US012395963B2

(12) **United States Patent**
Shimura et al.

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(45) **Date of Patent: Aug. 19, 2025**

(54) **COMMUNICATION APPARATUS, INFORMATION PROCESSING APPARATUS, AND POSITION INFORMATION MANAGEMENT METHOD**

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(73) Assignee: **Canon Kabushiki Kaisha**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 175 days.

(21) Appl. No.: **17/929,653**

(22) Filed: **Sep. 2, 2022**

(65) **Prior Publication Data**

US 2022/0417895 A1 Dec. 29, 2022

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2021/008032, filed on Mar. 3, 2021.

(30) **Foreign Application Priority Data**

Mar. 4, 2020 (JP) 2020-037063

(51) **Int. Cl.**
H04W 64/00 (2009.01)
G06K 7/10 (2006.01)
G06K 19/07 (2006.01)

(52) **U.S. Cl.**
CPC ***H04W 64/003*** (2013.01); *G06K 7/10297* (2013.01); *G06K 19/0723* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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Primary Examiner — Adolf Dsouza
(74) *Attorney, Agent, or Firm* — Canon U.S.A., Inc. IP Division

(57) **ABSTRACT**

A communication apparatus detects a wireless device and calculates a relative position of the detected wireless device with respect to a reference wireless device to be a reference in identifying a position based on a movement amount of the communication apparatus from when the reference wireless device is detected by the communication apparatus. The communication apparatus associates the calculated relative position, identification information about the detected wireless device, and identification information about the reference wireless device.

16 Claims, 19 Drawing Sheets

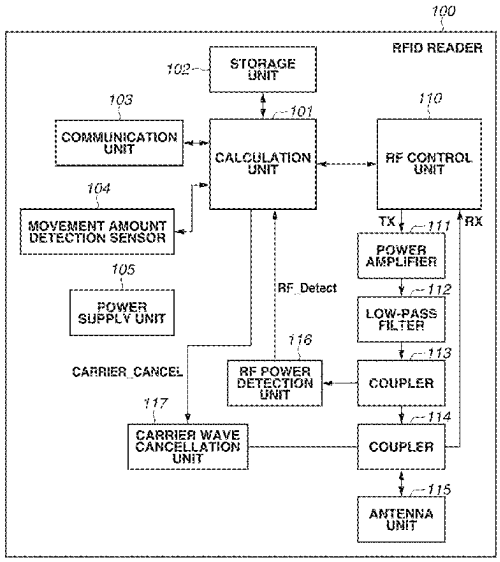

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FIG.1

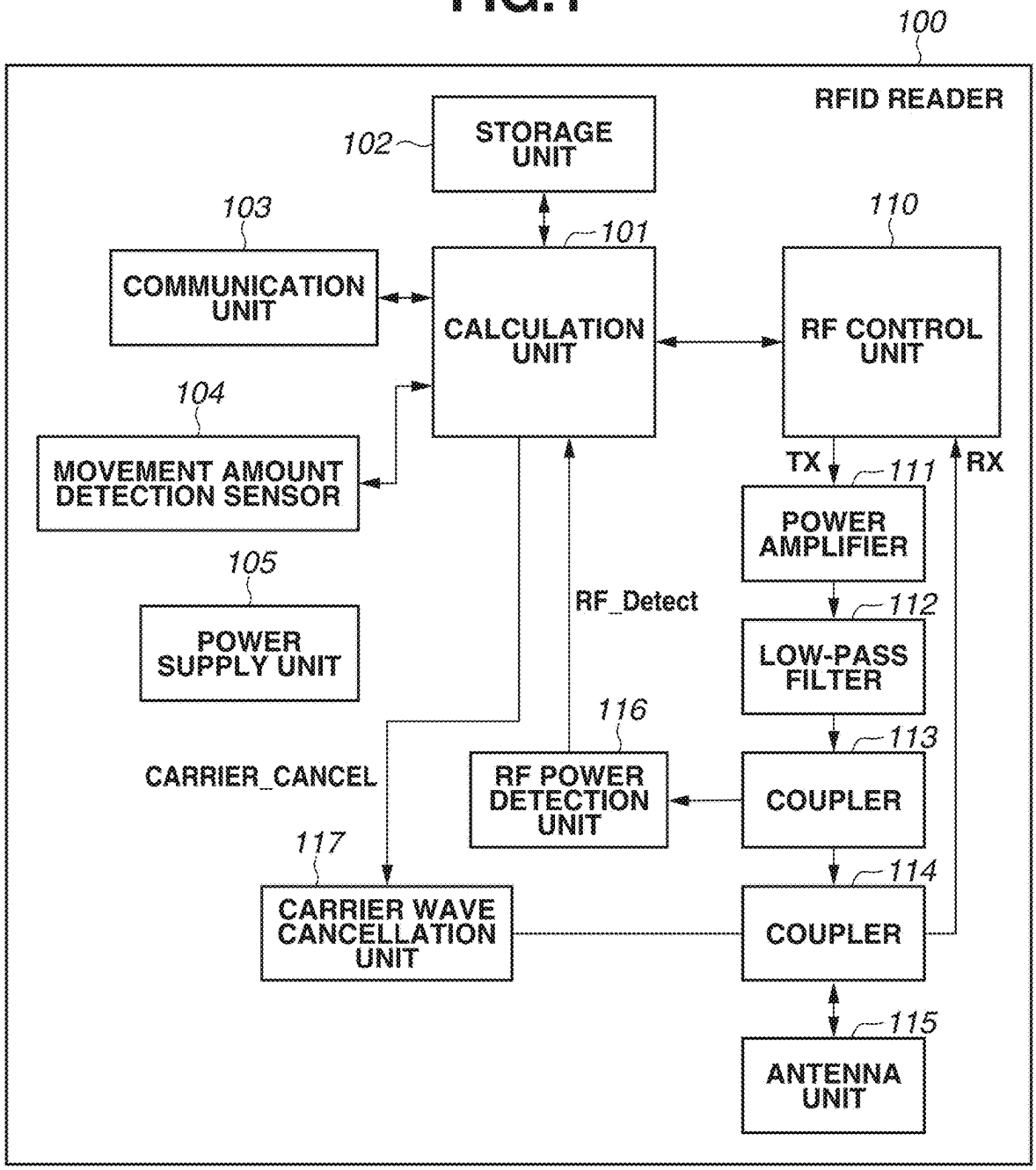

100
RFID READER
102
STORAGE UNIT
103
COMMUNICATION UNIT
101
CALCULATION UNIT
110
RF CONTROL UNIT
104
MOVEMENT AMOUNT DETECTION SENSOR
105
POWER SUPPLY UNIT
TX
111
RX
POWER AMPLIFIER
RF_Detect
112
LOW-PASS FILTER
116
113
CARRIER_CANCEL
RF POWER DETECTION UNIT
COUPLER
117
114
CARRIER WAVE CANCELLATION UNIT
COUPLER
115
ANTENNA UNIT

FIG.2A

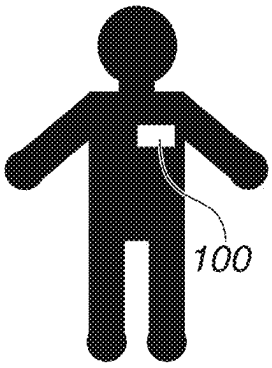


FIG.2B

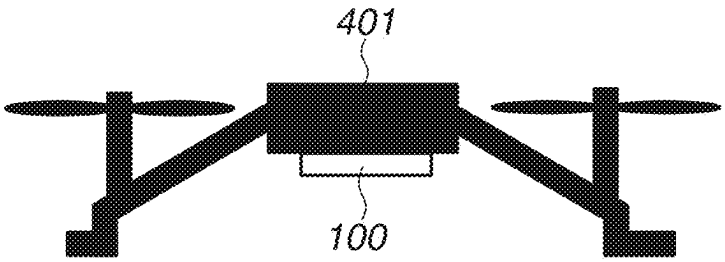


FIG.2C

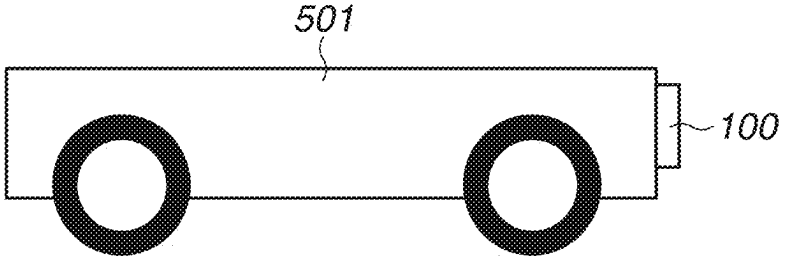


FIG.3

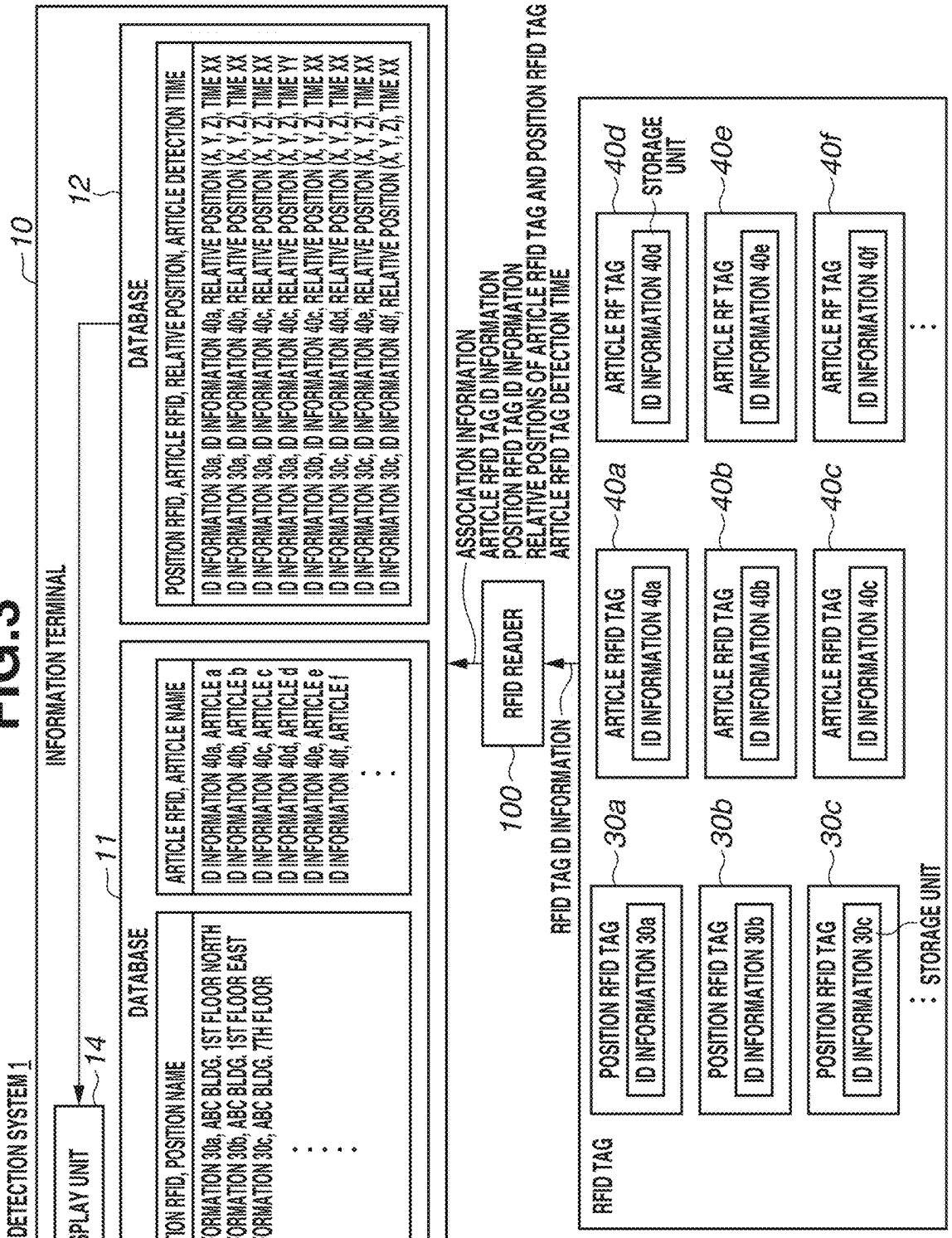

POSITION DETECTION SYSTEM 1
10
INFORMATION TERMINAL
DISPLAY UNIT
14
11
DATABASE
POSITION RFID, POSITION NAME
ID INFORMATION 30a, ABC BLDG. 1ST FLOOR NORTH
ID INFORMATION 30b, ABC BLDG. 1ST FLOOR EAST
ID INFORMATION 30c, ABC BLDG. 7TH FLOOR
ARTICLE RFID, ARTICLE NAME
ID INFORMATION 40a, ARTICLE a
ID INFORMATION 40b, ARTICLE b
ID INFORMATION 40c, ARTICLE c
ID INFORMATION 40d, ARTICLE d
ID INFORMATION 40e, ARTICLE e
ID INFORMATION 40f, ARTICLE f
12
DATABASE
POSITION RFID, ARTICLE RFID, RELATIVE POSITION, ARTICLE DETECTION TIME
ID INFORMATION 30a, ID INFORMATION 40a, RELATIVE POSITION (X, Y, Z), TIME XX
ID INFORMATION 30a, ID INFORMATION 40b, RELATIVE POSITION (X, Y, Z), TIME XX
ID INFORMATION 30a, ID INFORMATION 40c, RELATIVE POSITION (X, Y, Z), TIME XX
ID INFORMATION 30a, ID INFORMATION 40c, RELATIVE POSITION (X, Y, Z), TIME YY
ID INFORMATION 30b, ID INFORMATION 40c, RELATIVE POSITION (X, Y, Z), TIME XX
ID INFORMATION 30c, ID INFORMATION 40d, RELATIVE POSITION (X, Y, Z), TIME XX
ID INFORMATION 30c, ID INFORMATION 40e, RELATIVE POSITION (X, Y, Z), TIME XX
ID INFORMATION 40f, RELATIVE POSITION (X, Y, Z), TIME XX
100
RFID READER
ASSOCIATION INFORMATION
ARTICLE RFID TAG ID INFORMATION
POSITION RFID TAG ID INFORMATION
RELATIVE POSITIONS OF ARTICLE RFID TAG AND POSITION RFID TAG
ARTICLE RFID TAG DETECTION TIME
RFID TAG ID INFORMATION
RFID TAG
POSITION RFID TAG
ID INFORMATION 30a
30a
POSITION RFID TAG
ID INFORMATION 30b
30b
POSITION RFID TAG
ID INFORMATION 30c
30c
: STORAGE UNIT
ARTICLE RFID TAG
ID INFORMATION 40a
40a
ARTICLE RFID TAG
ID INFORMATION 40b
40b
ARTICLE RFID TAG
ID INFORMATION 40c
40c
ARTICLE RF TAG
ID INFORMATION 40d
40d
STORAGE UNIT
ARTICLE RF TAG
ID INFORMATION 40e
40e
ARTICLE RF TAG
ID INFORMATION 40f
40f

FIG.4

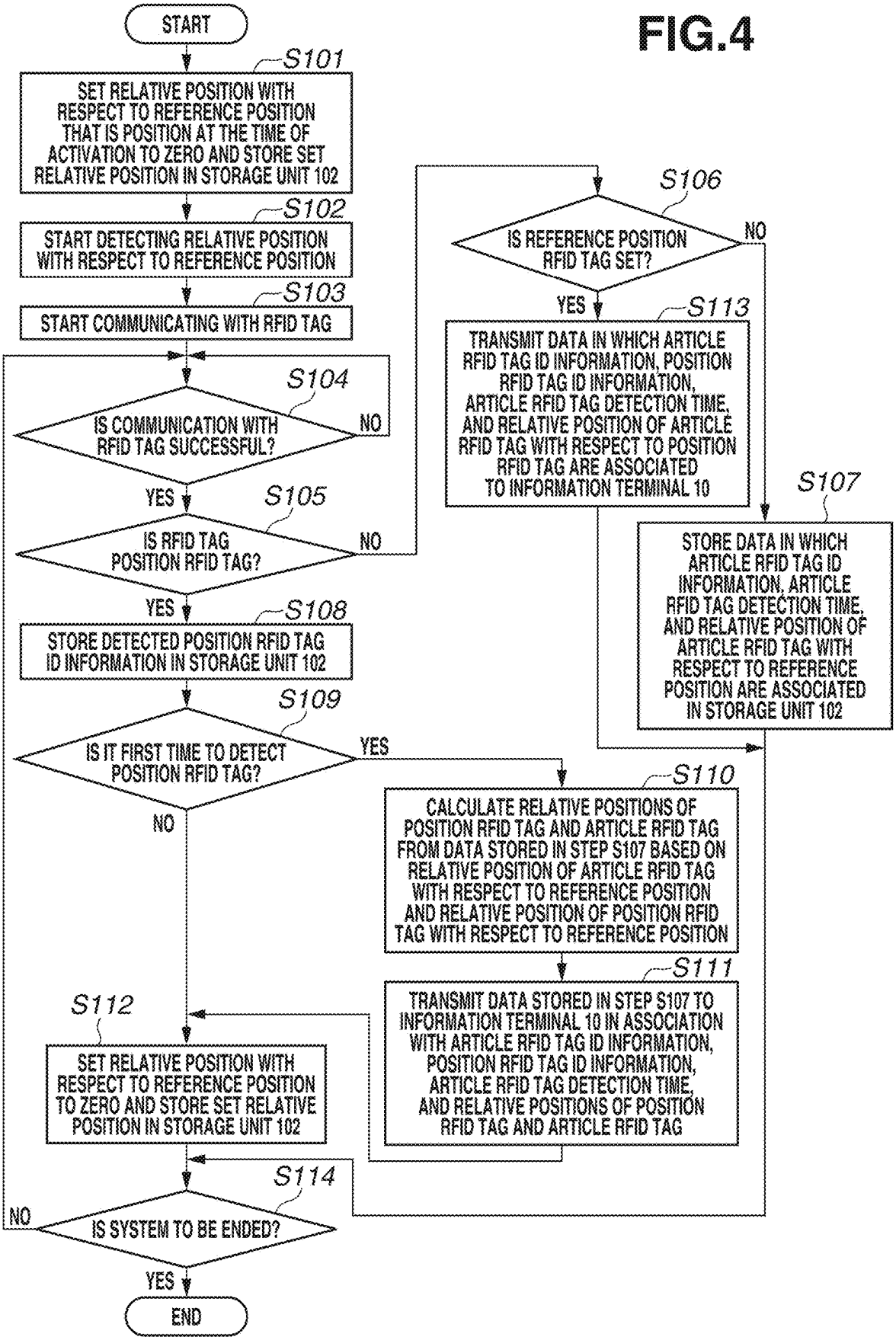

START
S101
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION THAT IS POSITION AT THE TIME OF ACTIVATION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
S102
START DETECTING RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION
S103
START COMMUNICATING WITH RFID TAG
S104
IS COMMUNICATION WITH RFID TAG SUCCESSFUL?
NO
YES
S105
IS RFID TAG POSITION RFID TAG?
NO
YES
S108
STORE DETECTED POSITION RFID TAG ID INFORMATION IN STORAGE UNIT 102
S109
IS IT FIRST TIME TO DETECT POSITION RFID TAG?
YES
NO
S106
IS REFERENCE POSITION RFID TAG SET?
NO
YES
S113
TRANSMIT DATA IN WHICH ARTICLE RFID TAG ID INFORMATION, POSITION RFID TAG ID INFORMATION, ARTICLE RFID TAG DETECTION TIME, AND RELATIVE POSITION OF ARTICLE RFID TAG WITH RESPECT TO POSITION RFID TAG ARE ASSOCIATED TO INFORMATION TERMINAL 10
S107
STORE DATA IN WHICH ARTICLE RFID TAG ID INFORMATION, ARTICLE RFID TAG DETECTION TIME, AND RELATIVE POSITION OF ARTICLE RFID TAG WITH RESPECT TO REFERENCE POSITION ARE ASSOCIATED IN STORAGE UNIT 102
S110
CALCULATE RELATIVE POSITIONS OF POSITION RFID TAG AND ARTICLE RFID TAG FROM DATA STORED IN STEP S107 BASED ON RELATIVE POSITION OF ARTICLE RFID TAG WITH RESPECT TO REFERENCE POSITION AND RELATIVE POSITION OF POSITION RFID TAG WITH RESPECT TO REFERENCE POSITION
S111
TRANSMIT DATA STORED IN STEP S107 TO INFORMATION TERMINAL 10 IN ASSOCIATION WITH ARTICLE RFID TAG ID INFORMATION, POSITION RFID TAG ID INFORMATION, ARTICLE RFID TAG DETECTION TIME, AND RELATIVE POSITIONS OF POSITION RFID TAG AND ARTICLE RFID TAG
S112
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
S114
NO
IS SYSTEM TO BE ENDED?
YES
END

FIG.5A

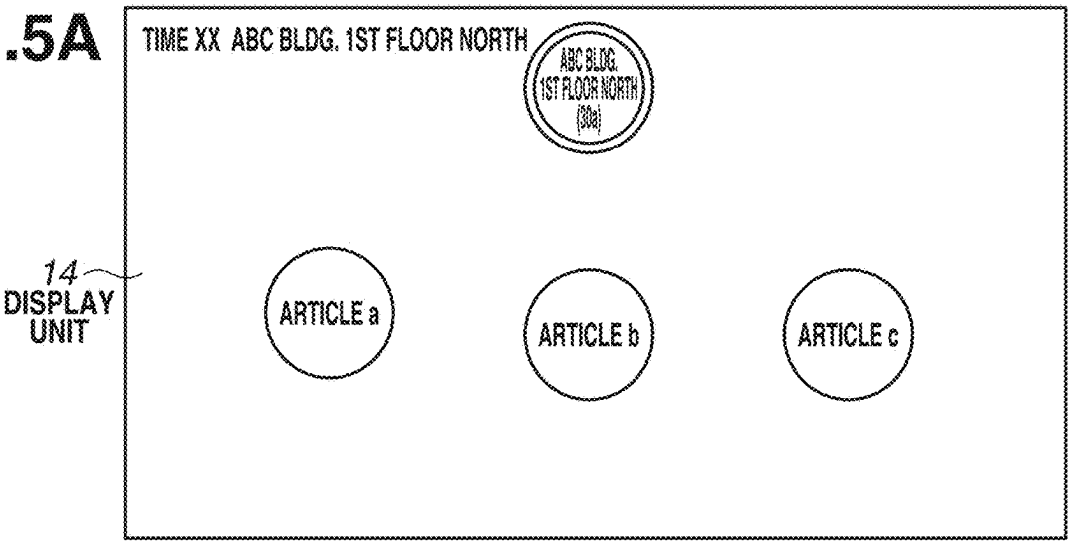


FIG.5B

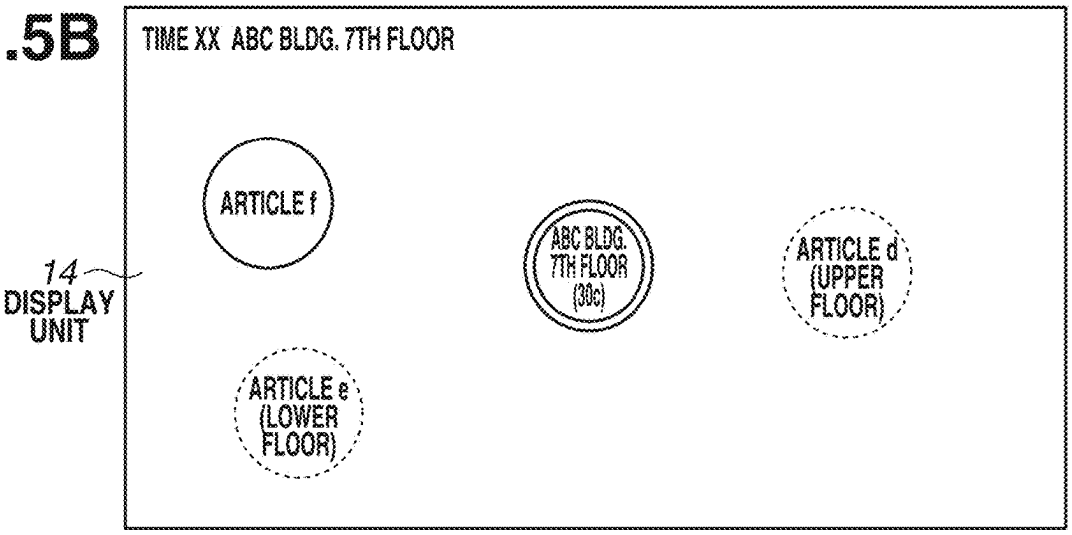


FIG.5C

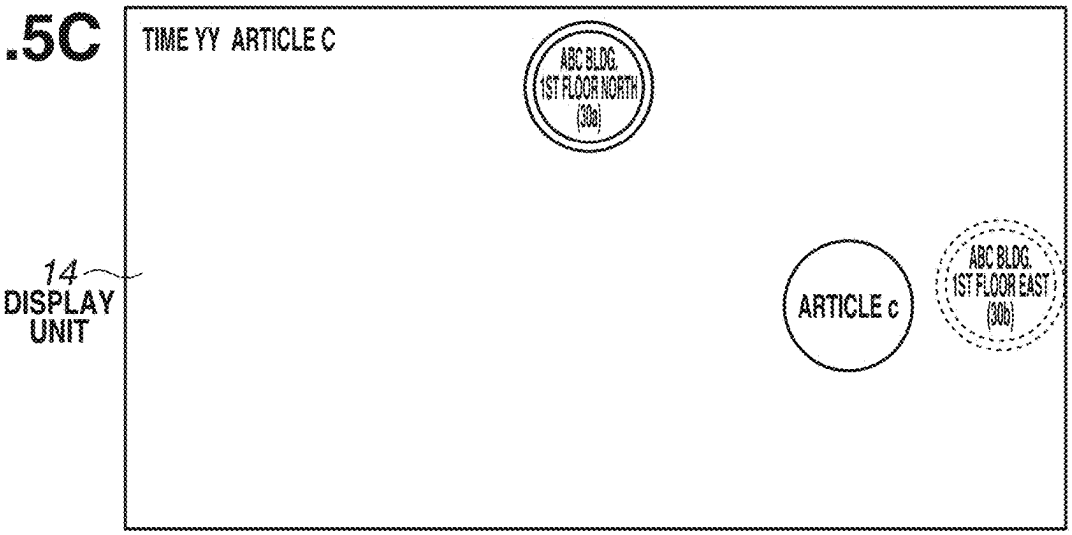


FIG.6

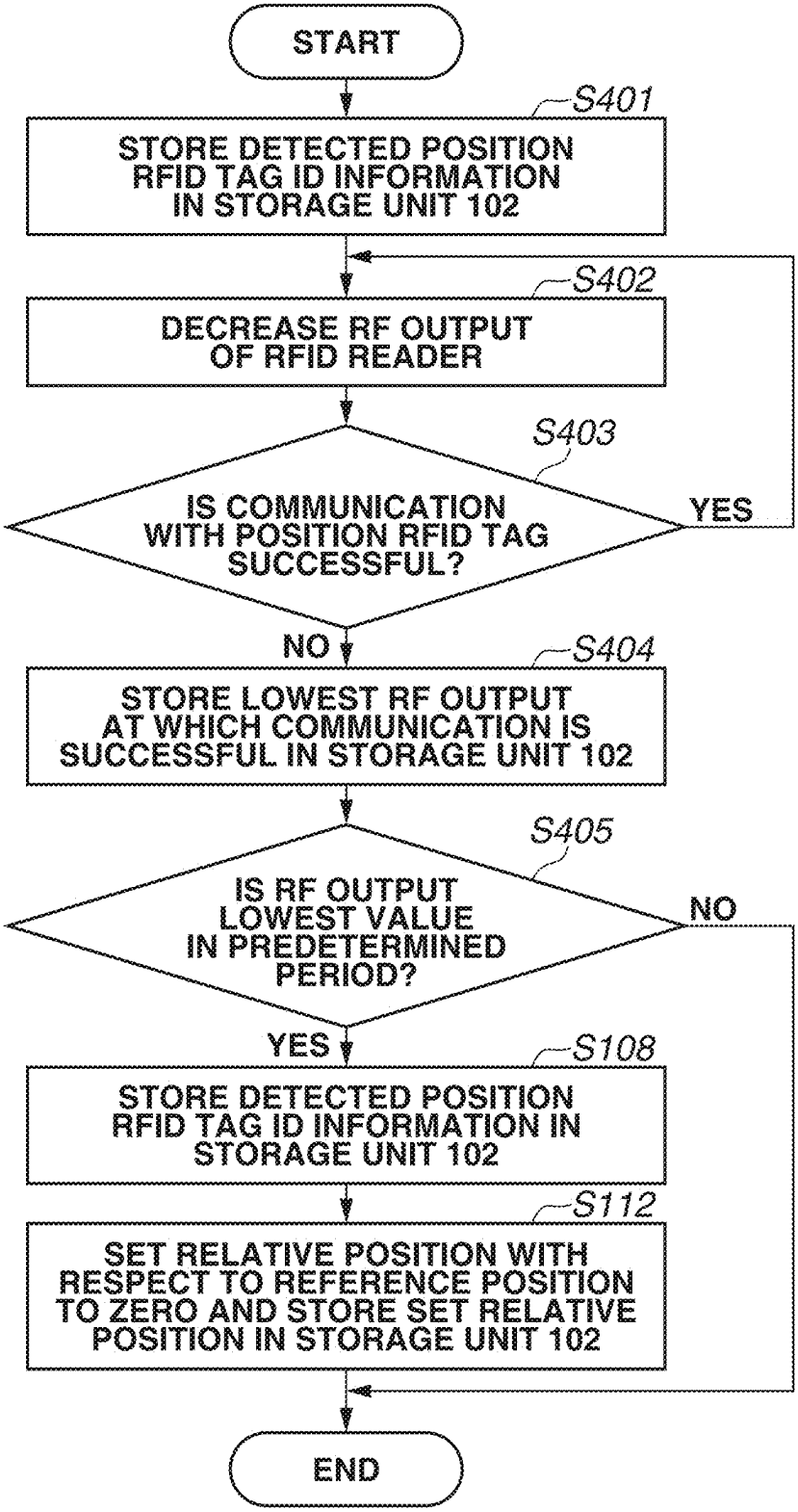

START
S401
STORE DETECTED POSITION RFID TAG ID INFORMATION IN STORAGE UNIT 102
S402
DECREASE RF OUTPUT OF RFID READER
S403
IS COMMUNICATION WITH POSITION RFID TAG SUCCESSFUL?
YES
NO
S404
STORE LOWEST RF OUTPUT AT WHICH COMMUNICATION IS SUCCESSFUL IN STORAGE UNIT 102
S405
IS RF OUTPUT LOWEST VALUE IN PREDETERMINED PERIOD?
NO
YES
S108
STORE DETECTED POSITION RFID TAG ID INFORMATION IN STORAGE UNIT 102
S112
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
END

FIG.7

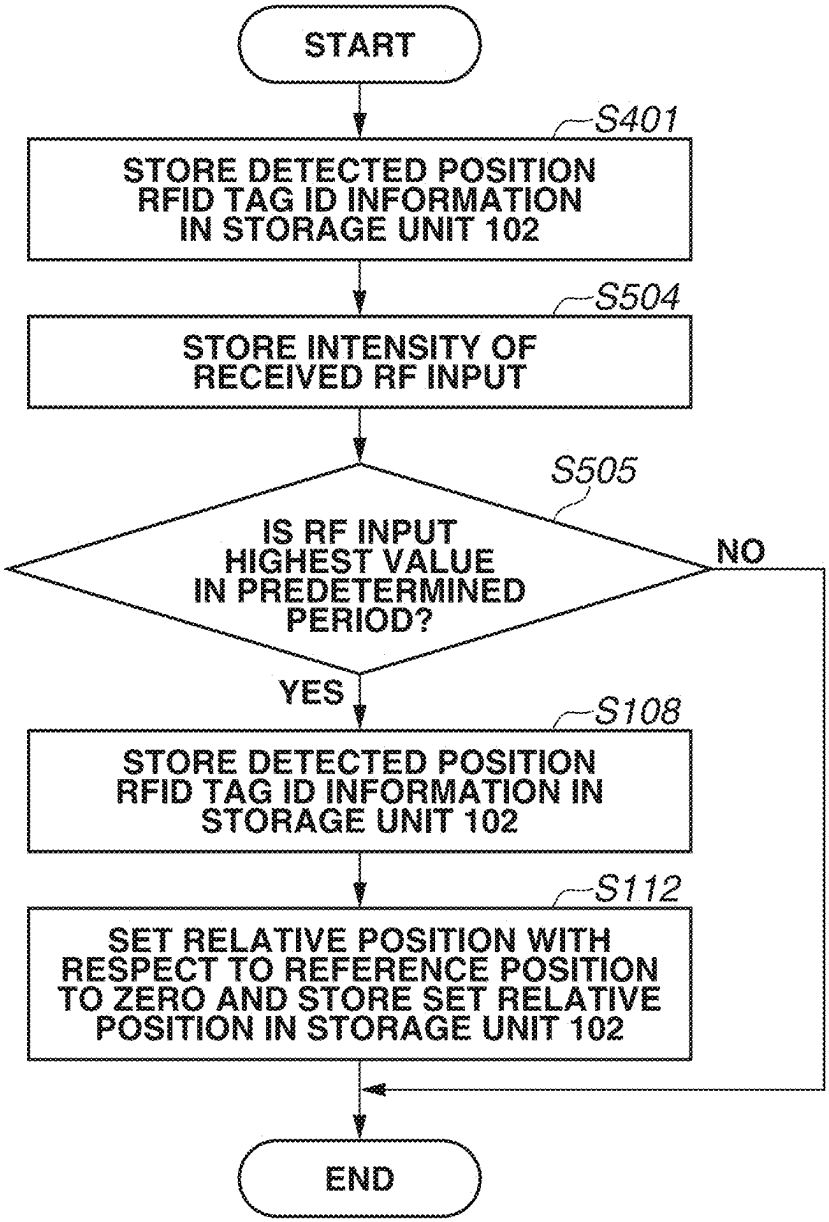

START
S401
STORE DETECTED POSITION RFID TAG ID INFORMATION IN STORAGE UNIT 102
S504
STORE INTENSITY OF RECEIVED RF INPUT
S505
IS RF INPUT HIGHEST VALUE IN PREDETERMINED PERIOD?
NO
YES
S108
STORE DETECTED POSITION RFID TAG ID INFORMATION IN STORAGE UNIT 102
S112
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
END

FIG.8

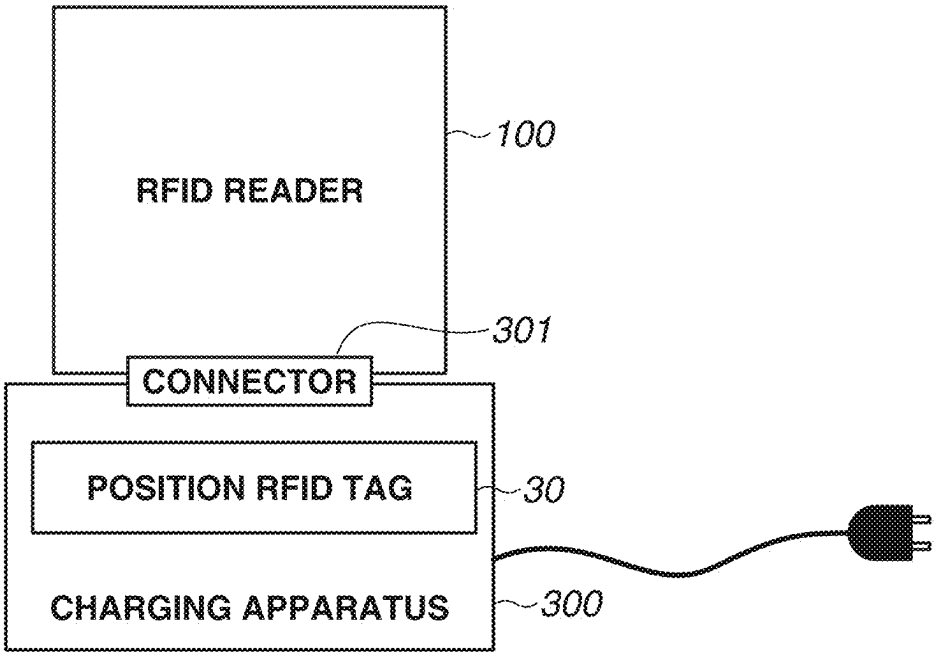

RFID READER
100
301
CONNECTOR
POSITION RFID TAG
30
CHARGING APPARATUS
300

FIG.9A

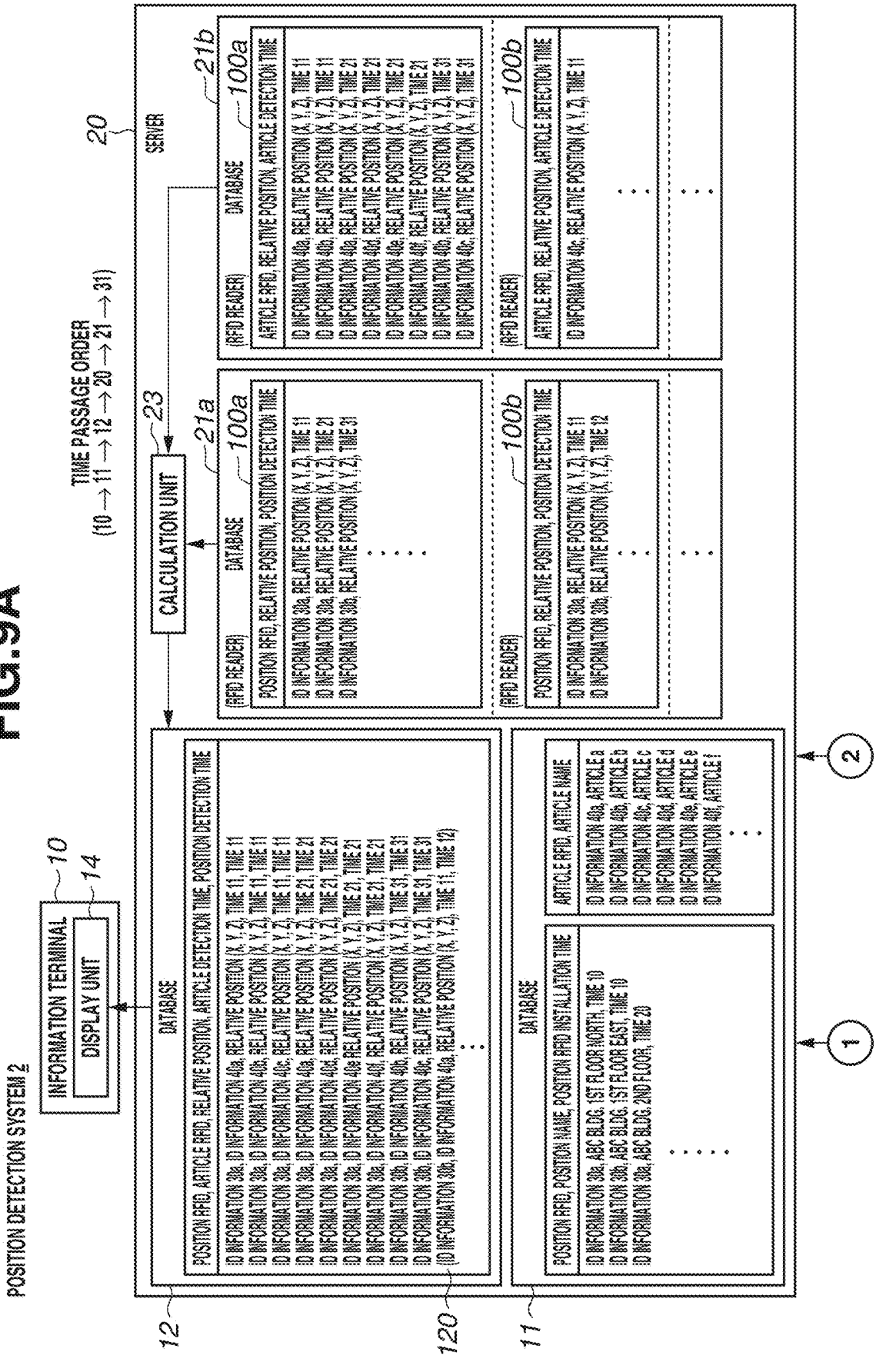

POSITION DETECTION SYSTEM 2
INFORMATION TERMINAL
10
DISPLAY UNIT
14
SERVER
20
TIME PASSAGE ORDER
(10 → 11 → 12 → 20 → 21 → 31)
CALCULATION UNIT
23
DATABASE
21a
21b
(RFID READER)
POSITION RFID, RELATIVE POSITION, POSITION DETECTION TIME
ARTICLE RFID, RELATIVE POSITION, ARTICLE DETECTION TIME
100a
100b
12
120
11
1
2

FIG.9B

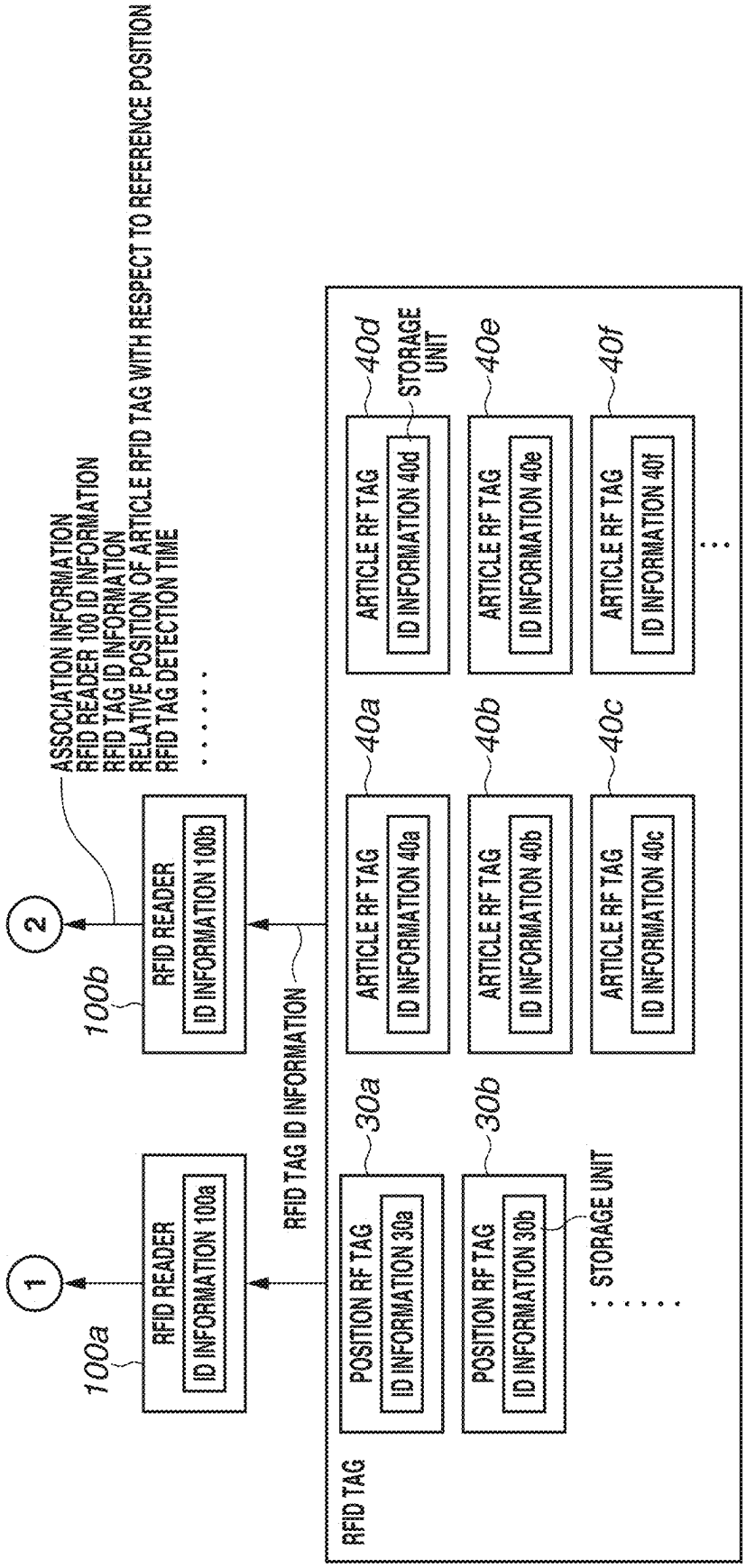

ASSOCIATION INFORMATION
RFID READER 100 ID INFORMATION
RFID TAG ID INFORMATION
RELATIVE POSITION OF ARTICLE RFID TAG WITH RESPECT TO REFERENCE POSITION
RFID TAG DETECTION TIME
. . . . . .
2
100b
RFID READER
ID INFORMATION 100b
RFID TAG ID INFORMATION
1
100a
RFID READER
ID INFORMATION 100a
RFID TAG
POSITION RF TAG
ID INFORMATION 30a
30a
POSITION RF TAG
ID INFORMATION 30b
30b
: STORAGE UNIT
ARTICLE RF TAG
ID INFORMATION 40a
40a
ARTICLE RF TAG
ID INFORMATION 40b
40b
ARTICLE RF TAG
ID INFORMATION 40c
40c
ARTICLE RF TAG
ID INFORMATION 40d
40d
STORAGE UNIT
ARTICLE RF TAG
ID INFORMATION 40e
40e
ARTICLE RF TAG
ID INFORMATION 40f
40f

FIG.10

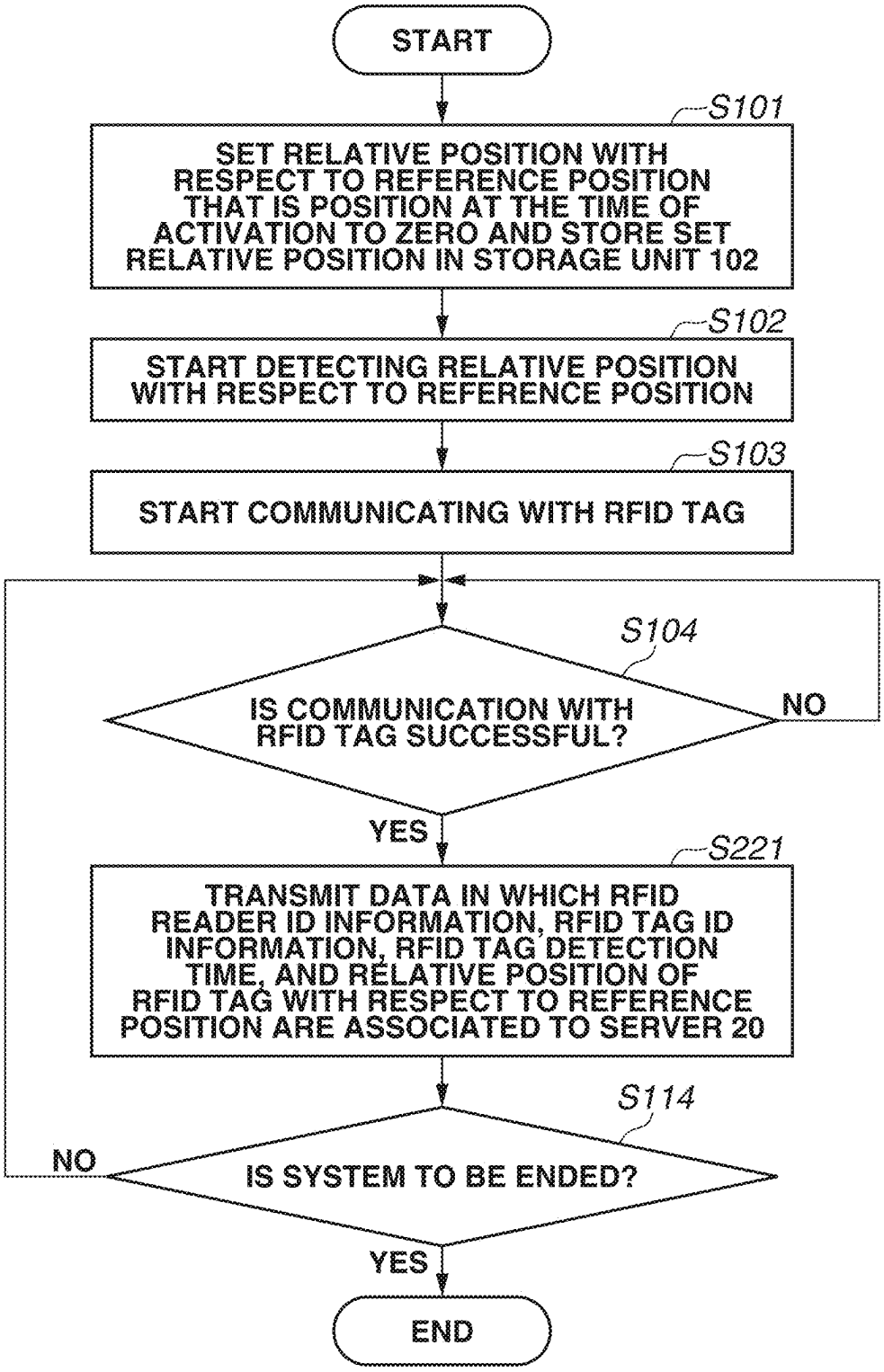

START
S101
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION THAT IS POSITION AT THE TIME OF ACTIVATION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
S102
START DETECTING RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION
S103
START COMMUNICATING WITH RFID TAG
S104
IS COMMUNICATION WITH RFID TAG SUCCESSFUL?
NO
YES
S221
TRANSMIT DATA IN WHICH RFID READER ID INFORMATION, RFID TAG ID INFORMATION, RFID TAG DETECTION TIME, AND RELATIVE POSITION OF RFID TAG WITH RESPECT TO REFERENCE POSITION ARE ASSOCIATED TO SERVER 20
S114
IS SYSTEM TO BE ENDED?
NO
YES
END

FIG.11

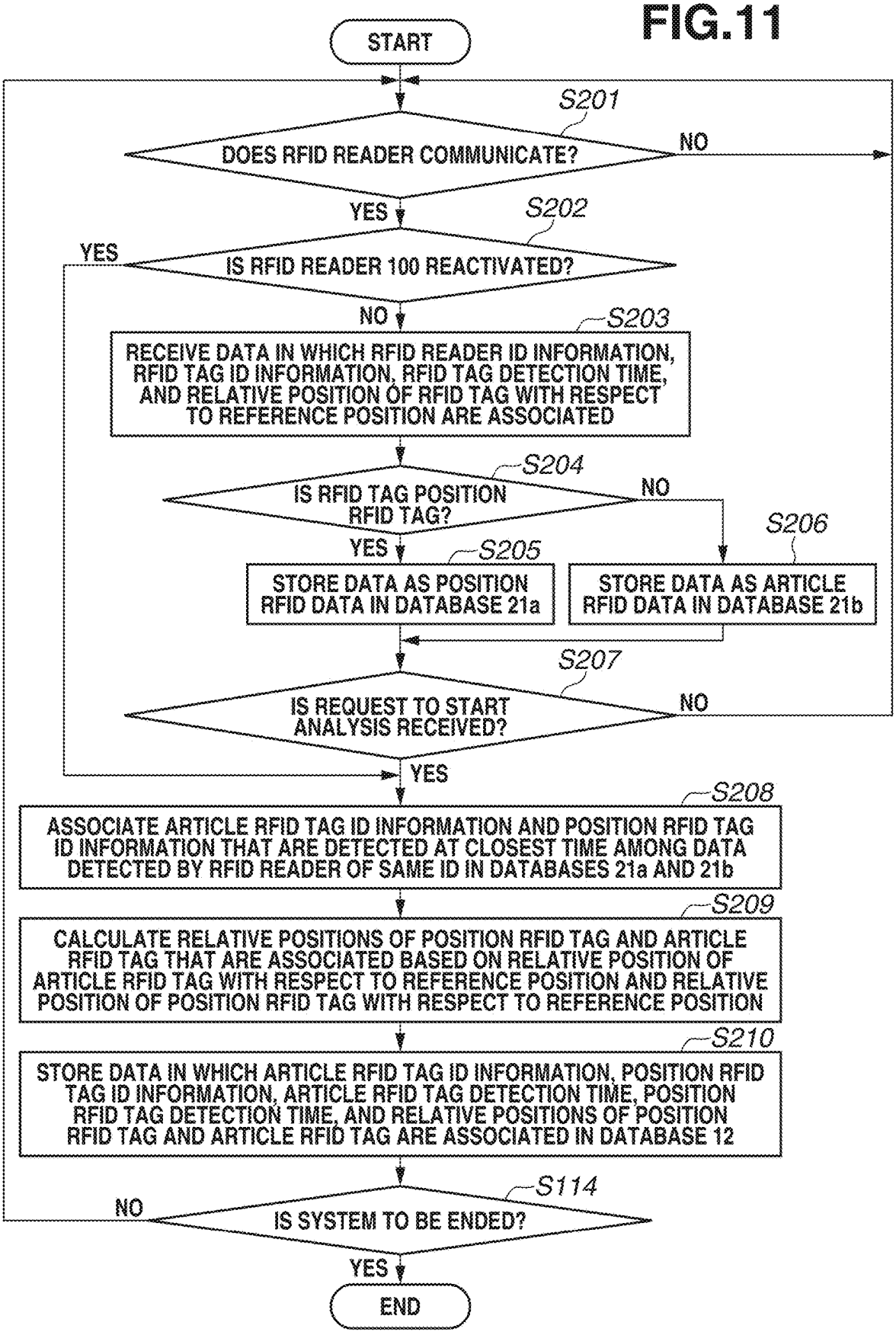

START
S201
DOES RFID READER COMMUNICATE?
NO
YES
S202
IS RFID READER 100 REACTIVATED?
YES
NO
S203
RECEIVE DATA IN WHICH RFID READER ID INFORMATION, RFID TAG ID INFORMATION, RFID TAG DETECTION TIME, AND RELATIVE POSITION OF RFID TAG WITH RESPECT TO REFERENCE POSITION ARE ASSOCIATED
S204
IS RFID TAG POSITION RFID TAG?
NO
YES
S205
STORE DATA AS POSITION RFID DATA IN DATABASE 21a
S206
STORE DATA AS ARTICLE RFID DATA IN DATABASE 21b
S207
IS REQUEST TO START ANALYSIS RECEIVED?
NO
YES
S208
ASSOCIATE ARTICLE RFID TAG ID INFORMATION AND POSITION RFID TAG ID INFORMATION THAT ARE DETECTED AT CLOSEST TIME AMONG DATA DETECTED BY RFID READER OF SAME ID IN DATABASES 21a AND 21b
S209
CALCULATE RELATIVE POSITIONS OF POSITION RFID TAG AND ARTICLE RFID TAG THAT ARE ASSOCIATED BASED ON RELATIVE POSITION OF ARTICLE RFID TAG WITH RESPECT TO REFERENCE POSITION AND RELATIVE POSITION OF POSITION RFID TAG WITH RESPECT TO REFERENCE POSITION
S210
STORE DATA IN WHICH ARTICLE RFID TAG ID INFORMATION, POSITION RFID TAG ID INFORMATION, ARTICLE RFID TAG DETECTION TIME, POSITION RFID TAG DETECTION TIME, AND RELATIVE POSITIONS OF POSITION RFID TAG AND ARTICLE RFID TAG ARE ASSOCIATED IN DATABASE 12
S114
NO
IS SYSTEM TO BE ENDED?
YES
END

FIG.12A

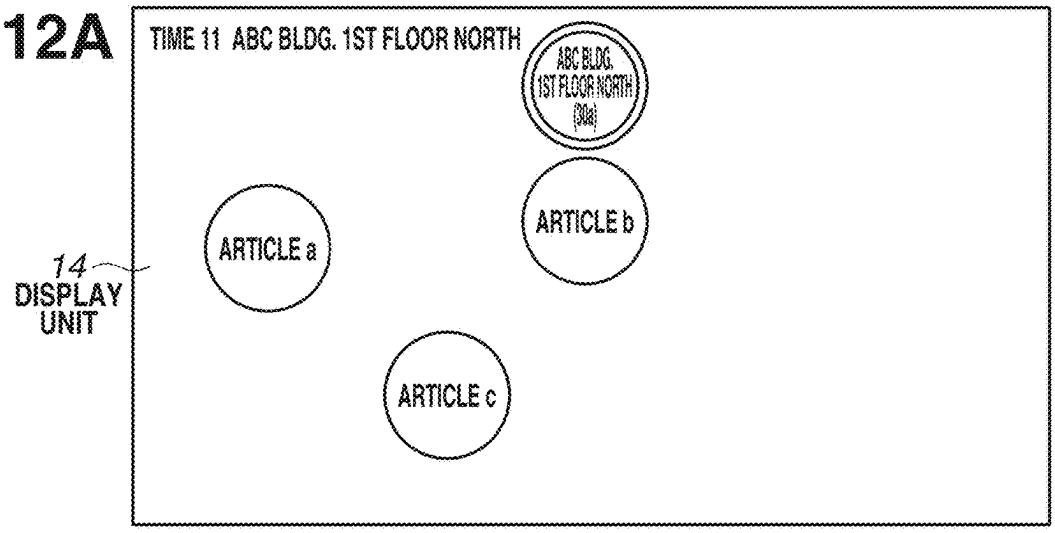


FIG.12B

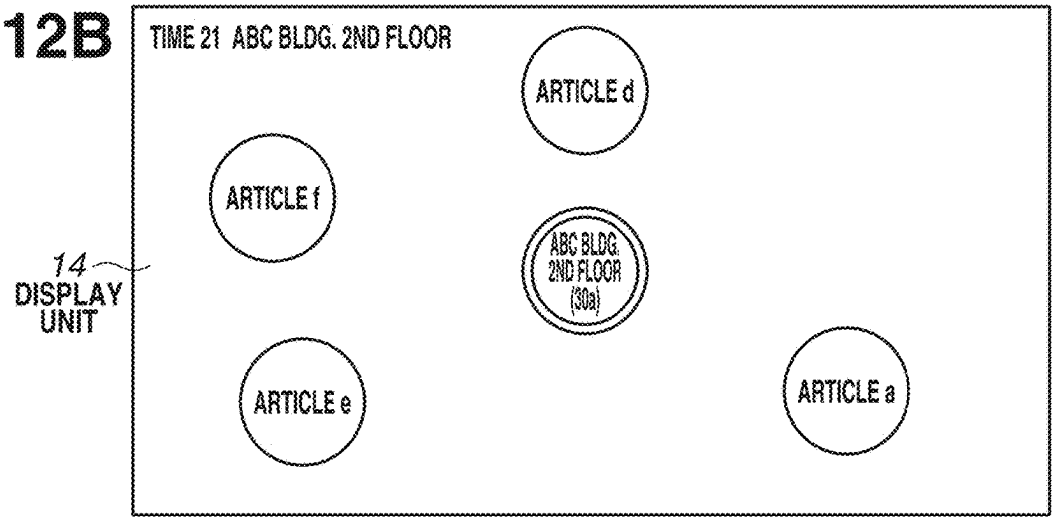


FIG.12C

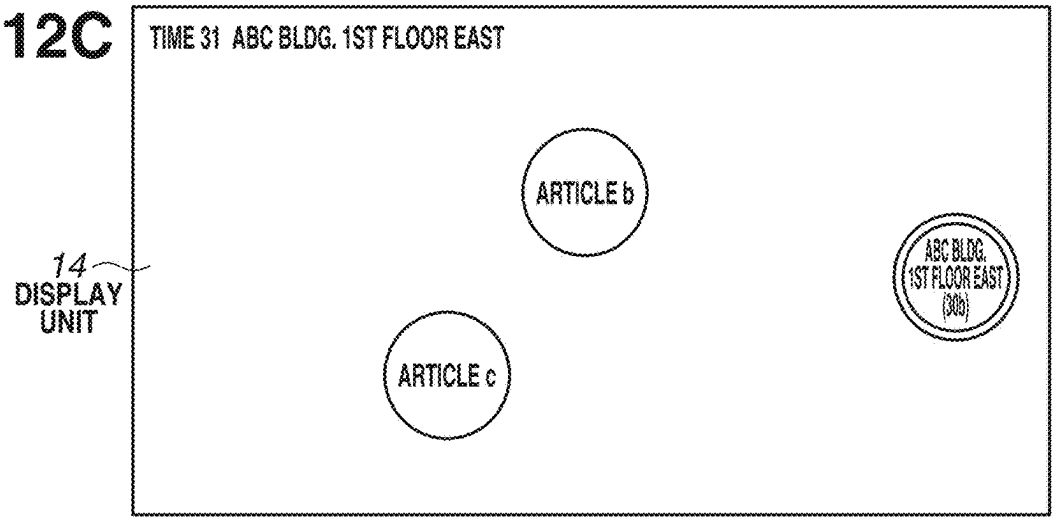


FIG.13

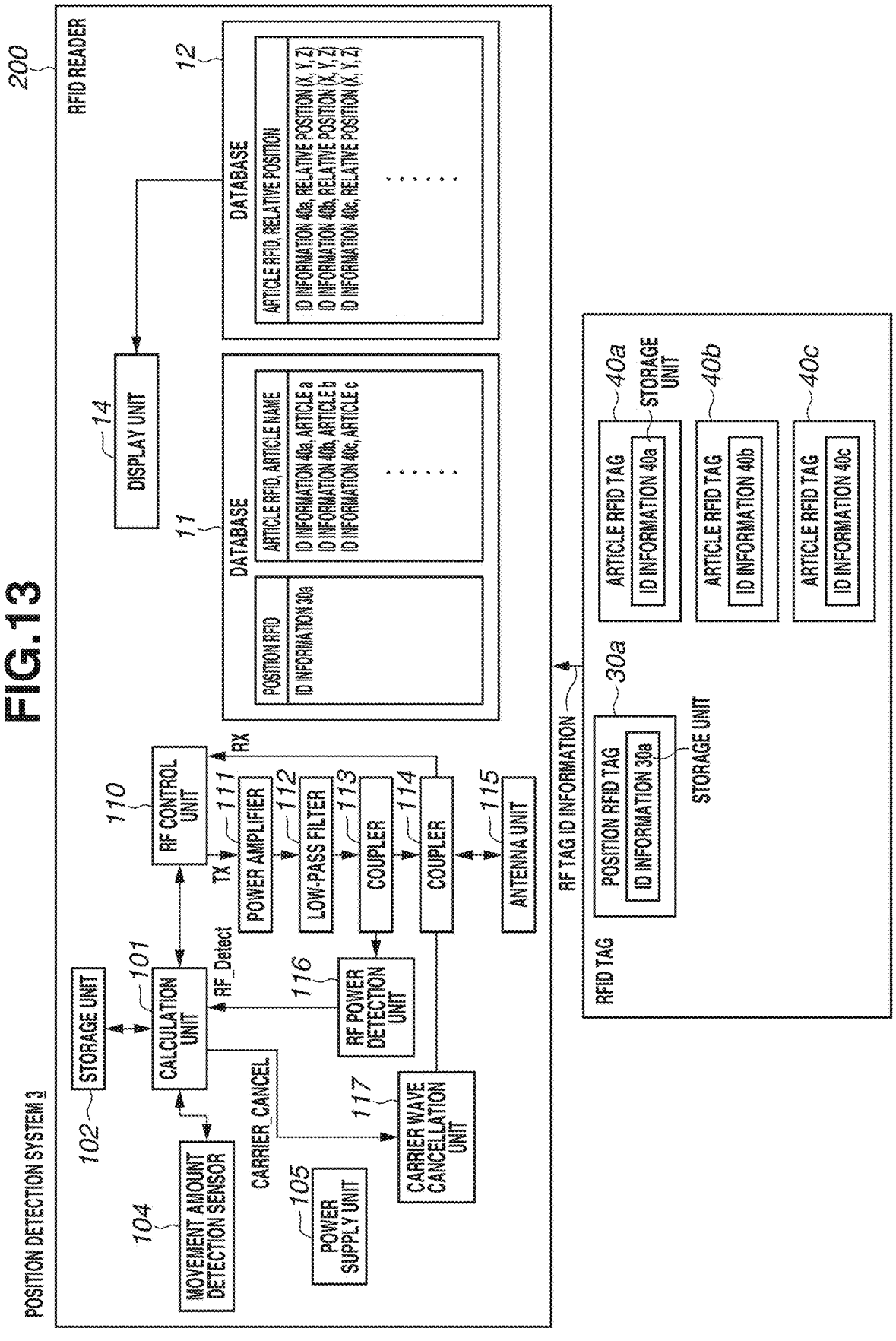

200
RFID READER
POSITION DETECTION SYSTEM 3
STORAGE UNIT
102
CALCULATION UNIT
101
MOVEMENT AMOUNT DETECTION SENSOR
104
POWER SUPPLY UNIT
105
CARRIER_CANCEL
CARRIER WAVE CANCELLATION UNIT
117
RF_Detect
RF POWER DETECTION UNIT
116
RF CONTROL UNIT
110
TX
RX
111
POWER AMPLIFIER
112
LOW-PASS FILTER
113
COUPLER
114
COUPLER
115
ANTENNA UNIT
DISPLAY UNIT
14
DATABASE
11
POSITION RFID
ID INFORMATION 30a
ARTICLE RFID, ARTICLE NAME
ID INFORMATION 40a, ARTICLE a
ID INFORMATION 40b, ARTICLE b
ID INFORMATION 40c, ARTICLE c
DATABASE
12
ARTICLE RFID, RELATIVE POSITION
ID INFORMATION 40a, RELATIVE POSITION (X, Y, Z)
ID INFORMATION 40b, RELATIVE POSITION (X, Y, Z)
ID INFORMATION 40c, RELATIVE POSITION (X, Y, Z)
RF TAG ID INFORMATION
RFID TAG
POSITION RFID TAG
30a
ID INFORMATION 30a
STORAGE UNIT
ARTICLE RFID TAG
40a
ID INFORMATION 40a
STORAGE UNIT
ARTICLE RFID TAG
40b
ID INFORMATION 40b
ARTICLE RFID TAG
40c
ID INFORMATION 40c

FIG.14

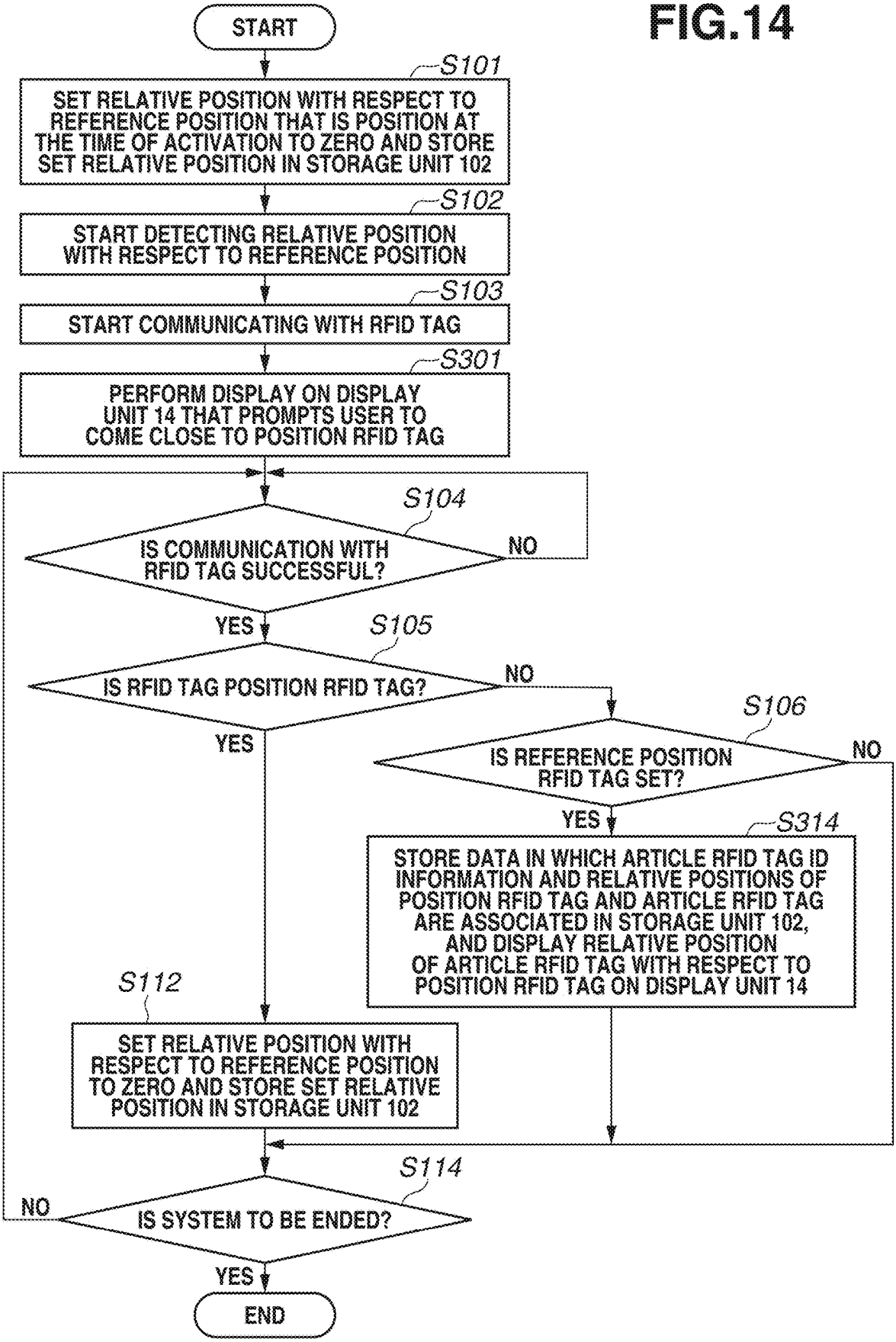

START
S101
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION THAT IS POSITION AT THE TIME OF ACTIVATION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
S102
START DETECTING RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION
S103
START COMMUNICATING WITH RFID TAG
S301
PERFORM DISPLAY ON DISPLAY UNIT 14 THAT PROMPTS USER TO COME CLOSE TO POSITION RFID TAG
S104
IS COMMUNICATION WITH RFID TAG SUCCESSFUL?
NO
YES
S105
IS RFID TAG POSITION RFID TAG?
NO
YES
S106
IS REFERENCE POSITION RFID TAG SET?
NO
YES
S314
STORE DATA IN WHICH ARTICLE RFID TAG ID INFORMATION AND RELATIVE POSITIONS OF POSITION RFID TAG AND ARTICLE RFID TAG ARE ASSOCIATED IN STORAGE UNIT 102, AND DISPLAY RELATIVE POSITION OF ARTICLE RFID TAG WITH RESPECT TO POSITION RFID TAG ON DISPLAY UNIT 14
S112
SET RELATIVE POSITION WITH RESPECT TO REFERENCE POSITION TO ZERO AND STORE SET RELATIVE POSITION IN STORAGE UNIT 102
S114
IS SYSTEM TO BE ENDED?
NO
YES
END

FIG.15A

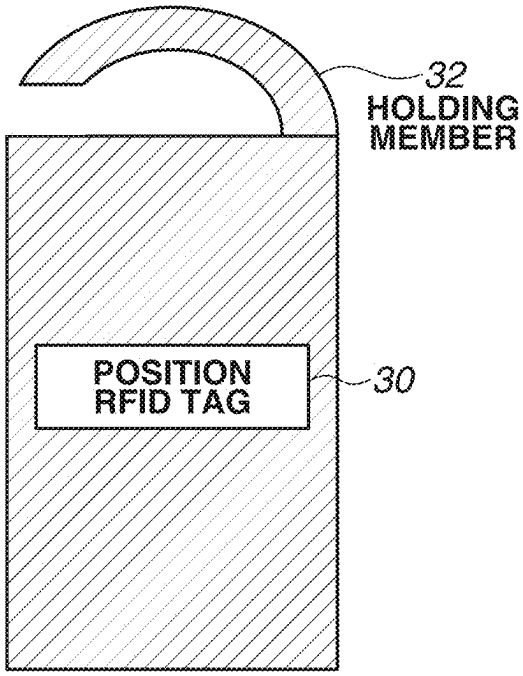


FIG.15B

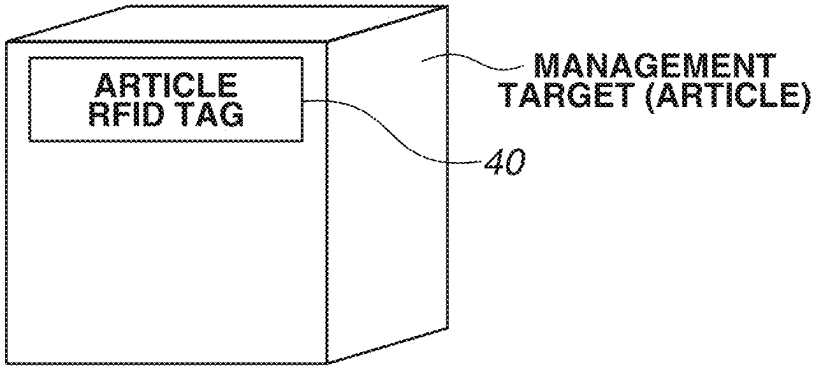


FIG.16A

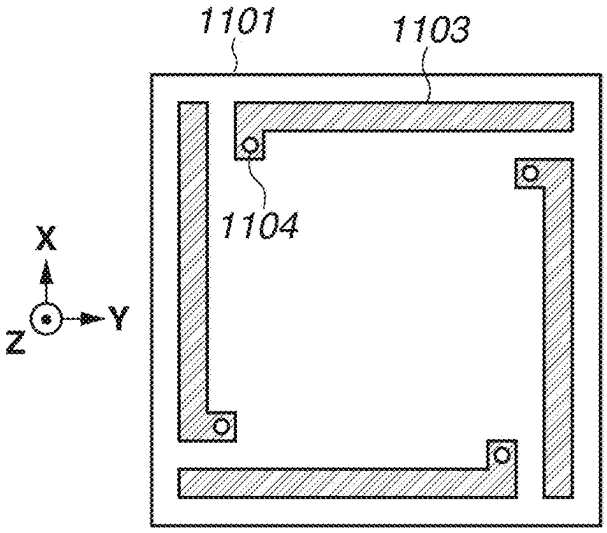


FIG.16B

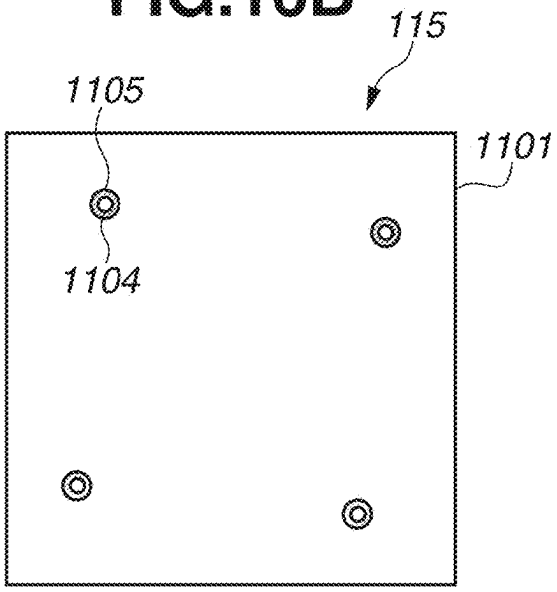


FIG.16C

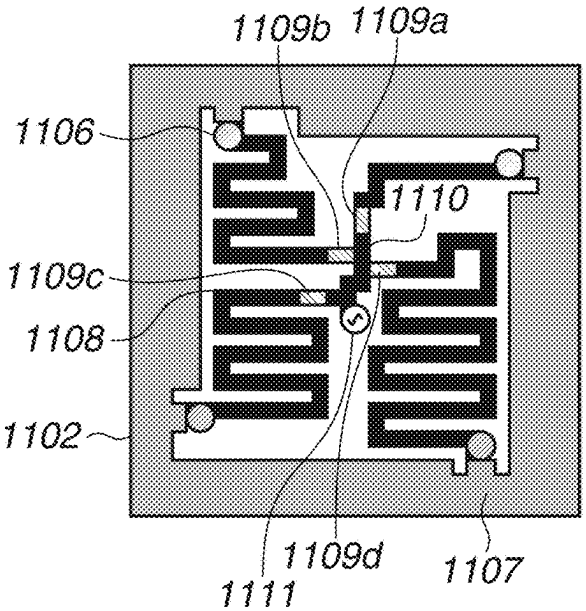


FIG.16D

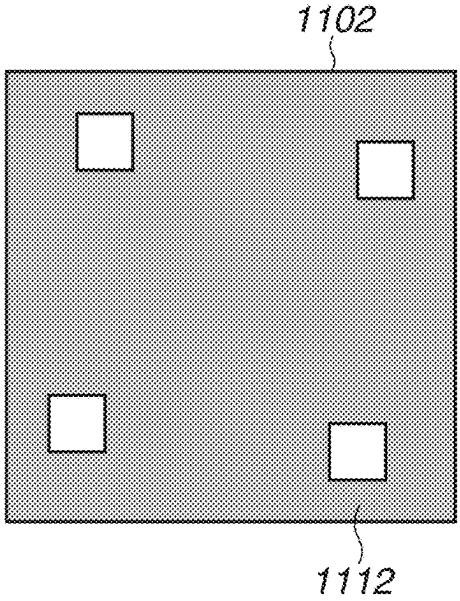


FIG.17A

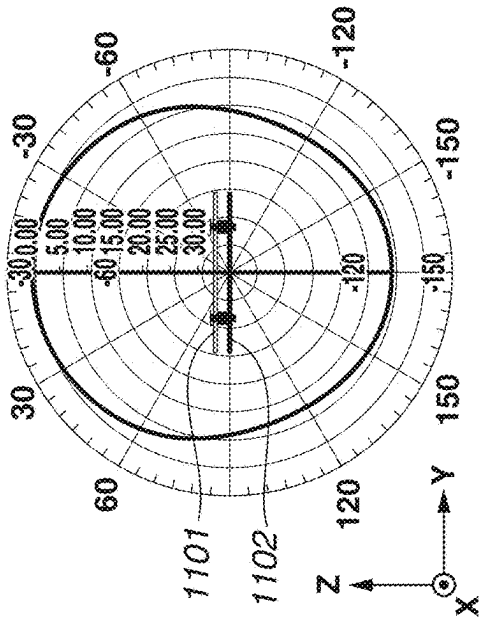


FIG.17B

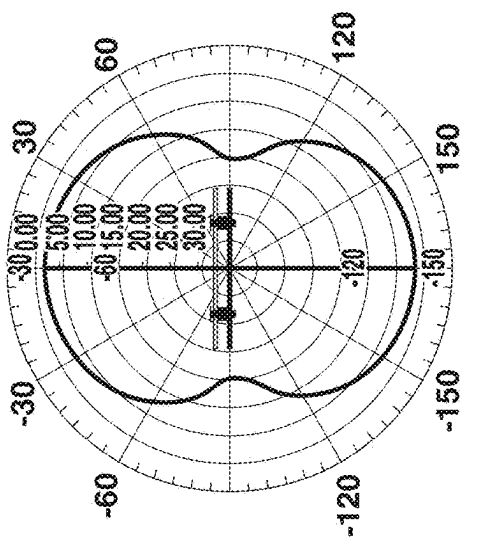
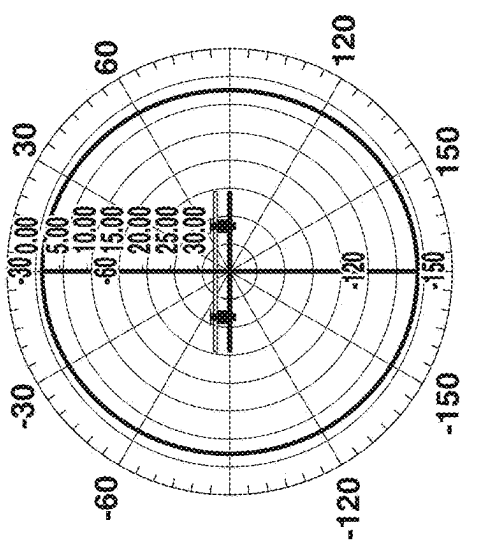
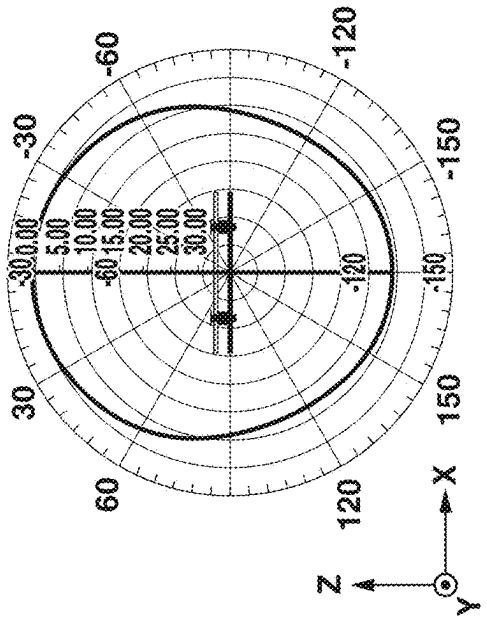
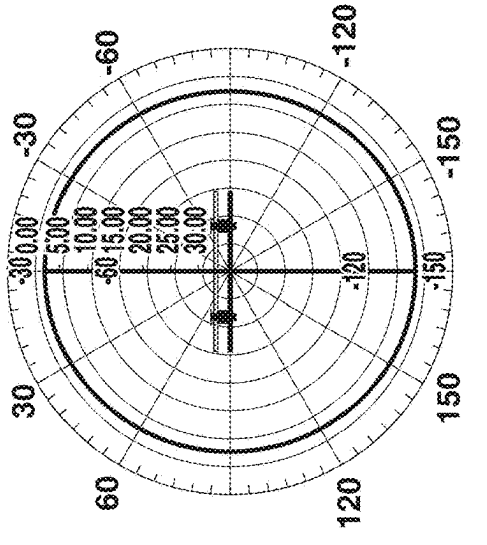


FIG.17C







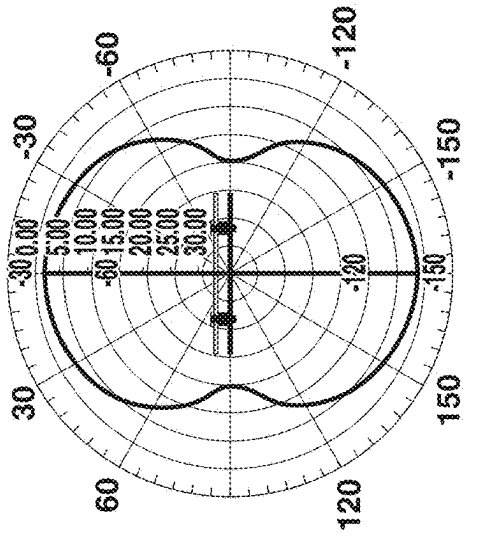
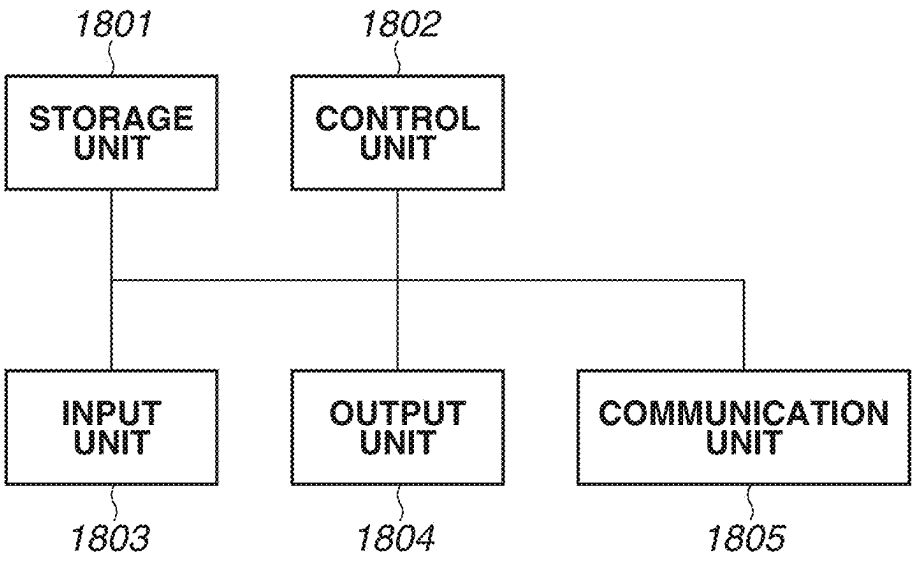


FIG.18


1801
1802
STORAGE UNIT
CONTROL UNIT
INPUT UNIT
OUTPUT UNIT
COMMUNICATION UNIT
1803
1804
1805

COMMUNICATION APPARATUS, INFORMATION PROCESSING APPARATUS, AND POSITION INFORMATION MANAGEMENT METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of International Patent Application No. PCT/JP2021/008032, filed Mar. 3, 2021, which claims the benefit of Japanese Patent Application No. 2020-037063, filed Mar. 4, 2020, both of which are hereby incorporated by reference herein in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a technique for managing position information about a wireless device.

Background Art

In logistics, inventory taking, or animal management, a system of managing management target articles or animals using ultra-high frequency (UHF) passive radio frequency identification tags (hereinafter, referred to as RFID tags) as wireless devices are used. The RFID tags receive electric waves (electromagnetic waves) emitted from an antenna of an RFID reader and operate using power generated by the received electric waves (electromagnetic waves). This produces advantages that no batteries are needed and the RFID tags can be manufactured to be thin and at a low cost. However, since an RFID tag and the RFID reader can communicate only within short distances, there is a disadvantage that the RFID tags existing over a large area cannot be detected at one time.

Thus, a method for managing position information about management targets that exist over a wide area and to which RFID tags are attached has been discussed. Specifically, an RFID reader configured to detect the position information is carried, and the position information at the time of detection of an RFID tag is automatically associated with identification (ID) information about the RFID tag. Japanese Patent Application Laid-Open No. 2007-114003 discusses a technique for detecting position information about an RFID reader using the Global Positioning System (GPS).

CITATION LIST

Patent Literature

PTL 1: Japanese Patent Application Laid-Open No. 2007-114003

SUMMARY OF THE INVENTION

However, the method of detecting position information about the RFID reader using GPS is not suitable for indoor use. Furthermore, a GPS reception circuit needs to be provided, and thus there is an issue of an increased cost of the RFID reader.

Thus, the present invention is directed to a technique of managing position information about management target wireless devices existing over a large area with ease while preventing an increase in cost.

According to an aspect of the present invention, a communication apparatus includes a detection unit configured to detect a wireless device, a calculation unit configured to calculate a relative position of the detected wireless device with respect to a first wireless device to be a reference in identifying a position based on a movement amount of the communication apparatus from when the first wireless device is detected by the communication apparatus, and an association unit configured to associate the relative position calculated by the calculation unit, identification information about the detected wireless device, and identification information about the first wireless device.

According to another aspect of the present invention, an information processing apparatus includes a reception unit configured to receive, from a communication apparatus that detects a wireless device, identification information about the detected wireless device and information about a relative position of the detected wireless device with respect to a reference position, a calculation unit configured to calculate a relative position of the wireless device with respect to a first wireless device to be a reference in identifying a position based on the information received by the reception unit using information about a relative position of the first wireless device with respect to the reference position and the information about the relative position of the detected wireless device different from the first wireless device with respect to the reference position, and an association unit configured to associate the relative position calculated by the calculation unit, the identification information about the detected wireless device, and identification information about the first wireless device.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating a radio frequency identification (RFID) reader **100**.

FIG. **2**A is a diagram illustrating a moving body that carries the RFID reader **100**.

FIG. **2**B is a diagram illustrating the moving body that carries the RFID reader **100**.

FIG. **2**C is a diagram illustrating the moving body that carries the RFID reader **100**.

FIG. **3** is a system diagram according to a first exemplary embodiment.

FIG. **4** is a flowchart illustrating a process of control by the RFID reader **100** according to the first exemplary embodiment.

FIG. **5**A is a diagram illustrating a display method of a display unit **14** according to the first exemplary embodiment.

FIG. **5**B is a diagram illustrating the display method of the display unit **14** according to the first exemplary embodiment.

FIG. **5**C is a diagram illustrating the display method of the display unit **14** according to the first exemplary embodiment.

FIG. **6** is a flowchart illustrating a process of control to increase the accuracy of position information.

FIG. **7** is a flowchart illustrating a process of control to increase the accuracy of position information.

FIG. **8** is diagram illustrating a charging apparatus **300** of the RFID reader **100**.

FIG. **9**, which includes FIGS. **9**A and **9**B, is a system diagram according to a second exemplary embodiment.

FIG. **10** is a flowchart illustrating a process of control by a RFID reader **100** according to the second exemplary embodiment.

FIG. **11** is a flowchart illustrating a process of control by a server **20** according to the second exemplary embodiment.

FIG. **12**A is a diagram illustrating a display method of a display unit **14** according to the second exemplary embodiment.

FIG. **12**B is a diagram illustrating the display method of the display unit **14** according to the second exemplary embodiment.

FIG. **12**C is a diagram illustrating the display method of the display unit **14** according to the second exemplary embodiment.

FIG. **13** is a system diagram according to a third exemplary embodiment.

FIG. **14** is a flowchart illustrating a process of control by a RFID reader **200** according to a third exemplary embodiment.

FIG. **15**A is a diagram illustrating a position RFID tag **30** and an article RFID tag **40**.

FIG. **15**B is a diagram illustrating the position RFID tag **30** and the article RFID tag **40**.

FIG. **16**A is a diagram illustrating a configuration of an antenna **115**.

FIG. **16**B is a diagram illustrating the configuration of the antenna **115**.

FIG. **16**C is a diagram illustrating the configuration of the antenna **115**.

FIG. **16**D is a diagram illustrating the configuration of the antenna **115**.

FIG. **17**A is a diagram illustrating radiation characteristics of the antenna **115**.

FIG. **17**B is a diagram illustrating radiation characteristics of the antenna **115**.

FIG. **17**C is a diagram illustrating radiation characteristics of the antenna **115**.

FIG. **18** is a diagram illustrating a hardware configuration of a server **20**.

DESCRIPTION OF THE EMBODIMENTS

A method of managing position information about a management target wireless device according to various exemplary embodiments of the present invention will be described in detail below with reference to the drawings. In the management method according to an exemplary embodiment of the present invention, a communication apparatus configured to detect wireless devices is carried by a moving body such as a person or a machine to detect the wireless devices existing over a large area. The wireless devices are, for example, radio frequency identification (RFID) tags, and the communication apparatus is, for example, an RFID reader.

As illustrated in FIGS. **2**A, **2**B, and **2**C, there are methods in which, for example, a person (animal) wears an RFID reader **100** (FIG. **2**A) or the RFID reader **100** is attached to a machine such as a drone **401** or an automated guided vehicle **501** (FIGS. **2**B and **2**C). With the methods, the RFID reader **100** can be moved extensively and can detect RFID tags existing over a large area.

The RFID reader **100** has a function of feeding ultrahigh-frequency (UHF) electromagnetic waves to an RFID tag to cause an integrated circuit (IC) chip in the RFID tag to operate and to read identification (ID) information stored in a storage unit of the RFID tag. Further, the RFID reader **100** and the RFID tag can wirelessly communicate with each other over a distance of several meters.

In the present exemplary embodiment, as illustrated in FIG. **15**B, an RFID tag attached to a management target such as an article or an animal will be referred to as an article RFID tag **40**. The article RFID tag **40** is used to identify the management target to which the article RFID tag **40** is attached based on ID information stored in the article RFID tag **40**. Further, as illustrated in FIG. **15**A, an RFID tag for use as a reference in identifying a position of the article RFID tag **40** will be referred to as a position RFID tag **30**. The RFID reader **100** calculates a relative position of the article RFID tag **40** with respect to the position RFID tag **30** being a reference using a movement amount detection sensor **104** described below.

Information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30** is displayed on a display unit **14** in FIG. **3** so that a user can locate the management target to which the article RFID tag is attached. Details of each process will be described below in the following exemplary embodiments.

While examples in which the RFID tags are used as detection target wireless devices and the RFID reader is used as a communication apparatus that detects the wireless devices are described in the exemplary embodiments of the present invention, the wireless devices and the communication apparatus are not limited to those in the examples. For example, other wireless communications such as short-range wireless communication, e.g., near field communication (NFC) or Bluetooth®, can be used instead of RFID. Alternatively, RFID using another frequency band can be used instead of UHF RFID.

First Exemplary Embodiment

FIG. **1** is a circuit block diagram illustrating the RFID reader **100** for use in a first exemplary embodiment. The RFID reader **100** is controlled by a calculation unit **101** including one or more processors such as a central processing unit (CPU). A radio frequency (RF) control unit **110** outputs UHF RF output from a transmission (TX) terminal based on the control by the calculation unit **101**. The RF output is amplified by a power amplifier **111**, and then a low-pass filter **112** cuts unnecessary frequency bands. The power of the RF output is variably set by the calculation unit **101**. A coupler **113** is used in detecting power by a RF power detection unit **116**.

A power detection result of the RF power detection unit **116** can be detected as an RF_Detect signal by the calculation unit **101**. A coupler **114** is used to separate RF output to an antenna unit **115** and RF input received from the antenna unit **115**. The antenna unit **115** is used to supply power to the RFID tags and to communicate with the RFID tags. A carrier wave cancellation unit **117** cancels a carrier wave component of the RF input based on a CARRIER_CANCEL signal, and a signal component of the RF input is received by a reception (RX) terminal of the RF control unit **110**, and ID information that is identification information about the RFID tag is detected.

The calculation unit **101** stores the ID information about the RFID tag that is detected by the RF control unit **110** in a storage unit **102**, performs necessary data processing, and then communicates with an information terminal **10**, which will be described below with reference to FIG. **3**, via a communication unit **103**. The storage unit **102** includes one or more memories such as a read-only memory (ROM) and a random access memory (RAM) and stores various types of

data and programs to be processed by the calculation unit **101**. The communication unit **103** can communicate with the information terminal **10** via wired communication using Ethernet® or Universal Serial Bus (USB) or via wireless communication using a wireless local area network (wireless LAN) or a public wireless system.

The movement amount detection sensor **104** is a sensor that includes a three-axis acceleration sensor, a gyro sensor, and a geomagnetic sensor and detects a movement amount of the RFID reader **100**. The movement amount detection sensor **104** is used to calculate relative positions of the position RFID tag **30** to be a reference and the article RFID tag **40**. The movement amount detection sensor **104** can use any detection method by which a movement distance and a movement direction of the RFID reader are detectable. In exemplary embodiments of the present invention, information about a combination of a movement distance and a movement direction (two- or three-dimensional direction) is used as a movement amount.

While the RFID reader **100** automatically detects ID information about the RFID tags, the movement amount detection sensor **104** calculates relative positions of the RFID tags and associates the ID information about the plurality of RFID tags with information about the relative positions of the plurality of RFID tags. A power supply unit **105** is a circuit that includes a battery and a direct-current (DC)-DC converter and is used to supply a power source voltage to the RFID reader **100**.

FIG. **3** is a system diagram according to the present exemplary embodiment. The RFID tags are classified into the position RFID tag **30** (**30***a* to **30***c*) for use in detecting a reference position and the article RFID tag **40** (**40***a* to **40***f*) attached to a management target. Details of the RFID tags will be described below with reference to FIGS. **15**A and **15**B.

The RFID reader **100** associates ID information about the article RFID tag **40**, ID information about the position RFID tag **30**, information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30**, and detection time of the article RFID tag **40**. Then, the pieces of information are transmitted to the information terminal **10**.

The information terminal **10** is an information terminal such as a smartphone or a personal computer (PC) and includes databases **11** and **12** and the display unit **14**. The database **11** stores data in which the ID information about the position RFID tag **30** and a position name are associated with each other and data in which the ID information about the article RFID tag **40** and an article name are associated with each other.

It is difficult for a user to recognize the ID information about the RFID tags directly, so that the ID information is converted into a name based on the database **11** and the converted name is displayed on the display unit **14**. Alternatively, the ID information about the RFID tags can be displayed directly on the display unit without using the database **11**.

The database **12** stores information received from the RFID reader **100**. Specifically, the database **12** stores data in which the ID information about the position RFID tag **30**, the ID information about the article RFID tag **40**, the relative position of the article RFID tag **40** with respect to the position RFID tag **30**, and the detection time of the article RFID tag **40** are associated with one another. The display unit **14** displays article position information based on a user instruction via an interface (not illustrated) of the information terminal **10**. A specific display method of the display unit **14** will be described below with reference to FIGS. **5**A, **5**B, and **5**C.

FIG. **4** is a flowchart illustrating a method of detecting position information about the article RFID tag by the RFID reader **100** according to the present exemplary embodiment. If a power source is changed to an ON state, the RFID reader **100** starts controlling the detection of article position information. The calculation unit **101** of the RFID reader **100** executes a program stored in the storage unit **102** to thereby implement each step of the flowchart in FIG. **4**.

In step S**101**, the RFID reader **100** sets the information about the relative position with respect to the reference position in the storage unit **102** to zero (x=0, y=0, z=0). The reference position is the position of the RFID reader **100** at the time of activation.

In step S**102**, the RFID reader **100** starts controlling calculation of an integral value of movement amounts based on detection results of the movement amount detection sensor **104**, updating of the information about the relative position with respect to the reference position, and storing of the information in the storage unit **102**. In step S**103**, the RFID reader **100** periodically causes the RF control unit **110** to operate to communicate with an RFID tag and starts controlling communication with the RFID tag.

In step S**104**, the RFID reader **100** determines whether ID information about the RFID tag is acquired from the RFID tag. In a case where the ID information about the RFID tag is acquired, the processing proceeds to step S**105**. On the other hand, in a case where the ID information about the RFID tag is not acquired, the processing of step S**104** is repeated.

In step S**105**, the RFID reader **100** determines whether the RFID tag is the position RFID tag **30** or the article RFID tag **40** based on the acquired ID information. As a method of discriminating the position RFID tag **30** from the article RFID tag **40**, for example, the ID information about the RFID tag can include an identifier for discriminating the position RFID tag **30** from the article RFID tag **40**. Further, the database **11** of the information terminal **10** can be referred to in the determination. In a case where the RFID tag is the article RFID tag, the processing proceeds to step S**106**. On the other hand, in a case where the RFID tag is the position RFID tag, the processing proceeds to step S**108**.

In step S**106**, the RFID reader **100** determines whether a reference position RFID tag is set. In a case where the reference position RFID tag is not set yet, e.g., in a case where it is immediately after activation of the RFID reader **100**, the processing proceeds to step S**107**. On the other hand, in a case where the reference position RFID tag is set, the processing proceeds to step S**113**.

In step S**107**, the RFID reader **100** stores data in which the ID information about the article RFID tag **40**, the detection time of the article RFID tag **40**, and the relative position of the article RFID tag **40** with respect to the reference position (initial position at the time of activation) are associated with one another in the storage unit **102**.

In step S**108**, the RFID reader **100** stores the ID information about the detected position RFID tag **30** as a reference position RFID tag in the storage unit **102**, and the processing proceeds to step S**109**. In step S**109**, the RFID reader **100** determines whether it is the first time to detect a position RFID tag after the activation of the RFID reader **100**. In a case where it is the first time to detect the position RFID tag, the processing proceeds to step S**110**. On the other hand, in a case where it is the second time or subsequent time, the processing proceeds to step S**112**.

In step S110, the RFID reader **100** performs the following processing on the data stored in the storage unit **102** in step S107. Specifically, relative positions of the position RFID tag **30** and the article RFID tag **40** are calculated based on the information about the relative position of the article RFID tag **40** with respect to the reference position and the information about the relative position of the position RFID tag **30** that is stored in the storage unit **102** in step S108 with respect to the reference position. As used herein, the term reference position refers to the initial position at the time of activation of the RFID reader **100** (the position stored in step S101).

In step S111, the RFID reader **100** performs the following processing on the data stored in the storage unit **102** in step S107. Specifically, the RFID reader **100** associates the ID information about the article RFID tag **40**, the ID information about the position RFID tag **30**, the detection time of the article RFID tag **40**, and the information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30**. Then, the RFID reader **100** transmits the information to the information terminal **10**. The communication unit **103** is used in the transmission.

In step S112, the RFID reader **100** sets the information about the relative position with respect to the reference position in the storage unit **102** to zero (x=0, y=0, z=0), and the processing returns to step S102. In step S113, the RFID reader **100** associates the ID information about the detected article RFID tag **40**, the ID information about the position RFID tag **30**, the detection time of the article RFID tag **40**, and the information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30**. Then, the RFID reader **100** transmits the information to the information terminal **10**.

The RFID reader **100** repeats the foregoing control until a system end request is received (S114). With the process, the calculation unit **101** of the RFID reader **100** controls automatic detection of position information about the article RFID tag **40** attached to a management target and transmission of the detected position information to the information terminal **10**.

FIGS. **5**A, **5**B, and **5**C illustrates an example of a display that is displayed on the display unit **14** of the information terminal **10**. In the display examples in FIGS. **5**A, **5**B, and **5**C, position information about management target articles is displayed based on the information in the databases **11** and **12**. In the display examples in FIGS. **5**A, **5**B, and **5**C, the display unit **14** displays the position RFID tag **30** as a double circle and the article RFID tag **40** as a single circle.

FIG. **5**A illustrates an example of a display on the display unit **14** in a case where a user instructs the information terminal **10** to display information about ABC building 1^{st} floor north at time XX. In the database **12**, first, with respect to ID information **40***a* to **40***c* (articles a to c) about the article RFID tag **40** associated with ID information **30***a* (ABC building 1^{st} floor north), data having the closest article detection time to the time XX is selected for each ID. Then, the information about the relative positions of the articles with respect to the position RFID tag is referred to so that the display unit **14** displays position information about the articles a to c based on the position of ABC building 1^{st} floor north as a reference. A user can locate the articles in actuality using the display information displayed on the display unit **14** and the disposed position RFID tag as a mark.

FIG. **5**B illustrates an example of a display on the display unit **14** in a case where a user issues an instruction to display ABC building 7th floor at the time XX. In FIG. **5**B, a display example in a case where articles d and e are each on a floor different from the 7^{th} floor of ABC building is illustrated. In a case where a distance between the relative positions of the articles d and e and a position RFID tag **30***c* on the 7^{th} floor of ABC building in a height direction is greater than a predetermined setting value, the articles d and e are detected as being on a floor different from the 7th floor of ABC building. The display unit **14** displays each article that is on a different floor as a dotted circle to indicate to a user that the articles d and e are not on the same floor as the position RFID tag **30***c*. The display unit **14** displays a display indicating that the article d is on an upper floor of the 7^{th} floor of ABC building and the article e is on a lower floor of the 7^{th} floor of ABC building based on the information about the relative position with respect to the position RFID tag **30***c*.

FIG. **5**C illustrates an example of a display on the display unit **14** in a case where a user issues an instruction to display the article c at time YY. With respect to the position RFID tag **30***a* (ABC building 1^{st} floor north) associated with the ID information **40***c* (article c) in the database **12** and a position RFID tag **30***b* (ABC building 1st floor east), data with the closest article detection time to the time YY is selected for each ID. Then, the information about the relative positions of the article with respect to the position RFID tag is referred to so that the display unit **14** displays the position of the article c with respect to the positions of the position RFID tag **30***a* at ABC building 1^{st} floor north and the position RFID tag **30***b* at ABC building 1^{st} floor east as a reference. In this display method, a user can locate the article c using the plurality of position RFID tags as marks. The position RFID tags **30** are displayed as follows. Specifically, the position RFID tag **30***a* associated with data of detection of the article c at the closest time to the time YY is illustrated as a solid double circle, and the position RFID tag **30***b*, which is another position RFID tag, is illustrated as a dashed double circle. With this display method, a user can preferentially refer to the position information about the article detected at the closest time to the designated time YY.

As described above, the method of managing article position information according to the first exemplary embodiment uses the position RFID tag **30** as a reference in identifying a position for use in article management. Thus, the position RFID tag **30** does not have to be stored in association with quantitative position information. Thus, a user can introduce a position information detection system **1** with ease by simply attaching the article RFID tag **40** to a management target and installing the position RFID tag **30**.

When a user is to locate an article, even if quantitative coordinates indicating the position of an article are displayed on the display unit **14**, it is difficult for the user to intuitively locate the article. Displaying the position of the article with respect to the position of one position RFID tag **30** or the positions of the plurality of position RFID tags **30** as a reference makes it easier for the user to locate the article.

The position RFID tag **30** does not need connection of a power source cable. Thus, the position RFID tag **30** can be installed by a simple method, e.g., placing the position RFID tag **30** on a floor or attaching the position RFID tag **30** to a wall, so that the position information detection system **1** can be introduced with ease not only for indoor use but also for outdoor use.

The position RFID tag **30** does not have to be situated at a fixed position. For example, the position RFID tag **30** can be installed in a truck bed to detect position information about an article in the moving truck bed.

As described above, the system of managing article position information according to the present exemplary

embodiment can be easily introduced both inside and outside with at low cost and can manage position information about management targets to which the RFID tags are attached existing over a large area.

Second Exemplary Embodiment

FIG. **9** is a system diagram according to a second exemplary embodiment. A system according to the present exemplary embodiment is different from the first exemplary embodiment in that a server **20**, instead of the RFID reader **100**, processes data necessary for position detection and that the database **12** also manages the position RFID detection time in association. Each configuration similar to that in the first exemplary embodiment is given the same reference numeral, and a redundant description thereof is omitted.

In a position detection system **2** in FIG. **9**, the plurality of RFID readers **100** (**100***a*, **100***b*, . . .) is connected to the server **20**. Each RFID reader **100** transmits data to the server **20** in association with ID information about the RFID tags (the article RFID tag **40** and the position RFID tag **30**), relative positions of the RFID tags with respect to a reference position described below, and the detection time of each of the RFID tags. A time display in FIG. **9** indicates that the detection time proceeds in the order of **10**, **11**, **12**, **20**, **21**, and **31**.

FIG. **18** illustrates a hardware configuration of the server **20** according to the present exemplary embodiment. A storage unit **1801** includes one or more memories, such as one or both of a ROM and a RAM, and stores programs for executing various operations described below and databases described below. Besides the memories such as the ROM and RAM, a storage medium such as a flexible disk, a hard disk, an optical disk, a magneto-optical disk, a compact disk (CD) ROM, a CD recordable (CD-R), a magnetic tape, a non-volatile memory card, or a digital versatile disk (DVD) can be used as the storage unit **1801**.

A control unit **1802** includes a calculation unit **23** illustrated in FIG. **9** and includes, for example, one or more processors such as a CPU and a micro processing unit (MPU), an application-specific integrated circuit (ASIC), a digital signal processor (DSP), and a field-programmable gate array (FPGA). CPU is the abbreviation for Central Processing Unit, and MPU is the abbreviation for Micro Processing Unit. The control unit **1802** executes a program stored in the storage unit **1801** to thereby control the entire apparatus.

An input unit **1803** receives various operations from a user. An output unit **1804** outputs various types of output to a user. The output of the output unit **1804** includes at least one of a display on a screen, audio output via a speaker, and vibration output. Alternatively, the input unit **1803** and the output unit **1804** can be implemented by a single module such as a touch panel. A communication unit **1805** can perform wired or wireless communication, and the server **20** can communicate with the RFID reader using the communication unit **1805**.

In the system diagram in FIG. **9**, databases to be stored in the storage unit **1801** of the server **20** are illustrated. The server **20** discriminates the position RFID tag **30** from the article RFID tag **40**, as described below with reference to FIG. **11**. In a case where the server **20** receives data on the position RFID tag **30** from the RFID reader **100**, the server **20** stores the data in a database **21***a*, whereas in a case where the server **20** receives data on the article RFID tag **40**, the server **20** stores the data in a database **21***b*. The databases **21***a* and **21***b* store ID information about the RFID reader **100** to identify the RFID reader by which the data is received. The databases **21***a* and **21***b* are databases for temporary storage for use in data processing and generating of the database **12** by the server **20**.

The database **11** of the server **20** stores the time of installation of the position RFID tag in addition to the position name of the position RFID tag **30**. Here, data on a case where the position RFID tag **30** of the ID information **30***a* is installed at ABC building 1st floor north at time **10** and is then moved to and installed at ABC building 2nd floor at time **20** is illustrated. The position RFID tag **30** of ID information **30***b* indicates that the position RFID tag **30** is installed at ABC building 1st floor east at the time **10**.

The database **12** stores the ID information about the position RFID tag **30**, the ID information about the article RFID tag **40**, the relative position of the article RFID tag **40** with respect to the position RFID tag **30**, the detection time of the article RFID tag **40**, and the detection time of the position RFID tag **30** in association.

Use of an installation time of the position RFID tag **30** in the database **11** and an installation time of the position RFID tag **30** in the database **12** makes it possible to process data as suitable for a case where the position RFID tag **30** is moved, as described below with reference to FIGS. **12**A, **12**B, and **12**C. The RFID reader and the server **20** can communicate via a network such as the Internet or an intranet. The server **20** as an information processing apparatus can include a single apparatus or a plurality of apparatuses. Further, the server **20** can include a plurality of apparatuses cooperating via a network such as the cloud. Further, the server **20** and the information terminal **10** can be integrated.

FIG. **10** is a flowchart illustrating a process that is executed by the RFID reader **100** according to the present exemplary embodiment. The calculation unit **101** of the RFID reader **100** executes a program stored in the storage unit **102** to thereby implement the steps in the flowchart in FIG. **10**.

In step S**221**, the RFID reader **100** transmits information associated with RFID reader ID information, RFID tag ID information, RFID tag detection time, and the relative positions of the RFID tag with respect to the reference position to the server **20**.

The RFID reader **100** according to the present exemplary embodiment performs only the minimum data processing and transmits the data to the server **20**, and the server **20** processes the data used for position detection. Thus, in the system **2** according to the present exemplary embodiment, the data processing to be performed by the RFID reader **100** is reduced, so that the calculation unit **101** that has low calculation capacity can be used, and the necessary data capacity for the storage unit **102** is reduced.

FIG. **11** is a flowchart illustrating a process that is executed by the server **20** according to the present exemplary embodiment. The control unit **1802** of the server **20** executes a program stored in the storage unit **1801** to thereby implement the steps in the flowchart in FIG. **11**.

In step S**201**, the server **20** waits until data is transmitted from the RFID reader **100**, and the processing proceeds to step S**202**. In step S**202**, the server **20** determines whether the RFID reader **100** is reactivated by turning on and off the power source. In the case where the RFID reader **100** is reactivated, the reference position at the time of activation that is to be used as a reference is changed, so that information about the relative position in the RFID tag detection result before the reactivation and the RFID tag detection result after the reactivation can no longer be detected. Thus,

in a case where the RFID reader **100** is reactivated, the processing proceeds to steps S**208** to S**210**, and the data processing on the RFID tag detected before the reactivation is completed. Thereafter, the data in the databases that has been analyzed is erased, and the processing returns to step S**201**. The databases **21***a* and **21***b* erase old data that has been analyzed so that the amount of data to be stored in the server **20** is reduced.

In the present exemplary embodiment, a case where the RFID readers **100***a* and **100***b* are reactivated between time **12** and the time **20** and between time **21** and time **31** in FIG. **9** will be described below. For a purpose of description, the old data to be erased is also displayed in the databases **21***a* and **21***b* in FIG. **9**.

In step S**203**, the server **20** receives the data in which the RFID reader ID information, the RFID tag ID information, the RFID tag detection time, and the relative position of the RFID tag with respect to the reference position are associated with one another. In step S**204**, the server **20** determines whether the RFID tag is the position RFID tag **30** or the article RFID tag **40** based on the RFID tag ID information. In a case where the RFID tag is the position RFID tag **30**, the processing proceeds to step S**205**. On the other hand, in a case where the RFID tag is the article RFID tag **40**, the processing proceeds to step S**206**.

In step S**205**, the server **20** stores the data received in step S**203** in the database **21***a* as data on the position RFID tag **30**. In step S**206**, the server **20** stores the data received in step S**203** in the database **21***b* as data on the article RFID tag **40**. In step S**207**, the server **20** checks whether a request to analyze the data in the databases **21***a* and **21***b* is received. The server **20** performs data analysis, for example, in a case where a predetermined number of pieces of data or more are accumulated in the databases **21***a* and **21***b*, at regular timings, or based on a user instruction.

In step S**208**, the server **20** associates the position RFID tag **30** and the article RFID tag **40** from the databases **21***a* and **21***b* that are detected at the closest time among the data detected by the same RFID reader **100**. Thereafter, the processing proceeds to step S**208**.

In a method of associating the data in the databases **21***a* and **21***b* according to a modified example, the position RFID tag **30** and the article RFID tag **40** that are detected at the closest relative positions by the same RFID reader **100** are stored in association with each other. Further, in a case where the database **12** has a large storage capacity, combinations of data to associate the position RFID tag **30** and the article RFID tag **40** can be increased. For example, the article RFID tag **40** can be stored in the database **12** in association with both the position RFID tag **30** detected at the closest time and the position RFID tag **30** detected at the closest relative position.

Associated data **120** in the parentheses in the database **12** in FIG. **9** is an example of data in which the position RFID tag **30** and the article RFID tag **40** that are detected not at the closest time are associated with each other.

In step S**209**, the server **20** calculates the relative position of the article RFID tag **40** with respect to the position RFID tag **30** that has been associated in step S**208** based on the relative position of the position RFID tag **30** with respect to the reference position and the relative position of the article RFID tag **40** with respect to the reference position.

As described above, the data transmitted from the RFID reader **100** to the server **20** is associated with the information about the relative positions of the article RFID tag **40** and the position RFID tag **30** based on a common reference position (the common reference position in the present exemplary embodiment is the initial position at the time of activation of the RFID reader **100**). Thus, the relative position of the article RFID tag **40** with respect to the position RFID tag **30** can be calculated by data processing by the server **20**.

The common reference position does not have to be the initial position at the time of activation of the RFID reader **100** and, for example, a position at which an RFID tag is detected for the first time after the RFID reader **100** is activated can be used as the reference position. The method illustrated in FIG. **11** is a mere example of a method of transmitting information about relative positions of a plurality of RFID tags detected by the RFID reader **100**, and any other methods can be used.

The RFID reader **100** includes at least a unit that detects the RFID tag ID information and the information about a relative position of an RFID tag with respect to the reference position. The server **20** can calculate the relative position of the position RFID tag **30** with respect to the article RFID tag **40** based on the ID information and the information about the relative positions of the plurality of RFID tags that are transmitted from the RFID reader **100**.

In step S**210**, the server **20** associates the ID information about the article RFID tag **40**, the ID information about the position RFID tag **30**, the detection time of the article RFID tag **40**, the detection time of the position RFID tag **30**, and the relative position of the article RFID tag **40** with respect to the position RFID tag **30**. Then, the information is stored in the database **12**.

The foregoing process is repeated until a system end request is received (S**114**).

FIGS. **12**A, **12**B, and **12**C each illustrate an example of a display that is displayed on the display unit **14** of the information terminal **10** according to the present exemplary embodiment. In the display examples illustrated in FIGS. **12**A, **12**B, and **12**C, position information about management target articles is displayed based on the information in the databases **11** and **12**.

The information terminal **10** transmits information such as position name, article name, and time to the server **20** based on a user instruction via an interface (not illustrated) of the information terminal **10**. The server **20** having received the information selects data necessary for the display on the display unit **14** from the database **12** and transmits the selected data to the information terminal **10**. The information terminal **10** displays article position information on the display unit **14** based on the data received from the server **20**.

FIG. **12**A illustrates a display example in which position information about the article RFID tag **40** with respect to ABC building 1st floor north (ID information **30***a* about the position RFID tag **30**) at time **11** as a reference is displayed. From the database **11** in FIG. **9** it is understood that the position RFID tag **30** is installed at ABC building 1st floor north during the period from the time **10** to the time **20**. The server **20** selects data with the ID information about the position RFID tag **30** that matches **30***a* and with the detection time of the article RFID tag closest to the time **11** during the period from the time **10** to the time **20**. The server **20** transmits the article name of the article RFID tag **40** of the selected data and the information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30***a* in association, so that the information terminal **10** can display the article position information illustrated in FIG. **12**A on the display unit **14**.

Meanwhile, in data processing by the server **20**, the information about the articles a and b is associated with ABC building 1st floor north based on a detection result of the

RFID reader **100***a*. The information about the article c is associated with ABC building 1st floor north based on a detection result of the RFID reader **100***b*. As described above, information detected by the plurality of RFID readers **100** is combined by the server **20** to reduce detection omissions of the article RFID tag **40**.

FIG. **12**B illustrates position information about the article RFID tag **40** with respect to ABC building 2nd floor (ID information **30***a* about the position RFID tag **30**) at time **21** as a reference. From the database **11** in FIG. **9** it is understood that the position RFID tag **30** of the ID information **30***a* is at ABC building 2nd floor at the time **20**. Thus, the display in FIG. **12**B uses the position RFID tag **30** detected at the time **20** or after and the detection result of the article RFID tag **40**.

As described above, in a case where the position RFID tag **30** is moved, a user only needs to register a new position name and installation time in the database **11** after the position RFID tag **30** is moved. Thus, the user can move a use site of the position detection system **2** by a simple operation.

Further, the database **12** stores the detection time of the position RFID tag **30** in addition to the detection time of the article RFID tag **40**. Thus, even in a case where a user installs the position RFID tag **30** at a new position and, after a while, the user registers the name of the new position of the position RFID tag **30** and installation time thereof in the database **11**, article position information of past data in the database **12** can be retrospectively displayed. In the case where the position RFID tag **30** is moved, a method in which the detection time of the position RFID tag **30** is also stored in the database **12** is effective.

FIG. **12**C illustrates position information about the article RFID tag **40** with respect to ABC building 1st floor east (ID information **30***b* about the position RFID tag **30**) at time **31** as a reference. As specified in the database **11** in FIG. **9**, the position RFID tag **30** of the ID information **30***b* is installed at ABC building 1st floor east at the time **10**. Thus, the display in FIG. **12**C uses the position RFID tag **30** detected at the time **10** or after and the detection result of the article RFID tag **40** among the data on the article RFID tag **40** associated with the position RFID tag **30** of the ID information **30***b*.

An advantage of the control method according to the present exemplary embodiment in a case where a user A of the RFID reader **100***a* installs the position RFID tag **30***a* and a user B of the RFID reader **100***b* installs the position RFID tag **30***b* will be described below. Since the user B has installed the position RFID tag **30***b* at ABC building 1st floor east by the time **31**, the user A can detect the position RFID tag **30***b* and the relative positions of the articles b and c at the time **31** with use of the RFID reader **100***a*. Thus, it is understood that as more users use the position detection system **2** and install the position RFID tag **30**, it becomes easier to detect the position of the article RFID tag **40**.

In the position detection system **2** according to a modified example, the information terminal **10** is not used, the RFID reader **100** includes the display unit **14**, and the server **20** transmits data to the RFID reader **100** to display the data on the display unit **14** of the RFID reader **100**. Further, instead of the RFID reader **100** and the server **20** communicating directly, the RFID reader **100** and the information terminal **10** can be connected so that the RFID reader **100** and the server **20** communicate via the information terminal **10**. Further, instead of using the server **20**, the information terminal **10** can perform the data processing of the server **20** according to the present exemplary embodiment.

As described above, the RFID reader **100** according to the present exemplary embodiment includes a unit that detects the ID information about the RFID tag and detects the information about the relative position of the RFID tag with respect to the reference position. The server **20** can calculate the relative position of an article RFID tag with respect to the position RFID tag based on the information transmitted from the RFID reader **100**.

Third Exemplary Embodiment

FIG. **13** is a system diagram according to a third exemplary embodiment. The system according to the present exemplary embodiment uses an RFID reader **200** in which the RFID reader **100** according to the first exemplary embodiment and the information terminal **10** are integrated. The present exemplary embodiment is different from the first exemplary embodiment in that the database **12** stores the ID information about the article RFID tag **40** in association with only the information about the relative position with respect to the reference position. Each configuration similar to that in the first exemplary embodiment is given the same reference numeral, and a redundant description thereof is omitted.

The RFID reader **200** in FIG. **13** includes the functions of the display unit **14** and the databases **11** and **12** in addition to the function of the RFID reader **100** according to the first exemplary embodiment. Instead, the communication unit **103** is not included.

The position detection system **3** according to the present exemplary embodiment includes only one position RFID tag **30**, and it is unnecessary to store the ID information about the position RFID tag **30** in association with the ID information about the article RFID tag **40** and the relative position information in the database **12**. Further, it is also unnecessary to store the position RFID tag **30** in the database **11** in association with the position name. In order to discriminate between the position RFID tag **30** and the article RFID tag **40**, only the ID information about the position RFID tag **30** is stored in the database **11**.

Further, the position detection system **3** can display only the newest position information detection result on the display unit **14**, and it is unnecessary to store the detection time of the article RFID tag **40** in association in the database **12**. The detection result of the newest article RFID tag **40** is updated and stored for each ID.

FIG. **14** is a flowchart illustrating a process that is executed by the RFID reader **200** according to the present exemplary embodiment. The flowchart is different from the flowchart in FIG. **4** according to the first exemplary embodiment in that after a position RFID tag is detected in step **S105**, updating of article RFID tag data is started. Another difference is that only the ID information about the article RFID tag **40** and the information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30** are stored in step **S314**. The calculation unit **101** of the RFID reader **200** executes the steps in the flowchart in FIG. **14** as in FIG. **4**.

Under the control according to the present exemplary embodiment, the RFID reader **200** does not update the RFID tag data until the position RFID tag **30** is detected in step **S105**. Thus, in step **S301**, the display unit **14** displays a display that prompts a user to come close to the position RFID tag until the position RFID tag **30** is detected for the first time.

Further, in a case where the position RFID tag **30** is not detected for a predetermined period from the start of the

control by the RFID reader **100**, control is performed to prompt a user to detect the position RFID tag **30** using a display on the display unit **14** or a buzzer. This can be performed also in the cases of the first and second exemplary embodiments.

In step S**314**, the RFID reader **200** updates the ID information about the article RFID tag **40** and the information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30***a* in the database **12**. The display unit **14** displays the relative position of the article RFID tag with respect to the position RFID tag **30***a*.

The foregoing process is repeated until a system end request is received (S**114**).

As described above, in the position detection system **3** according to the present exemplary embodiment, the ID information about the position RFID tag **30** and the detection time of the article RFID tag **40** do not have to be stored, so that the necessary data capacity of the database **12** can be further reduced. Thus, the system is applicable even in a case where the storage unit **102** of the RFID reader **200** has a small data capacity. Further, since it is not necessary to communicate with the information terminal **10** or the server **20**, the communication unit **103** is not needed, so that the cost of the RFID reader **200** can be reduced.

Only the ID information about the article RFID tag **40** and the information about the relative position of the article RFID tag **40** with respect to the position RFID tag **30** are the data to be managed in the database **12** according to the present exemplary embodiment. Even in this case, position information about management targets to which RFID tags are attached and that can be used both indoor and outdoor with ease at a low cost and are existing over a large area can be managed.

[Description of Position RFID Tag and Article RFID Tag]

FIGS. **15**A and **15**B are diagrams illustrating RFID tags that are examples of the position RFID tag **30** and the article RFID tag **40** that can be used in the first to third exemplary embodiments.

The position RFID tag **30** illustrated in FIG. **15**A is used as a reference position in managing position information about an article to which the article RFID tag **40** is attached. A holding member **32** is an exterior package used to hold the position RFID tag **30**.

As illustrated in FIG. **15**B, the article RFID tag **40** is a RFID tag attached to an article.

Meanwhile, the position RFID tag **30** and the article RFID tag **40** are RFID tags that can communicate with the RF control unit **110** of the RFID reader **100** and operate based on the same principles. Thus, in the position information management methods according to the first to third exemplary embodiments, it is unnecessary to separately provide a detection circuit for article detection and a detection circuit for position detection, so that advantages such as reduced cost, reduced size, and reduced power consumption of the RFID reader **100** can be obtained.

[Method of Increasing Article Position Detection Accuracy]

FIGS. **6** and **7** are flowcharts each illustrating a process of control of a method of further increasing the accuracy of position information about the article RFID tag **40**. The processes are executed as needed when the RFID reader detects the position RFID tag in the first to third exemplary embodiments. The calculation unit of the RFID reader executes a program stored in the storage unit to thereby execute the steps in the flowcharts in FIGS. **6** and **7**.

The control in FIG. **6** is started if the RFID reader **100** detects the position RFID tag **30**.

In step S**401**, the RFID reader **100** stores the detected ID information about the position RFID tag **30** in the storage unit **102**. In step S**402**, the RFID reader **100** decreases a level of RF output (Tx signal) of the RF control unit **110** of the RFID reader **100**. In step S**403**, the RFID reader **100** determines whether communication with the position RFID tag **30** stored in step S**401** is successful again. In a case where the communication is successful, the processing proceeds to step S**402**, and the RF output of the RFID reader is further reduced, and the processing is repeated until the communication is no longer successful in step S**403**. On the other hand, in a case where the communication is not successful, the processing proceeds to step S**404**.

In step S**404**, the RFID reader **100** stores the lowest RF output at which the communication with the position RFID tag **30** is successful in association with the ID information about the position RFID tag **30**. In step S**405**, the RFID reader **100** determines whether the RF output is the lowest RF output value in a predetermined period in a history of successful communication with the position RFID tag **30** of the same ID information. In step S**405**, in a case where the RF output is the lowest RF output value, the processing proceeds to step S**108**. In step S**108**, the ID information about the position RFID tag **30** that is detected is stored in the storage unit **102**, and the processing proceeds to step S**112**. In step S**112**, the relative position is set to zero. On the other hand, in step S**405**, in a case where the RF output is not the lowest RF output value, the position RFID tag detection result is voided, and the relative position is not set to zero.

In the control flowchart in FIG. **6**, in a case where the RFID reader **100** successfully detects the position RFID tag **30** at low RF output, it is determined that the position RFID tag **30** and the RFID reader **100** are near each other. Then, at this timing, the relative position is set to zero so that data upon successful detection of the position RFID tag **30** at the low RF output is associated with the detected data on the article RFID tag **40**.

Similarly, the control in FIG. **7** is started if the RFID reader **100** detects the position RFID tag **30**.

In step S**504**, the RFID reader **100** stores the intensity of the RF input (Rx signal) received by the RF control unit **110** of the RFID reader **100** in the storage unit **102**. In step S**505**, the RFID reader **100** determines whether the RF input is the highest RF input value in a predetermined period in a history of successful communication with the position RFID tag **30** of the same ID information. In step S**505**, in a case where the RF input is the highest RF input value, the processing proceeds to step S**108**. In step S**108**, the ID information about the position RFID tag **30** that is detected is stored in the storage unit **102**, and the processing proceeds to step S**112**. In step S**112**, the relative position is set to zero. On the other hand, in step S**505**, in a case where the RF input is not the highest RF input value, the position RFID tag detection results are voided, and the relative position is not set to zero.

In the control flowchart in FIG. **7**, in a case where the RFID reader **100** successfully detects the position RFID tag **30** at high RF input, it is determined that the position RFID tag **30** and the RFID reader **100** are near each other. Then, at this timing, the relative position is reset so that data on successful detection of the position RFID tag **30** at the high RF input is associated with the detected data on the article RFID tag **40**.

In the article position management system according to each of the exemplary embodiments of the present invention, the position RFID tag **30** is used as the reference position. Thus, performing the control methods illustrated in

FIGS. **6** and **7** particularly on the position RFID tag **30** increases accuracy of position information to be managed.

Further, performing control similar to those in FIGS. **6** and **7** on the article RFID tag **40** can increase the accuracy of position information to be managed.

In a case where the server **20** performs data processing as in the second exemplary embodiment, data on the intensity of the RF input or the intensity of RF output of the RFID reader **100** is stored in association with the databases **21***a* and **21***b* of the server **20**. This enables the server **20** to perform control similar to those in FIGS. **6** and **7**. The methods of increasing the accuracy of position information that are illustrated in FIGS. **6** and **7** are also applicable to the cases of the second exemplary embodiment.

FIG. **8** illustrates a method of using a charging apparatus **300** of the RFID reader **100** as the position RFID tag **30** by including the function of the position RFID tag **30** in the charging apparatus **300**. A connector **301** is used to connect the charging apparatus **300** with the RFID reader **100**.

Use of the charging apparatus **300** makes it possible to detect the position RFID tag **30** in short range at the time of charging the RFID reader **100**. In particular, by combining with the control in FIGS. **6** and **7**, the accuracy of position information about the RFID reader **100** is increased.

[Control of Radiation Directivity of Antenna]

FIGS. **16**A, **16**B, **16**C, and **16**D illustrate the antenna unit **115** with a radiation directivity control function that can be used in the first to third exemplary embodiments. Substrates **1101** and **1102** are overlaid along a Z-axis, which is a thickness direction of the substrates **1101** and **1102**, in this order in a −Z direction.

FIG. **16**A illustrates a front surface of the substrate **1101**. Four antenna elements **1103** are arranged in such a manner that extension directions of the antenna elements **1103** are each changed by 90 degrees along X- and Y-axes so that open ends do not overlap, and a power-feed end, which is an end portion on the opposite side of the open end, is connected to a via **1104**. The extension directions of the open ends can be the opposite directions, or an element shape can be a meander line shape.

FIG. **16**B illustrates a back surface of the substrate **1101**. Four vias **1104** are through the substrate **1101** and are connected to four pads **1105**.

FIG. **16**C illustrates a front surface of the substrate **1102**. Four pads **1106** are connected to a ground **1107** and respectively to four RF lines **1108**. The pads **1105** and **1106** are each in surface contact with a metallic spacer that is a conductive portion (not illustrated) to become conductive.

The four RF lines **1108** pass through respective four RF switches **1109** (**1109***a* to **1109***d*) and a shared RF line **1110**, and are connected to a transmission/reception unit **1111** (coupler **114**).

One end of each of the RF switches **1109** is connected to each of the RF lines **1108**, and another end thereof is connected to the RF line **1110**, and the RF switch **1109** controls whether to short-circuit or open. Thus, in a case where the RF switch **1109** is in a short-circuited state, RF signals can pass through between the transmission/reception unit **1111** and the antenna element **1103**, whereas in a case where the RF switch **1109** is in an open state, RF signals cannot pass through between the transmission/reception unit **1111** and the antenna element **1103**.

FIG. **16**D illustrates a back surface of the substrate **1102**. A ground **1112** is disposed over an entire surface except for regions that overlap the pads **1106** and is electrically connected to the ground **1107** through a plurality of vias (not illustrated) through the substrate **1102**. The line width and thickness of the RF lines **1108** and **1110** are determined based on a layer structure and permittivity of the substrate **1102** to obtain about 50 ohm at RF signal frequencies.

The four pads **1106** are respectively defined as A, B, C, and D in this order in a counterclockwise direction from the top right in the drawing, and total electric lengths of the RF lines connecting A, B, C, D and the transmission/reception unit **1111** are respectively denoted by a, b, c, and d. At this time, the four RF lines **1108** are arranged in a meander line shape to satisfy the relationships $b=a+\lambda/4$, $c=b+\lambda/4$, and $d=c+\lambda/4$ and to not overlap the ground **1107**. The four RF lines **1108** are each to have a phase difference of $\lambda/4$, i.e., about 90 degrees, and rotation directions and implementation methods to provide the phase differences can be any directions and methods, and a phase shifter can be used instead of line lengths.

The RF signals that are transmitted and received by the antenna unit **115** are circularly polarized waves in a case where the RF signals are combined waves of the four antenna elements **1103**, whereas the RF signals are linearly polarized waves in a case where the RF signals are combined waves of a combination of the two facing antenna elements **1103**.

FIGS. **17**A, **17**B, and **17**C illustrate radiation characteristics of an antenna that resonates at 920 MHz in the present exemplary embodiment. At this time, the substrates **1101** and **1102** each have a substrate thickness of 1 mm and a relative permittivity of 4.3, and a distance between the substrates **1101** and **1102** is 7 mm, and an element length of an inverted-F antenna is about $\lambda/4$. Further, the RF lines each have a line width of 1.6 mm and a line thickness of 35 um.

FIG. **17**A illustrates radiation characteristics in a case where all of the RF switches **1109***a* to **1109***d* are short-circuited, and RF signals of circularly polarized waves with the main directivity in a +Z direction are emitted.

FIG. **17**B illustrates radiation characteristics in a case where the RF switches **1109***a* and **1109***c* are short-circuited and the RF switches **1109***b* and **1109***d* are opened, and RF signals of linearly polarized waves are emitted in +X and −X directions.

FIG. **17**C illustrates radiation characteristics in a case where the RF switches **1109***b* and **1109***d* are short-circuited and the RF switches **1109***a* and **1109***c* are opened, and RF signals of linearly polarized waves are emitted in +Y and −Y directions.

With the techniques described above, RFID tags that are situated in X-axis and Y-axis directions and cannot be read by RF signals of circularly polarized waves emitted in the +Z direction alone become readable by changing the directivity. Furthermore, position information about articles to which the RFID tags are attached existing over a large area become detectable. The RFID reader **100** detects the RFID tags while changing the radiation characteristics of the antenna unit **115** in a plurality of directions, and the antenna unit **115** is suitable for use in the first to third exemplary embodiments.

Other Embodiments

The first to third exemplary embodiments described above can be implemented in combination as needed. For example, the RFID reader including the display unit according to the third exemplary embodiment does not necessarily have to display position information about management target articles on the display unit of the RFID reader and can transmit the information to a server or an information terminal. Alternatively, whether to display the information

on the RFID reader or to transmit the information to the server or the information terminal can be selected by a user operation.

The present invention is not to be limited to the above described exemplary embodiments and can be altered or modified in various ways without departing from the spirit and the scope of the present invention. Therefore, the following claims are appended to make the scope of the present invention public.

Other Embodiments

Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

The invention claimed is:

1. A communication apparatus comprising:

a power supply;

a detection unit configured to detect a wireless device;

a storage unit configured to store identification information about the wireless device;

a calculation unit configured to calculate a first relative position of a second wireless device with respect to a first wireless device to be a reference in identifying a position based on a movement amount of the communication apparatus, the second wireless device being a device different from the first wireless device; and

an association unit configured to associate the first relative position, identification information about the second wireless device, and identification information about the first wireless device,

wherein, when a position of the communication apparatus at a time of activation of the power supply of the communication apparatus is defined as an initial position,

in a case where the second wireless device is detected in a state in which the first wireless device is not detected after detection of the initial position by the detection unit,

the storage unit stores a second relative position of the second wireless device with respect to the initial position, and, in a case where the first wireless device is detected after detection of the second wireless device by the detection unit, stores a third relative position of the first wireless device with respect to the initial position, and

based on the second relative position and the third relative position, the calculation unit calculates the first relative position.

2. The communication apparatus according to claim **1**, further comprising:

a determination unit configured to determine whether the wireless device detected by the detection unit is the first wireless device,

wherein the storage unit stores the identification information about the detected wireless device as the identification information about the first wireless device in a case where the determination unit determines that the detected wireless device is the first wireless device.

3. The communication apparatus according to claim **1**, wherein the association unit further associates information indicating time of detection of the wireless device.

4. The communication apparatus according to claim **1**, further comprising a transmission unit configured to transmit the information associated by the association unit to an information terminal.

5. The communication apparatus according to claim **1**, further comprising a display unit configured to display position information about the second wireless device based on the calculated first relative position.

6. The communication apparatus according to claim **1**, wherein the communication apparatus is a radio frequency identification (RFID) reader, the wireless device is an RFID tag, and the detection unit detects the wireless device using RFID.

7. The communication apparatus according to claim **1**, wherein the detection unit detects the wireless device using an antenna configured to change radiation directivity of an electric wave.

8. A non-transitory computer-readable storage medium storing a program that causes a computer to operate as the communication apparatus according to claim **1**.

9. An information processing apparatus comprising:

a reception unit configured to receive, from a communication apparatus that detects a wireless device, identification information about a detected first wireless device and information about a first relative position of the first wireless device with respect to an initial position;

a calculation unit configured to calculate a third relative position of a second wireless device with respect to the first wireless device, based on the information received by the reception unit, using information about a second relative position of the second wireless device to be a reference in identifying a position with respect to the initial position, the second wireless device being a device different from the first wireless device, and the information about the first relative position of the detected first wireless device; and

an association unit configured to associate the third relative position calculated by the calculation unit, the

identification information about the first wireless device, and identification information about the second wireless device,

wherein, when a position of the communication apparatus at a time of activation of a power supply of the communication apparatus is defined as the initial position,

in a case where the first wireless device is detected in a state in which the second wireless device is not detected after detection of the initial position,

based on the first relative position, and based on a second relative position of the second wireless device with respect to the initial position in a case where the second wireless device is detected after detection of the first wireless device, the calculation unit calculates the third relative position.

10. The information processing apparatus according to claim **9**,

wherein the reception unit receives information indicating time of the detection of the wireless device by the communication apparatus, and

wherein the calculation unit selects a wireless device to be a target of calculation of the third relative position, based on first time at which the first wireless device is detected and second time at which the second wireless device is detected.

11. The information processing apparatus according to claim **9**, further comprising a transmission unit configured to transmit information about the third relative position calculated by the calculation unit to an information terminal.

12. The information processing apparatus according to claim **9**, further comprising a display unit configured to display position information about the wireless device that is indicated by the identification information received by the reception unit, based on the third relative position calculated by the calculation unit.

13. The information processing apparatus according to claim **9**, wherein the wireless device is an RFID tag, the communication apparatus that detects the wireless device is an RFID reader, and the reception unit receives information about the wireless device detected by the communication apparatus using RFID.

14. A non-transitory computer-readable storage medium storing a program that causes a computer to operate as the information processing apparatus according to claim **9**.

15. A position information management method comprising:

detecting a wireless device by a communication apparatus;

calculating a first relative position of a second wireless device different from a first wireless device with respect to the first wireless device to be a reference in identifying a position, based on;

i) a movement amount of the communication apparatus detected by the detecting,

wherein, when a position of the communication apparatus at a time of activation of the power supply of the communication apparatus is defined as an initial position, in a case where the first wireless device is detected in a state in which the second wireless device is not detected after detection of the initial position,

ii) a third relative position of the first wireless device with respect to the initial position, and

iii) a second relative position of the second wireless device with respect to the initial position in a case where the second wireless device is detected after detection of the first wireless device; and

associating the first relative position calculated by the calculating, identification information about the second wireless device, and identification information about the first wireless device.

16. A position information management method comprising:

receiving, from a communication apparatus that detects a wireless device, identification information about a detected first wireless device and information about a first relative position of the first wireless device with respect to an initial position;

calculating, when a position of the communication apparatus at a time of activation of the power supply of the communication apparatus is defined as an initial position, in a case where the first wireless device is detected in a state in which a second wireless device to be a reference in identifying a position is not detected after detection of the initial position, the second wireless device being a device different from the first wireless device, a third relative position of the first wireless device with respect to the second wireless device, using the information about the first relative position received by the receiving and information about the second relative position of the second wireless device with respect to the initial position; and

associating the third relative position calculated by the calculating, the identification information about the second wireless device, and identification information about the first wireless device.

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