention will be exemplified below.

[0049]

The positioning signal receiver acquires the assist information which is offered low-frequently at a frequency of about once a month. The assist information which is offered low-frequently may be information acquired in an offline environment such as

by connecting the positioning signal receiver to a PC via the Internet. When a position is to be determined by the positioning signal receiver, the position can be determined in a short time without taking about 30 seconds to demodulate orbit and clock information from a low speed L1C/A signal of the GPS, by rapidly acquiring the GPS clock information from L1-SAIF signal of the QZS.

[0050]

Other embodiment of the present invention includes a positioning signal receiver of a digital camera. Specifically, if the assist information which is offered low-frequently is caused to be input to the digital camera when a picture in the digital camera is to be downloaded to a PC, it becomes possible for the digital camera to shorten the time for position determination by the assist information in conjunction with clock information from the L1-SAIF signal without having any communication means such as a mobile telephone line or a wireless LAN.

[0051]

An example use in other embodiment of the present invention will be further exemplified.

[0052]

The positioning signal receiver has a real-time wireless communication line with a limited utilization area, such as a wireless LAN. The positioning signal receiver acquires the assist information which is offered low-frequently when it is in a coverage area of the real-time wireless communication line. Within about one day after acquisition of the assist information which is offered low-frequently, a position can be determined in a short time only with the assist information which is offered low-frequently without taking about 30 seconds to demodulate orbit and clock information from a low speed L1C/A signal of the GPS. After determining the position, the positioning signal receiver can rapidly acquire the latest clock signal from the L1-ASIF signal of the QZS and immediately complete its operation. Within about several hours after the completion of operation, a position can be determined in a short time with the assist information which is offered low-frequently and the clock information previously acquired from the L1-ASIF signal, with even omitting the

demodulation of the clock information from the L1-ASIF signal. In this embodiment, the time period for position determination can be shortened in an intermittent operation of once in a several hours of the positioning signal receiver by requiring the positioning signal receiver to enter in a utilization area of the wireless communication line only once a month. This makes it possible to improve the convenience for the positioning signal receiver which has only communication means with severely limited utilization area, such as a wireless LAN.

[0053]

In the present invention, for the orbit information of the assist information, it is possible to create information effective for a long period by an accurate prediction model, while for the clock information, it is impossible to set a long effective period because an accurate prediction is theoretically impossible. Therefore, the present invention is characterized by repeatedly providing only the clock information as assist information to be input to the positioning signal receiver.

[0054]

Thus, the present invention focuses attention on a factor that the clock drift parameter of the positioning satellite is highly stable, with few changes, and capable of having a long effective period, and is characterized by reducing an amount of clock information to be provided and allowing assist information to be provided even in significantly low-speed communication means as compared to a high-speed wireless communication such as by mobile phones or over a wireless LAN by using the clock information for which old information is used for the clock drift parameter and only a clock offset (for bias) is frequently provided.

[0055]

FIG. 6 illustrates an example system configuration in other embodiment of a satellite positioning system according to the present invention.

[0056]

The satellite positioning system 600 comprises a global positioning system (GPS) 101, a positioning signal receiver 102, a low-frequent assist information providing system 103 for providing satellite orbit and clock information as assist

information which is offered low-frequently, a clock information generator 104 for providing clock information generated according to the present invention, and a terrestrial radio unit 605 for transmitting the clock information generated according to the present invention.

5 [0057]

In this case, the terrestrial radio unit 605 for transmitting the clock information can use a radio unit emitting a radio wave such as a television radio wave or an FM radio wave.

[0058]

10 While all papers and documents which are filed prior to filing this specification and which are publicly and freely available would be identified in connection with the present invention, the contents of such papers and documents are incorporated herein by reference.

[0059]

15 All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0060]

20 Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

25 [0061]

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one or any novel combination of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one or any novel combination of the steps of any method or
30 process so disclosed.

EXPLANATION OF CODES

[0062]

100: satellite positioning system

5 101: GPS

102: positioning signal receiver

103: low-frequent assist information providing system

104: clock information generator

105: QZS

10 605: terrestrial radio unit

CLAIMS

What is claimed is:

1. A satellite positioning system comprising: a global positioning system; a
5 positioning signal receiver; a low-frequent assist information providing system for
providing satellite orbit information as assist information which is offered
low-frequently; a clock information generator for generating clock information; and a
QZS for transmitting the clock information to the positioning signal receiver,

10 wherein the clock information generator is operable to superimpose the clock
information onto a L1-SAIF signal of the QZS and transmit it to the positioning signal
receiver via the QZS , and

the positioning signal receiver is operable to determine a position of the
positioning signal receiver by using a measured distance value between the GPS and the
positioning signal receiver, the satellite orbit information, and the clock information.

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2. The system as defined in claim 1, wherein the clock information is transmitted
to the positioning signal receiver over a satellite radio.

3. The system as defined in claim 1, wherein the QZS is a terrestrial radio unit,
20 and the clock information is transmitted to the positioning signal receiver over a
terrestrial radio of the terrestrial radio unit.

4. The system as defined in any one of claims 1 to 3, wherein the clock
information comprises clock information for a plurality of satellites in a bit assignment
25 format treated as one message.

5. The system as defined in claim 4, wherein the bit assignment format treated as
one message is 250 bits, in which the clock information comprises clock information for
eight to ten satellites.

30

6. A positioning signal receiver in the system as defined in any one of claims 1 to
- 5.