

DESCRIPTION

Title of Invention: POSITION DETECTION SYSTEM

Technical Field

5 [0001]

The present invention relates to a position detection system to locate a mobile unit using one or more beacon signal generators and one or more communication terminal devices.

10 Background Art

[0002]

Japanese Patent Publication No. 4757105 (PTL 1) discloses an intra-house surveillance system including beacon signal generators which are installed in different places in a house and transmit location information including an ID unique to a place where each is installed, communication terminal devices which are carried by inhabitants in the house, receive location information transmitted from the beacon signal generators, and transmit the location information with a terminal ID unique to each terminal, terminal location cognition means which cognizes the locations of the communication terminal devices in the house, based on the location information and terminal IDs transmitted from the communication terminal devices, and display means which displays the

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locations of the communication terminal devices cognized
by the terminal location cognition means.

[0003]

Moreover, Japanese Patent Publication No. 5396442
5 (PTL 2) discloses a location information system to cognize
the location of a mobile unit equipped with a receiving
terminal device on the basis of identification information
of a beacon signal generator and the radio field intensity
of a signal received.

10 Citation List

Patent Literature

[0004]

PTL 1: Japanese Patent Publication No. 4757105

PTL 2: Japanese Patent Publication No. 5396442

15 Summary of Invention

Technical Problem

[0005]

In the case of locating a mobile unit by utilizing
ID of a beacon signal generator and radio field intensity,
20 when a communication terminal device receives multiple
beacon signals emitted by multiple beacon signal
generators, the radio field intensities of the multiple
beacon signals vary in a boundary region between the
output ranges of multiple beacon signals; this poses a
25 problem of tending to make an incorrect position

determination.

[0006]

An object of the present invention resides in providing a position detection system that makes it possible to avoid incorrect position determinations as much as possible in a case of utilizing radio field intensity.

Solution to Problem

[0007]

10 A position detection system of the present invention includes multiple beacon signal generators which are installed respectively in multiple predetermined installation positions within moving regions where one or more mobile units move and generate beacon signals, each including a beacon ID, one or more communication terminal devices which are attached to one or more mobile units and receive one or more beacon signals, and a position determination unit. Each of the one or more communication terminal devices includes a beacon ID determination and storage unit which decides on a beacon signal for position determination at a given period for decision from the radio field intensities of one or more beacon signals received and determines and stores the beacon ID of a beacon signal generator emitting that beacon signal for position determination as a beacon ID for position

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determination and a transmitter which transmits information for position determination including the beacon ID for position determination and a terminal ID to identify the terminal device itself. The position
5 determination unit determines the position of each of the one or more mobile units within the moving regions at a given period for determination, based on the beacon ID for position determination decided by each of the one or more communication terminal devices and the terminal ID, and
10 information on the multiple predetermined installation positions within the moving regions. In the present invention, the beacon ID determination and storage unit in each of the communication terminal devices does not update the beacon ID for position determination, until an
15 intensity difference between the previous and current radio field intensities of the beacon signal for position determination decided at the given period for decision becomes at or below a predetermined marginal threshold.

[0008]

20 The radio field intensities of beacon signals have a large variability (intensity difference) in a region closer to a beacon signal generator and the intensity difference (variability) of the radio field intensities decreases with increasing distance from the beacon signal
25 generator. Hence, for a beacon signal for position

determination adopted to determine a beacon ID for position determination, until the intensity difference between the previous and current radio field intensities of the beacon signal becomes at or below a predetermined marginal threshold (from another perspective, until a communication terminal device moves some distance away from a beacon signal generator that was used to determine a beacon ID for position determination at the previous time), the beacon ID determination and storage unit does not update the beacon ID for position determination. In doing this way, the current position determined at the previous time is retained even when a mobile unit has entered a boundary region between the output ranges of multiple beacon signals overlap. When it is detected that the mobile unit (communication terminal) has moved some distance away from the beacon signal generator that was used to determine a beacon ID for position determination at the previous time by the intensity difference of radio field intensities, the beacon ID for position determination is to be updated. In consequence, according to the present invention, it is possible to increase the accuracy of position determination.

[0009]

As for how to fix a marginal threshold, it should be fixed to enable it to prevent misdetection caused by

receiving the outputs of two or more beacon signal
generators. Theoretically, it is preferable that the
marginal threshold should be fixed so that the intensity
difference does not become at or below the marginal
5 threshold within a boundary region where the output ranges
of two or more beacon signal generators overlap.

[0010]

It is preferable that the beacon ID determination
and storage unit determines the previous and current radio
10 field intensities based on an average value of radio field
intensities of multiple beacon signals received at a given
period for measurement shorter than the period for
decision within the time span of one period of for
decision. Using such an average value enables it to
15 compensate variation in measurement data.

[0011]

Now, an average value can be calculated as a simple
average of multiple radio field intensities of multiple
beacon signals, calculated as a median value of radio
20 field intensities of multiple beacon signals, or
calculated as a simple average of radio frequency
intensities of multiple beacon signals remaining with the
exception of the maximum and minimum values of radio field
intensity. A method hereof is optional.

25 [0012]

When an intensity difference between the radio field intensity of a beacon signal for position determination adopted to determine a beacon ID for position determination and the radio field intensity of another beacon signal becomes larger than a predetermined threshold of intensity difference, the beacon ID determination and storage unit regards the beacon ID of another beacon signal generator for which the intensity difference has become larger than the threshold of intensity difference as the beacon ID for position determination and updates the beacon ID. When the radio field intensity of beacon signals from another beacon signal generator is obviously larger, it is definite that a mobile unit lies near the beacon signal generator and it is preferable to update the beacon ID for position determination, since there is no possibility of misdetection.

[0013]

The period for determination has a length more than the period for decision; this makes it possible to reduce computational processing of the position determination unit even when the number of mobile units has increased and to respond to an increase in the number of mobile units.

[0014]

It is preferable that a length of the period for determination is adjustable. In doing this way, the computational burden of the position determination unit can be adjusted depending on increase/decrease in the number of mobile units.

[0015]

To promptly detect a displacement of the position of a mobile unit, it is expedient that, once the beacon ID determination and storage unit has updated and stored the beacon ID for position determination, the transmitter should immediately transmit the updated beacon ID for position determination and the terminal ID to the position determination unit.

[0016]

Even in such a case where the transmitter immediately transmits the updated beacon ID for position determination and the terminal ID to the position determination unit so that a displacement of the position of a mobile unit can be detected promptly, it is possible to reduce the computational burden of the position determination unit. For example, the transmitter is configured so that, when a request to transmit is issued from the position determination unit to the transmitter at a period for determination, the transmitter transmits the latest beacon ID for position determination stored in the

beacon ID determination and storage unit to the position determination unit. Moreover, the position determination unit configured not to issue a request to transmit even upon expiry of one period, when the updated beacon ID for position determination and the terminal ID have been transmitted to it from the transmitter before expiry of one period for determination. In doing this way, an unnecessary request to transmit is not issued and, therefore, the burden of the position determination unit can be reduced.

[0017]

In addition, even in such a case where the transmitter is configured so that, when a request to transmit is issued from the position determination unit to the transmitter at a period for determination, the transmitter transmits the latest beacon ID for position determination stored in the beacon ID determination and storage unit to the position determination unit, once the beacon ID determination and storage unit has updated and stored a beacon ID for position determination before expiry of one period for determination, the transmitter may immediately transmit the updated beacon ID for position determination and the terminal ID to the position determination unit without receiving a request to transmit. In doing this way, even when a period for determination

was set long, it is possible to promptly detect a displacement of the position of a mobile unit whenever it occurs.

[0018]

5 Moreover, even in the case where the transmitter is configured so that, when a request to transmit is issued from the position determination unit to the transmitter at a period for determination, the transmitter transmits the latest beacon ID for position determination stored in the
10 beacon ID determination and storage unit to the position determination unit, only when the beacon ID determination and storage unit has updated the beacon ID for position determination until expiry of one period for determination, the transmitter may transmit the updated beacon ID for
15 position determination and the terminal ID to the position determination unit in response to the request to transmit. In doing this way, unless the beacon ID for position determination is updated, the communication terminal device does not transmit; therefore, the life span of the
20 communication terminal device can be lengthened.

[0019]

Even in the case where the transmitter is configured so that, when a request to transmit is issued from the position determination unit to the transmitter at a period
25 for determination, the transmitter transmits the latest

beacon ID for position determination stored in the beacon ID determination and storage unit to the position determination unit, only when a beacon ID for position determination transmitted by the transmitter in response to the previous request to transmit differs from a beacon ID for position determination stored in the beacon ID determination and storage unit upon receiving the current request to transmit, the transmitter may transmit the beacon ID for position determination that differs from the one transmitted previously and the terminal ID to the position determination unit. This manner is based on a thought such that, even when the beacon ID for position determination has been updated for one period for determination, if it is the same as the previously transmitted beacon ID for position determination at the time of receiving a request to transmit, it is not necessary to transmit the beacon ID changed for one period for determination. In doing this way also, the burden of the position determination unit can be reduced and the burden of the communication terminal device can be reduced.

[0020]

In addition, it is preferable that, when the intensity difference between the radio field intensities of a beacon signal for position determination adopted to determine a beacon ID for position determination becomes

at or below the marginal threshold and the intensity difference between the radio field intensity of the beacon signal for position determination adopted to determine the beacon ID for position determination and the radio field intensity of another beacon signal is larger than a predetermined threshold of intensity difference, with regard to a peak hold value of radio field intensity of the beacon signal for position determination, adopted to determine the beacon ID for position determination, the beacon ID determination and storage unit decides on what is any of multiple predetermined peak hold value ranges in which the peak hold value falls and, when a peak hold value measured currently falls in the peak hold value range in which the peak hold value falls, the beacon ID determination and storage unit does not update the beacon ID for position determination, or when the peak hold value measured currently is beyond the peak hold value range, the beacon ID determination and storage unit updates the beacon ID for position determination, based on a beacon signal with the largest radio field intensity out of one or more beacon signals being received at that point of time. In doing this way, it is possible to update the beacon ID for position determination even before the radio field intensity of beacon signals from another beacon signal generator changes definitely and significantly, if

there is no possibility of errors caused by updating the beacon ID for position determination.

[0021]

Now, the peak hold value can be calculated as a
5 simple average of peak values of multiple radio field intensities of multiple beacon signals, calculated as a median value of peak values of radio field intensities of multiple beacon signals, or calculated as a simple average of peak hold values of radio field intensities of multiple
10 beacon signals remaining with the exception of the maximum and minimum peak values of radio field intensity. In doing this way, the possibility of making an incorrect position determination can be reduced greatly even when there is variation in radio field intensity data that is
15 measured.

Brief Description of Drawings

[0022]

Figure 1 is a plan view depicting beacon signal generators placed within moving regions and communication
20 terminal devices attached to mobile units which move within the moving regions, according to one embodiment of a position detection system of the present invention.

Figure 2 is a diagram for use to explain the configuration of the embodiment in Figure 1.

25 Figure 3 is a diagram representing a relationship

between distance from a beacon signal generator to a communication terminal device and radio field intensity.

Figure 4 is a diagram for use to explain a second condition for update.

5 Figure 5 is a diagram representing a relationship between distance and radio field intensity for use to explain the second condition for update.

Figure 6 is a flowchart illustrating a process flow in the embodiment in Figure 1.

10 Description of Embodiments

[0023]

In the following, one example of embodiment of the present invention will be described in detail with reference to the drawings. In Figure 1 and Figure 2, a position detection system which is an embodiment of the present invention includes multiple beacon signal generators 101 to 10N (N is an arbitrary positive integer), multiple communication terminal devices 20A to 20N attached to multiple mobile units 60A, 60B .. 60N, respectively, and a position determination unit 70 which determines the positions of the mobile units 60A, 60B .. 60N. The multiple communication terminal devices 20A to 20N incorporate beacon ID determination units 30A to 30N including beacon ID determination and storage units 40A to 40N and transmitters 50A to 50N.

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[0024]

N pieces of multiple beacon signal generators 101 to 10N are provided and the respective first, second ... N-th beacon signal generators 101 to 10N are installed
5 respectively in multiple predetermined installation positions within moving regions where the multiple mobile units 60A, 60B .. 60N, move, respectively. In Figure 1, eight beacon signal generators 101, 102 ... 108 are presented. It is preferable that the multiple beacon
10 signal generators 101 to 10N are, for example, installed on a ceiling within a moving region not to hinder the moving of the mobile units 60A, 60B .. 60N, and avoid the influence of an object existing in a moving region. As depicted in Figure 1, the respective beacon signal
15 generators 101, 102 ... 108 are placed in matrix form, spaced from each other by a given distance. Each of the beacon signal generators 101, 102 ... 108 emits downward a beacon signal including a unique beacon ID (identifier) at a predetermined radio field intensity.

20 [0025]

Multiple pieces of communication terminal devices 20A to 20N are provided and each one of the respective communication terminal devices 20A to 20N is attached to each of the multiple mobile units 60A to 60N, receives
25 each beacon signal emitted by the multiple beacon signal

generators 101 to 10N with a non-directional antenna, and processes a received result with each of the beacon ID determination units 30A to 30N incorporated in it. In Figure 1, mobile units 60A, 60B wear communication terminal devices 20A, 20B, respectively. It is preferable that a communication terminal device is attached to a helmet of a worker, if used in a construction site or inside a factory. Now, if a communication terminal device is equipped with a temporary data storage unit, it is a matter of course that the communication terminal device may store all measurement data in the temporary data storage unit and later transmit, to the position determination unit 70, information for position determination including a beacon ID for position determination determined by beacon ID determination units 30A to 30N and a terminal ID to identify the terminal device itself.

[0026]

Beacon ID determination units 30A to 30N include beacon ID determination and storage units 40A to 40B and transmitters 50A to 50N and are incorporated in each of the communication terminal devices 20A to 20N. At a given period for decision (in particular, e.g., one second), the beacon ID determination and storage units 40A to 40N decide on a beacon signal for position determination from

the radio field intensities of one or more beacon signals received and determines and stores the beacon ID of a beacon signal generator emitting that beacon signal for position determination as the beacon ID for position
5 determination. The transmitters 50A to 50N transmit information for position determination including the beacon ID for position determination and the terminal ID to identify the terminal device itself to the position determination unit 70.

10 [0027]

At a given period for determination (specifically, e.g., five seconds), the position determination unit 70 determines the position of each mobile unit 60A .. within its moving region, based on the beacon ID for position
15 determination and the terminal ID which are periodically transmitted from each of the communication terminal devices 20A to 20N and information on the multiple predetermined installation positions of the respective beacon signal generators 101 to 10N within the respective
20 moving regions (corresponding to information in which the installation positions of the beacon signal generators within the moving regions were stored as map data). It should be noted that, in the present embodiment, radio field intensity is not used for position determination
25 directly, but is used for conditional judgment to update a

beacon ID for position determination, and a determination of a precise current position is not made by radio field intensity.

[0028]

5 It should be noted that, in the present embodiment, by whether or not a mobile unit (communication terminal device) exists in a range in which radio waves from what beacon signal generator arrive, its current position is determined. Therefore, no further determination is made
10 as to how much distance from a beacon signal generator to a position in which a mobile unit (communication terminal device) exists. Thus, computation required for position determination does not become complex.

[0029]

15 Furthermore, in the present embodiment, for one beacon signal adopted to determine a beacon ID for position determination, until an intensity difference between the previous and current radio field intensities of the beacon signal becomes at or below a predetermined
20 marginal threshold, the beacon ID determination and storage units 40A to 40N in the beacon ID determination units 30A to 30N do not update the beacon ID for position determination. As presented in Figure 3, as for the radio field intensities of beacon signals, the values of radio
25 field intensity (RSSI) exhibit a large variability

(intensity difference) in a region closer to a beacon signal generator and the intensity difference (variability) of the values of radio field intensity (RSSI) decreases with increasing distance from the beacon signal generator. Hence, for one beacon signal adopted to determine a beacon ID for position determination, until the intensity difference between the previous and current radio field intensities of the beacon signal a predetermined marginal threshold (from another perspective, until the communication terminal device moves some distance away from the beacon signal generator that was used to determine a beacon ID for position determination at the previous time), the beacon ID determination and storage units 40A to 40N do not update the beacon ID for position determination. In doing this way, the beacon ID for position determination determined at the previous time is retained even when mobile units 60A to 60N have entered a boundary region between the output ranges of multiple beacon signals. When it is detected that the mobile unit (communication terminal) has moved some distance away from the beacon signal generator that was used to determine a beacon ID for position determination at the previous time by the intensity difference of radio field intensity values, the beacon ID for position determination is to be updated. The position determination unit 70 updates the

current position of the mobile unit in response to the update of the beacon ID for position determination.

[0030]

To illustrate this according to Figure 1, a mobile unit (a worker) 60A equipped with a communication terminal device 20A is doing work, while repeatedly moving within a work area R. In such a case, if a beacon ID (current position) for position determination is simply determined only by radio field intensity, the position of the mobile unit 60A would be variable, frequently switching between two of the beacon signal generators 101, 102, 103, and 104. In the present embodiment, for example, supposing that the mobile unit 60A has moved into a work area where a beacon signal generator 102 is installed from a direction where a beacon signal generator 103 is installed, the only matter is the radio field intensity of radio waves from the beacon signal generator 103 that was first used to determine a beacon ID (current position) for position determination among four beacon signal generators 101 to 104 and no update of the beacon ID (current position) for position determination is performed, unless the intensity difference between the previous and current radio field intensities of radio waves from the beacon signal generator 103 becomes at or below a predetermined marginal threshold.

[0031]

In an example of Figure 1, if the mobile unit 60A moves only within the work area, not moving far away from the beacon signal generator 103, even though the radio field intensity of radio waves from any other beacon signal generator 101, 102, or 104 has become higher, the beacon ID (current position) for position determination is not updated only because of that fact. Then, when the work within the work area finishes and the mobile unit 60A moves, the intensity difference between the previous and current radio field intensities of radio waves from the beacon signal generator 103 decreases. This is because the mobile unit 60A has moved far away from the beacon signal generator 103 and the beacon ID of a beacon signal generator emitting radio waves with the highest radio field intensity at that point of time is adopted as the beacon ID for position determination and the current position is updated. For instance, if the worker has entered the radio range of beacon signals that are emitted by the beacon signal generator 102, a position located by the beacon ID of the beacon signal generator 102 becomes the updated current position in which the worker exists now.

[0032]

Applying control in this way also provides an

advantageous effect of preventing faulty operation that is noted below: in a case where properly receiving a beacon signal from beacon signal generator 103 has failed despite the fact that the mobile unit 60A equipped with the communication terminal device 20A lies near the beacon signal generator 103 within, e.g., one second, a radio field intensity of -127 dBm is measured and a beacon signal from the beacon signal generator 102 or any other one that is farther from the terminal device is adopted and the current position is updated.

[0033]

This marginal threshold should be fixed to enable it to prevent misdetection caused by receiving the outputs of two or more beacon signal generators 101 ...

Theoretically, by fixing it so that the intensity difference (a difference between the previous and current radio field intensities of one beacon signal adopted to determine a beacon ID for position determination) does not become at or below the marginal threshold within a boundary region where the output ranges of two or more beacon signal generators 101 .. overlap, it is prevented that the beacon ID for position determination is switched frequently. Thus, accurate position detection can be realized. A specific value is fixed, based on the radio field intensities of radio waves emitted by the beacon

signal generators 101 .. and installation intervals among others.

[0034]

The beacon ID determination and storage units 40A to
5 40N calculate an average value of the radio field
intensities of multiple beacon signals received at a
period (1/10 second in the present embodiment) for
measurement shorter than the period for determination
within the time span of one period for determination,
10 determines this average value as a radio field intensity,
and stores it in an internal memory. The beacon ID
determination and storage units 40A to 40N determine the
beacon ID for position detection, based on this average
value. That is, the beacon ID determination and storage
15 units 40A to 40N record and retain an average value of
radio field intensity at the previous time in the internal
memory and, when determining the beacon ID for position
determination, compare an average value of radio field
intensity newly calculated now with the previous radio
20 field intensity read from the internal memory. Using an
average value in this way enables it to compensate
variation in measurement data and minimize influence of
measurement errors.

[0035]

25 While "an average value" in this embodiment is

calculated as a simple average of multiple radio field intensities of multiple beacon signals received at a given period for measurement shorter than the period for determination within the time span of one period for determination; in another embodiment, it is calculated as a median value of the radio field intensities of multiple beacon signals or it is calculated as a simple average of the radio frequency intensities of multiple beacon signals remaining with the exception of the maximum and minimum values of radio field intensity.

[0036]

In addition to the above condition for determination, the beacon ID determination and storage units 40A to 40N change the beacon ID for position determination under a condition for beacon ID update that is noted below. This condition for determination is explained with Figure 3 and Figure 4. As depicted in Figure 4, in a case where one passes regions where four beacon signal generators 1 to 4 are installed along a walking route indicated, the radio field intensities of beacon signals received by the communication terminal device attached to the mobile unit from the four beacon signal generators are as plotted in Figure 5. When an intensity difference D between the radio field intensity of one beacon signal (beacon 1 in Figure 5), first adopted to determine a beacon ID for

position determination, and the radio field intensity
(beacon 2) of another beacon signal becomes larger than a
predetermined threshold of intensity difference (e.g., 10
dB), the beacon ID of another beacon signal generator 2
5 (beacon 2 in Figure 4 and Figure 5) for which the
intensity difference has become larger than the threshold
of intensity difference shall be regarded as a new beacon
ID for position determination. The position determination
unit 70 updates the current position of the communication
10 terminal device, based on this update of the beacon ID for
position determination. This is because, when the radio
field intensity of beacon signals from another beacon
signal generator 2 is obviously larger, it is definite
that the mobile unit lies near the beacon signal generator
15 2 and updating the current position can result in a highly
accurate position determination, since there is no
possibility of misdetection.

[0037]

This current position update processing is, for
20 example, applied when there is an intensity difference
such that the difference between the current radio field
intensity of a beacon signal determined at the previous
time and the radio field intensity of a beacon signal with
the strongest receive strength among those measured
25 currently exceeds a threshold of intensity difference of

10 dBm. This threshold of intensity difference should be fixed depending on the radio field intensities of beacon signals emitted by the beacon signal generators 101 .. , installation intervals, the assumed moving speed of a
5 mobile unit 60A .. , etc.

[0038]

Furthermore, the beacon ID determination and storage units 40A to 40N in the present embodiment adopt a condition for update that is noted below. When the
10 intensity difference between the radio field intensities of a beacon signal adopted to determine a beacon ID for position determination for use in determining the current position becomes at or below the marginal threshold and the intensity difference between the radio field intensity
15 of one beacon signal adopted to determine a beacon ID for position determination and the radio field intensity of another beacon signal is larger than the threshold of intensity difference, with regard to a peak hold value of the radio field intensity of the beacon signal for
20 position determination, adopted to determine a beacon ID for position determination, a decision is made of what is any of multiple predetermined peak hold value ranges in which the peak hold value falls. When a peak hold value measured next falls within the peak hold value range in
25 which the above peak hold range falls, no update of the

beacon ID for position determination is performed. When
it is beyond the peak hold value range, the beacon ID of a
beacon signal with the largest radio field intensity out
of one or more beacon signals being received at that point
5 of time shall be regarded as the beacon ID for position
determination. The position determination unit 70 updates
the current position of the mobile unit, based on this
beacon ID for position determination and information on
the installation positions of the multiple beacon signal
10 generators.

[0039]

Now, a peak hold value is a value of the strongest
radio field intensity among beacon signals received for
each of multiple periods. Therefore, whenever radio field
15 intensity becomes strong, as the mobile unit approaches
the beacon signal generator which is adopted to determine
a beacon ID for position determination, its value is
recorded and updated with the beacon ID determination and
storage units 40A to 40N. In the course in which the
20 mobile unit moves away from the beacon signal generator,
the radio field intensity weakens gradually and, therefore,
the peak hold value is not updated.

[0040]

A peak hold value range can optically be set
25 according to the radio field intensities of radio waves

emitted by the beacon signal generators 101 to 10N and installation intervals among others. Table 1 represents one example of a relationship between a peak hold value and a peak hold value range corresponding to the peak hold value in accordance with the present embodiment. For example, if a peak hold value is -60 dBm, a peak hold value range corresponding to it is "peak hold value - 20"; therefore, when a peak hold value measured subsequently is less than -80 dBm, it is regarded as being beyond the peak hold value range.

[0041] [Table 1]

Table 1

Condition	Threshold (dBm)
Peak hold value > -55	Peak hold value - 25
$-55 \geq \text{Peak hold value} > -65$	Peak hold value - 20
$-65 \geq \text{Peak hold value} > -80$	Peak hold value - 10
$-80 \geq \text{Peak hold value}$	Peak hold value - 0

For example, in Figure 1, with regard to a mobile unit 60A, if a peak hold value of a beacon signal from the beacon signal generator 103 is -60 dBm, a peak hold value measured next is not beyond -80 dBm, as long as the mobile unit 60A moves within the work area where it is, no update of the beacon ID for position determination is performed. When the mobile unit 60A moves into another work area, leaving the current work area, a peak hold value measured next for a beacon signal from the beacon signal generator 103 weakens gradually and eventually becomes beyond -80

dBm; only after then the beacon ID for position determination is updated.

[0042]

In doing this way, update is enabled and position
5 determination with higher accuracy becomes possible even
before the radio field intensity of beacon signals from
another beacon signal generator 101 .. changes definitely
and significantly, if there is no possibility of errors
caused by updating the beacon ID for position
10 determination.

[0043]

A peak hold value in this embodiment is calculated
as a simple average of peak values of multiple radio field
intensities of multiple beacon signals; in another
15 embodiment, it is calculated as a median value of the peak
values of the radio field intensities of multiple beacon
signals or it is calculated as a simple average of the
peak hold values of the radio frequency intensities of
multiple beacon signals remaining with the exception of
20 the maximum and minimum peak values of radio field
intensity. Thereby, the possibility of making an
incorrect position determination can be reduced greatly
even when there is variation in radio field intensity data
that is measured.

25 [0044]

The position detection system of this embodiment can be configured of BLE beacons, each emitting a beacon signal including a beacon ID, communication terminal devices with which workers (mobile units) are equipped, a
5 base station which receives transmission data from the communication terminal devices, and a server and application which receives data from the base station and performs respective processing tasks. The position determination unit 70 is built within the server.

10 [0045]

Then, algorithm of software for use in a communication terminal device in the present embodiment is described with reference to Figure 6. Figure 6 illustrates a process of computational processing for one
15 communication terminal device 20A, 20B .. to update a beacon ID for position determination for use to determine the position of the communication terminal device 20A, 20B .., namely, the positions of mobile units 60A, 60B .. at each given period for determination. This
20 computational processing is performed on each of the multiple communication terminal devices 20A, 20B, etc.

[0046]

In Figure 6, the beacon ID determination and storage unit 40A .. judges whether the terminal device has
25 received a beacon within one period (step S1); if the

terminal device has received a beacon, the beacon ID determination and storage unit calculates an average value of radio field intensities per beacon ID emitted by each beacon signal generator 101 .. with respect to received
5 data that the communication terminal device 20A .. has received within one period at a given period for measurement shorter than the period for determination and records and retains the calculated average value as a radio field intensity in an internal memory of the beacon
10 ID determination and storage unit 40A .. (step S2). As described previously, the average value is a simple average of radio field intensities of signals per ID received at a given period for measurement shorter than the period for determination within the time span of one
15 period.

[0047]

Then, the beacon ID determination and storage unit 40A .. performs computational processing to judge whether, for a beacon signal adopted to determine a beacon ID for
20 position determination, an intensity difference between the previous and current radio field intensities of the beacon signal is at or below a predetermined marginal threshold (step S3), computational processing to judge whether an intensity difference between the radio field
25 intensity of one beacon signal adopted to determine a

beacon ID for position determination and the radio field intensity of another beacon signal is larger than a predetermined threshold of intensity difference (step S4), and computational processing to set a peak hold value
5 range depending on a peak hold value and judge whether a peak hold value measured next falls within the peak hold value range (steps S5, S6). Because these three processing steps are performed as premises for judgment to be made at step S7 and subsequent steps, the respective
10 computational processing steps may be performed in parallel regardless of order of them.

[0048]

First, it is judged whether judgment at step S3 is OK (step S7); if No (the intensity difference exceeds the
15 marginal threshold), the beacon ID for position determination is not updated (step S8) and the beacon ID for position determination at one preceding period is adopted.

[0049]

20 If the judgment at step S7 is Yes, then it is judged whether judgment at step S4 is OK (step S9); if No (the intensity difference is smaller than the threshold of intensity difference), the beacon ID for position determination is not updated (step S8). If the judgment
25 at step S4 is Yes, it is judged whether judgment at step

S6 is OK (step S10). If Yes, the beacon ID for position determination is updated (step S11); if No, the beacon ID for position determination is not updated (step S8).

[0050]

5 Now, as for updating the current position in the position determination unit 70, update is performed by regarding the installation position of any of the beacon signal generators 10A to 10N emitting radio waves with the highest value of radio field intensities measured
10 currently as the current position.

[0051]

 Finally, transmission data for judgment at a next period is recorded, retained, and updated in the beacon ID determination and storage unit 40A .. (step S12) and
15 processing for one period for determination then terminates. In particular, the beacon ID for position determination, the radio field intensity of a beacon signal used for determination, and the peak hold value are updated. Now, in the position determination unit 70, a
20 position storage unit to store the determined current position is incorporated.

[0052]

 As described above, by the position detection method according to the present embodiment, it is possible to
25 increase the accuracy of position determination. The

period for determination (e.g., five seconds) for which the position determination unit determines the position of a mobile unit has a length more than the period for decision (one second). Hence, computational processing of
5 the position determination unit 70 can be reduced even when the number of mobile units has increased and it is possible to respond to an increase in the number of mobile units. It is preferable that the length of the period for determination is adjustable. In doing this way, the
10 computational burden of the position determination unit 70 can be adjusted depending on increase/decrease in the number of mobile units.

[0053]

[Other Embodiments]

15 To promptly detect a displacement of the position of a mobile unit, once the beacon ID determination and storage units 40A to 40N have updated and stored a beacon ID for position determination before the expire of one period for determination, the transmitters 50A to 50B may
20 immediately transmit the updated beacon ID for position determination and the terminal ID to the position determination unit 70.

[0054]

In addition, even in such a case where the
25 transmitters 50A to 50N immediately transmit the updated

beacon ID for position determination and the terminal ID to the position determination unit 70 so that a displacement of the position of a mobile unit can be detected promptly, it is possible to reduce the computational burden of the position determination unit 70. For example, the transmitters 50A to 50N are configured so that, when a request to transmit is issued from the position determination unit 70 to the transmitters 50A to 50N at a period for determination, the transmitters 50A to 50N transmit the latest beacon ID for position determination stored in the beacon ID determination and storage units 40A to 40N to the position determination unit 70. Moreover, the position determination unit 70 is configured not to issue a request to transmit even upon expiry of one period when the updated beacon ID for position determination and the terminal ID have been transmitted to it from the transmitters 50A to 50N before expiry of one period for determination. In doing this way, an unnecessary request to transmit is not issued and, therefore, the burden of the position determination unit 70 can be reduced.

[0055]

In addition, even in such a case where the transmitters 50A to 50N are configured so that, when a request to transmit is issued from the position

determination unit 70 to the transmitters 50A to 50N at a period for determination, the transmitters 50A to 50N transmit the latest beacon ID for position determination stored in the beacon ID determination and storage units 40A to 40N to the position determination unit 70, once the beacon ID determination and storage units 40A to 40N has updated and stored a beacon ID for position determination before expiry of one period for determination, the transmitters 50A to 50N may immediately transmit the updated beacon ID for position determination and the terminal ID to the position determination unit 70 without receiving a request to transmit. In doing this way, even when a period for determination was set long, it is possible to promptly detect a displacement of the position of a mobile unit whenever it occurs.

[0056]

Furthermore, even in the case where the transmitters 50A to 50N are configured so that, when a request to transmit is issued from the position determination unit to the transmitters 50A to 50N at a period for determination, the transmitters 50A to 50N transmit the latest beacon ID for position determination stored in the beacon ID determination and storage units 40A to 40N to the position determination unit 70, only when the beacon ID determination and storage units 40A to 40N have updated

the beacon ID for position determination until expiry of one period for determination, the transmitters 50A to 50N may transmit the updated beacon ID for position determination and the terminal ID to the position determination unit 70 in response to the request to transmit. In doing this way, unless the beacon ID for position determination is updated, the communication terminal devices 20A to 20N do not transmit; therefore, the life span of the communication terminal devices 20A to 20N can be lengthened.

[0057]

Even in the case where the transmitters 50A to 50N are configured so that, when a request to transmit is issued from the position determination unit to the transmitters 50A to 50N at a period for determination, the transmitters 50A to 50N transmit the latest beacon ID for position determination stored in the beacon ID determination and storage units 40A to 40N to the position determination unit 70, only when a beacon ID for position determination transmitted by the transmitters 50A to 50N in response to the previous request to transmit differs from a beacon ID for position determination stored in the beacon ID determination and storage units 40A to 40B upon receiving the current request to transmit, the transmitters 50A to 50N may transmit the beacon ID for

position determination that differs from the one
transmitted previously and the terminal ID to the position
determination unit 70. This manner is based on a thought
such that, even when the beacon ID for position
5 determination has been updated for one period for
determination, if it is the same as the previously
transmitted beacon ID for position determination at the
time of receiving a request to transmit, it is not
necessary to transmit the beacon ID changed for one period
10 for determination. In doing this way also, the burden of
the position determination unit 70 can be reduced and the
burden of the communication terminal devices 20A to 20N
can be reduced.

Industrial Applicability

15 [0058]

According to the position detection system of the
present invention, it is possible to increase the accuracy
of position determination by avoiding incorrect position
determinations as much as possible.

20 Reference Signs List

[0059]

101 to 10N beacon signal generator

20A to 20N communication terminal device

30A to 30N beacon ID determination unit

25 40A to 40N beacon ID determination and storage unit

50A to 50N transmitter

60A, 60B mobile unit

70 position determination unit

{CLAIMS}

1. A position detection system comprising:
 - multiple beacon signal generators which are
 - 5 installed respectively in multiple predetermined
 - installation positions within moving regions where one or
 - more mobile units move and generate beacon signals, each
 - including a beacon ID;
 - one or more communication terminal devices which are
 - 10 attached to the one or more mobile units and receive one
 - or more of the beacon signals, each terminal device
 - including a beacon ID determination and storage unit which
 - decides on a beacon signal for position determination at a
 - given period for decision from radio field intensities of
 - 15 one or more of the beacon signals received and determines
 - and stores the beacon ID of one of the beacon signal
 - generators emitting that beacon signal for position
 - determination as a beacon ID for position determination
 - and a transmitter which transmits information for position
 - 20 determination including the beacon ID for position
 - determination and a terminal ID to identify the terminal
 - device itself; and
 - a position determination unit which determines the
 - position of each of the one or more mobile units within
 - 25 the moving regions at a given period for determination,

based on the beacon ID for position determination decided
by each of the one or more communication terminal devices
and the terminal ID, and information on the multiple
predetermined installation positions within the moving
5 regions,

wherein the beacon ID determination and storage unit
in each of the communication terminal devices does not
update the beacon ID for position determination, until an
intensity difference between the previous and current
10 radio field intensities of the beacon signal for position
determination decided at the given period for decision
becomes at or below a predetermined marginal threshold.

2. The position detection system according to claim 1,
15 wherein the marginal threshold is fixed so that the
intensity difference does not become at or below the
marginal threshold within a boundary region where the
output ranges of two or more of the beacon signal
generators overlap.

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3. The position detection system according to claim 1,
wherein the beacon ID determination and storage unit
determines the previous and current radio field
intensities based on an average value of radio field
25 intensities of the multiple beacon signals received at a

given period for measurement shorter than the period for decision within the time span of one period of the period for decision.

5 4. The position detection system according to claim 3,
wherein the average value is calculated as a simple
average of multiple radio field intensities of the
multiple beacon signals, calculated as a median value of
radio field intensities of the multiple beacon signals, or
10 calculated as a simple average of radio frequency
intensities of the multiple beacon signals remaining with
the exception of the maximum and minimum values of radio
field intensity.

15 5. The position detection system according to claim 1,
wherein, when an intensity difference between the radio
field intensity of the beacon signal for position
determination and the radio field intensity of another one
of the beacon signals becomes larger than a predetermined
20 threshold of intensity difference, the beacon ID
determination and storage unit regards the beacon ID of
the other one of the beacon signal generators for which
the intensity difference has become larger than the
threshold of intensity difference as the beacon ID for
25 position determination and updates the beacon ID.

6. The position detection system according to claim 1, wherein the period for determination has a length more than the period for decision.

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7. The position detection system according to claim 6, wherein a length of the period for determination is adjustable.

10 8. The position detection system according to claim 5, wherein, once the beacon ID determination and storage unit has updated and stored the beacon ID for position determination, the transmitter immediately transmits the updated beacon ID for position determination and the
15 terminal ID to the position determination unit.

9. The position detection system according to claim 8, wherein the transmitter is configured so that, when a request to transmit is issued from the position
20 determination unit to the transmitter at the period for determination, the transmitter transmits the latest beacon ID for position determination stored in the beacon ID determination and storage unit to the position determination unit; and
25 the position determination unit is configured not to

issue a request to transmit even upon expiry of one period,
when the updated beacon ID for position determination and
the terminal ID have been transmitted to it from the
transmitter before expiry of the one period of the period
5 for determination.

10. The position detection system according to claim 6,
wherein the transmitter is configured so that, when
a request to transmit is issued from the position
10 determination unit to the transmitter at the period for
determination, the transmitter transmits the latest beacon
ID for position determination stored in the beacon ID
determination and storage unit to the position
determination unit; and
15 once the beacon ID determination and storage unit
has updated and stored the beacon ID for position
determination before expiry of one period of the period
for determination, the transmitter immediately transmits
the updated beacon ID for position determination and the
20 terminal ID to the position determination unit without
receiving the request to transmit.

11. The position detection system according to claim 6,
wherein the transmitter is configured so that, when
25 a request to transmit is issued from the position

determination unit to the transmitter at the period for determination, the transmitter transmits the latest beacon ID for position determination stored in the beacon ID determination and storage unit to the position

5 determination unit; and

only when the beacon ID determination and storage unit has updated the beacon ID for position determination until expiry of one period of the period for determination, the transmitter transmits the updated beacon ID for

10 position determination and the terminal ID to the position determination unit in response to the request to transmit.

12. The position detection system according to claim 6,
wherein the transmitter is configured so that, when

15 a request to transmit is issued from the position determination unit to the transmitter at the period for determination, the transmitter transmits the latest beacon ID for position determination stored in the beacon ID determination and storage unit to the position

20 determination unit; and

only when the beacon ID for position determination transmitted by the transmitter in response to the previous request to transmit differs from the beacon ID for position determination stored in the beacon ID

25 determination and storage unit upon receiving the current

request to transmit, the transmitter transmits the beacon ID for position determination that differs from the one transmitted previously and the terminal ID to the position determination unit.

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13. The position detection system according to claim 3, wherein, when the intensity difference between the radio field intensities of the beacon signal for position determination adopted to determine the beacon ID for position determination becomes at or below the marginal threshold and the intensity difference between the radio field intensity of the beacon signal for position determination adopted to determine the beacon ID for position determination and the radio field intensity of another one of the beacon signals is larger than a predetermined threshold of intensity difference, with regard to a peak hold value of radio field intensity of the beacon signal for position determination, adopted to determine the beacon ID for position determination, the beacon ID determination and storage unit decides on what is any of multiple predetermined peak hold value ranges in which the peak hold value falls and, when a peak hold value measured next falls in the peak hold value range in which the peak hold value falls, the beacon ID determination and storage unit does not update the beacon

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ID for position determination, or when the peak hold value measured next is beyond the peak hold value range, the beacon ID determination and storage unit regards the beacon ID of a beacon signal with the largest radio field intensity out of the one or more beacon signals being received at that point of time as the beacon signal for position determination.

14. The position detection system according to claim 13, wherein, the peak hold value is calculated as a simple average of peak values of multiple radio field intensities of the multiple beacon signals, calculated as a median value of peak values of radio field intensities of the multiple beacon signals, or calculated as a simple average of peak hold values of radio field intensities of the multiple beacon signals remaining with the exception of the maximum and minimum peak values of radio field intensity.