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(54) **HAND HYGIENE COMPLIANCE MONITORING**

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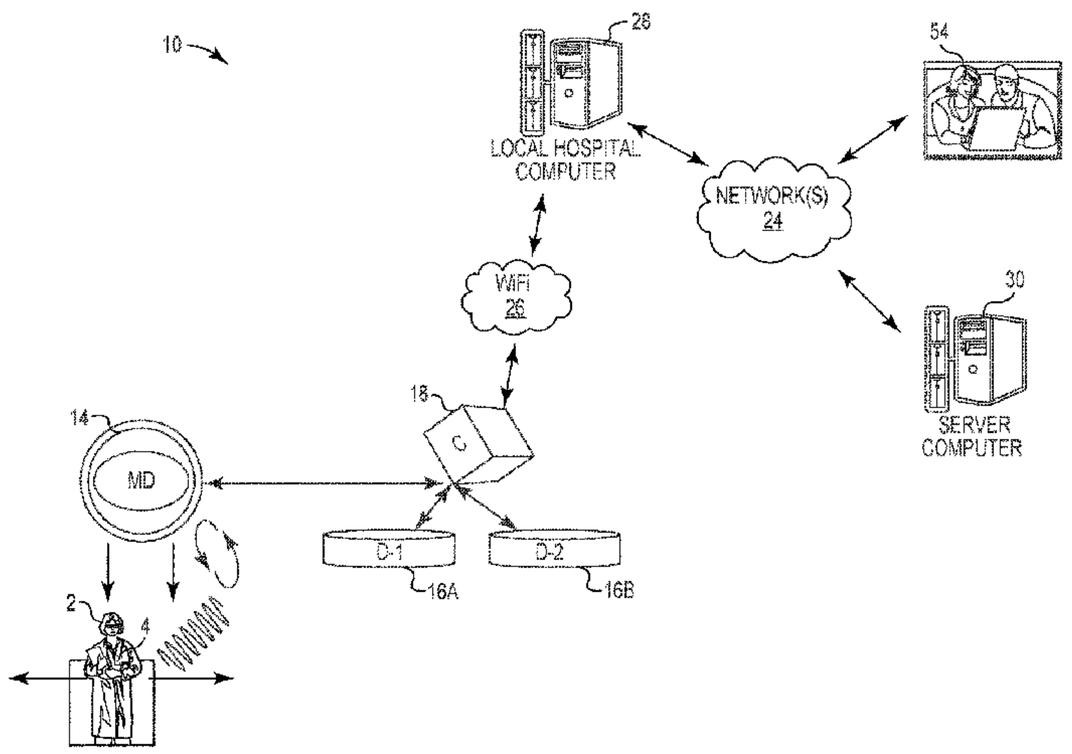
(57) **ABSTRACT**

A system and associated processes monitor hand hygiene compliance. The system includes hand hygiene product dispensers positioned within areas of concern (AOC) in a facility in which hand hygiene events are to be monitored. The dispensers detect dispense events initiated at the dispenser and transmit a dispense event signal indicative that a dispense event occurred along with dispenser identification information. The system also includes a plurality of compliance badges, each worn by a different person in the facility. Each compliance badge receives dispense event signals corresponding dispenser identification information associated with dispense events initiated by the wearer of the compliance badge. The badges store dispense event records associated with each dispense event initiated by the wearer and thus keep track of all dispense events initiated by the wearer of the compliance badge. One or more data gathering stations positioned at various locations through the facility receive the dispense event information from the individual badges when they come within range. The dispense event
(Continued)



information may then be transferred to a local or remote computer for analysis and reporting on hand hygiene events taking place within the facility.

26 Claims, 56 Drawing Sheets

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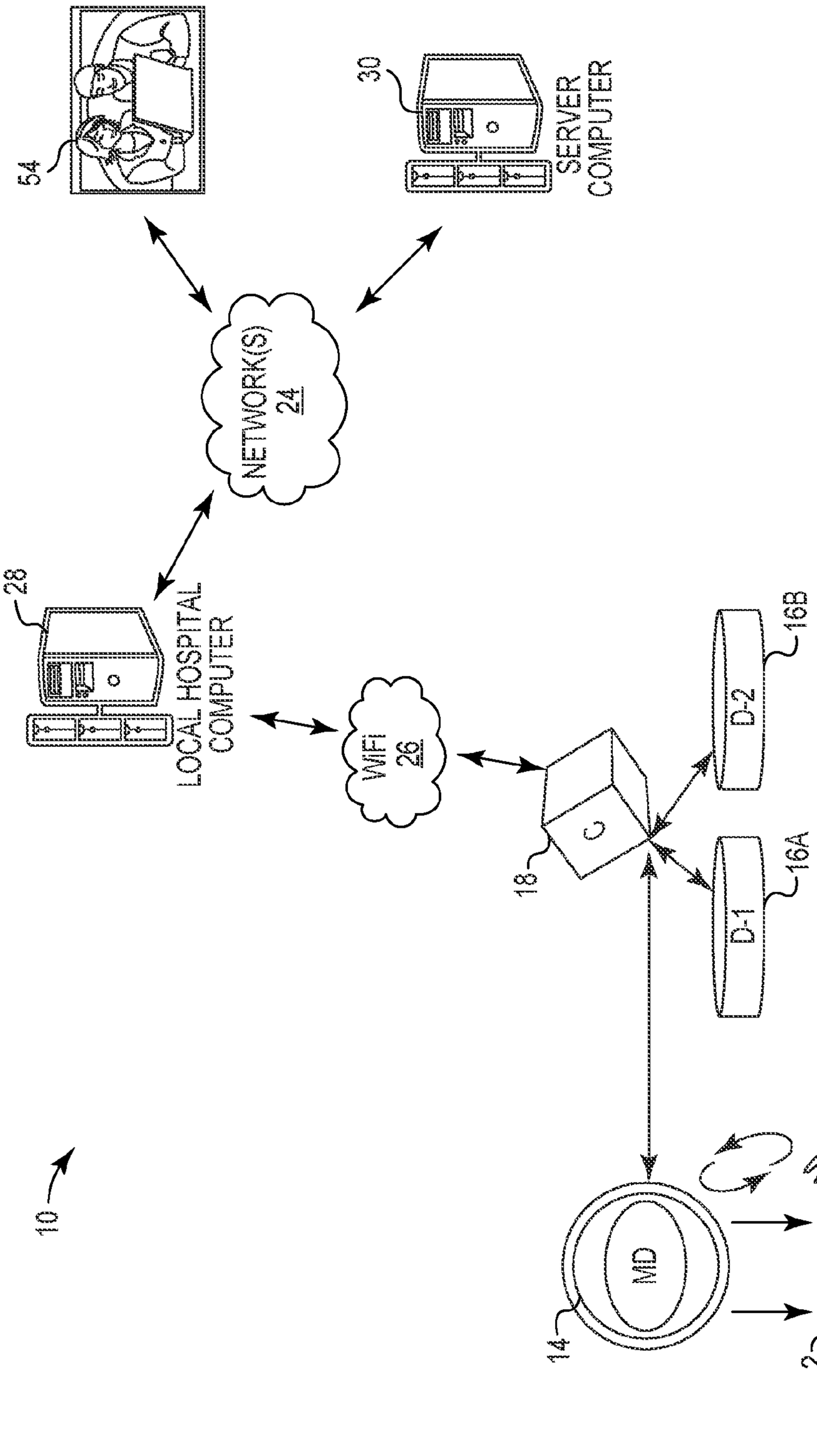
54
30
SERVER COMPUTER
NETWORK(S) 24
28
LOCAL HOSPITAL COMPUTER
WIFI 26
18
C
D-2
16B
D-1
16A
10
MD
14
4
2

Fig. 1

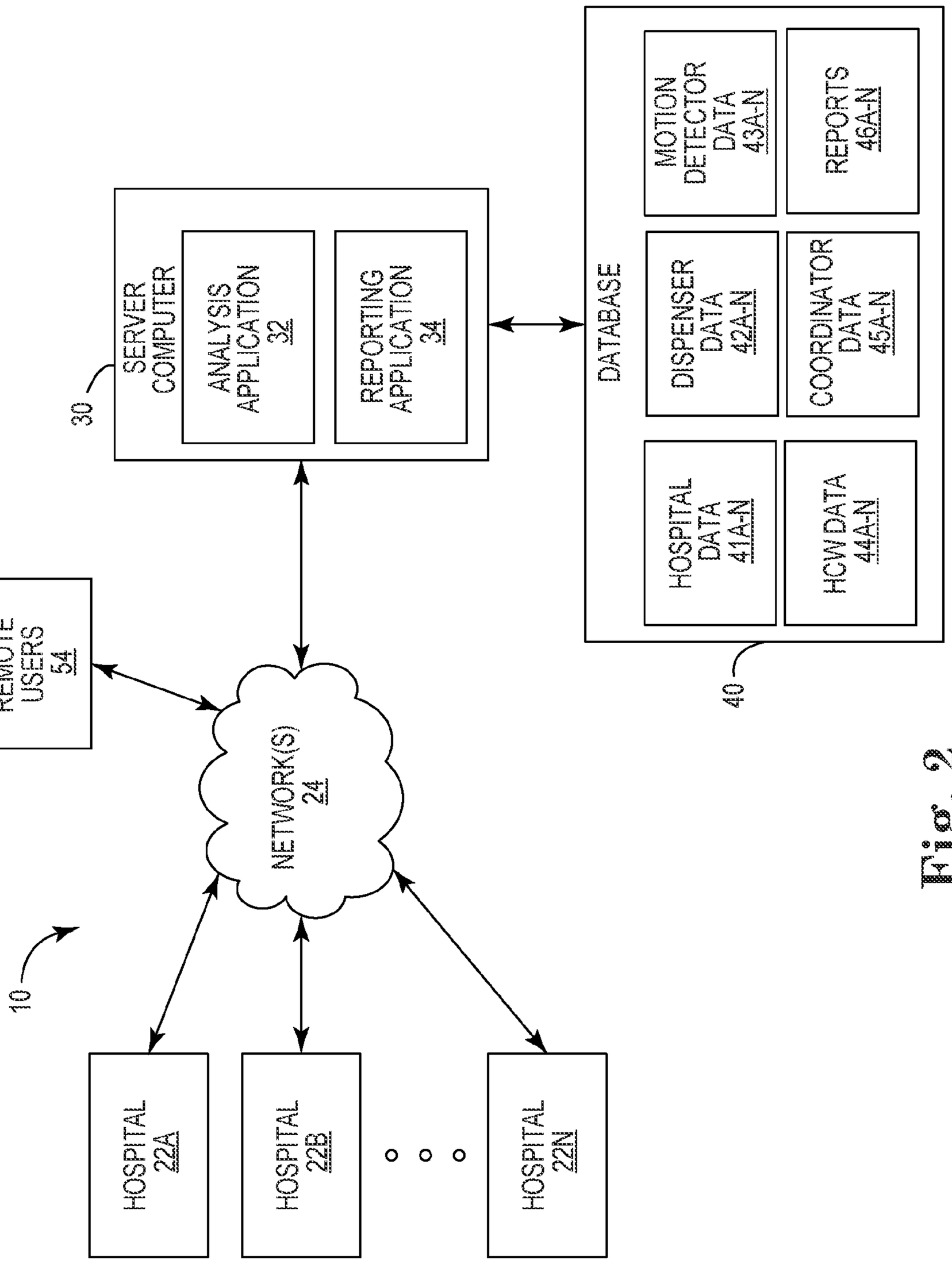
HOSPITAL 22A
HOSPITAL 22B
HOSPITAL 22N
10
NETWORK(S) 24
REMOTE USERS 54
SERVER COMPUTER 30
ANALYSIS APPLICATION 32
REPORTING APPLICATION 34
DATABASE 40
HOSPITAL DATA 41A-N
DISPENSER DATA 42A-N
MOTION DETECTOR DATA 43A-N
HCW DATA 44A-N
COORDINATOR DATA 45A-N
REPORTS 46A-N

Fig. 2

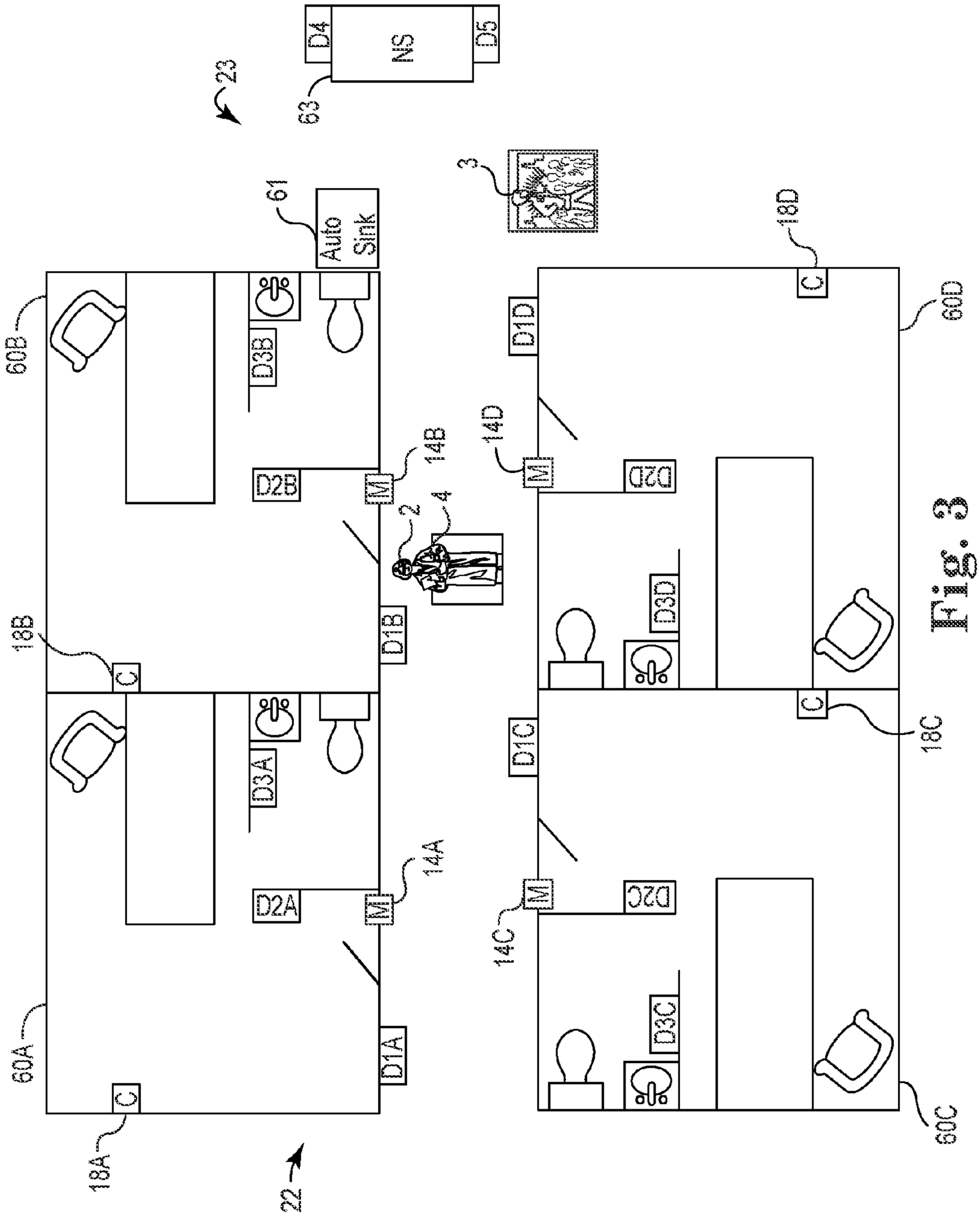
23
63
D4
NS
D5
61
Auto Sink
3
60B
D3B
D2B
14B
M
2
4
18B
C
D1B
D3A
D2A
14A
M
C
60A
18A
C
D1A
22
18D
C
60D
D1D
14D
M
D2D
D3D
C
18C
D1C
M
D2C
14C
C
D3C
60C

Fig. 3

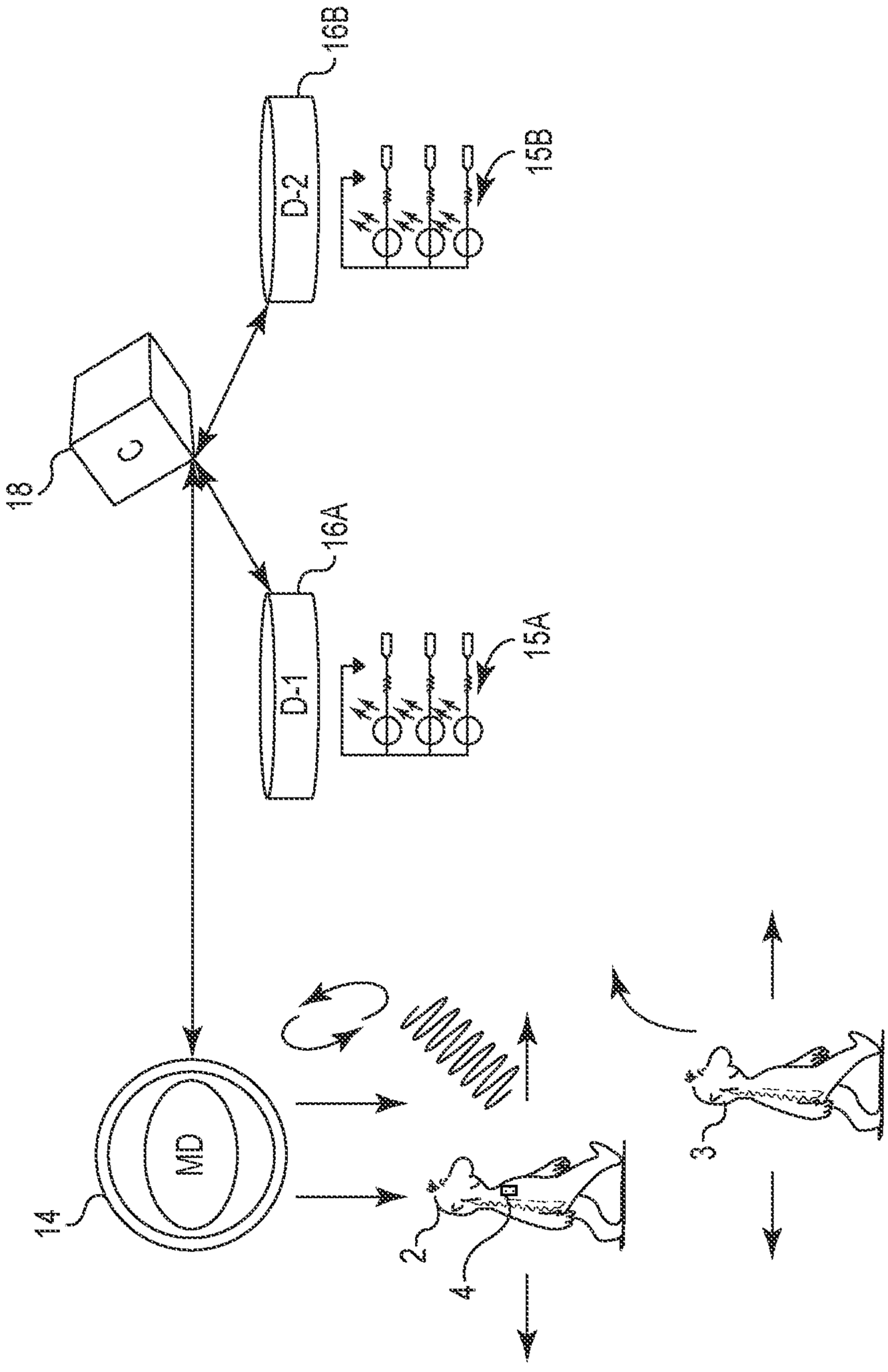

Fig. 4

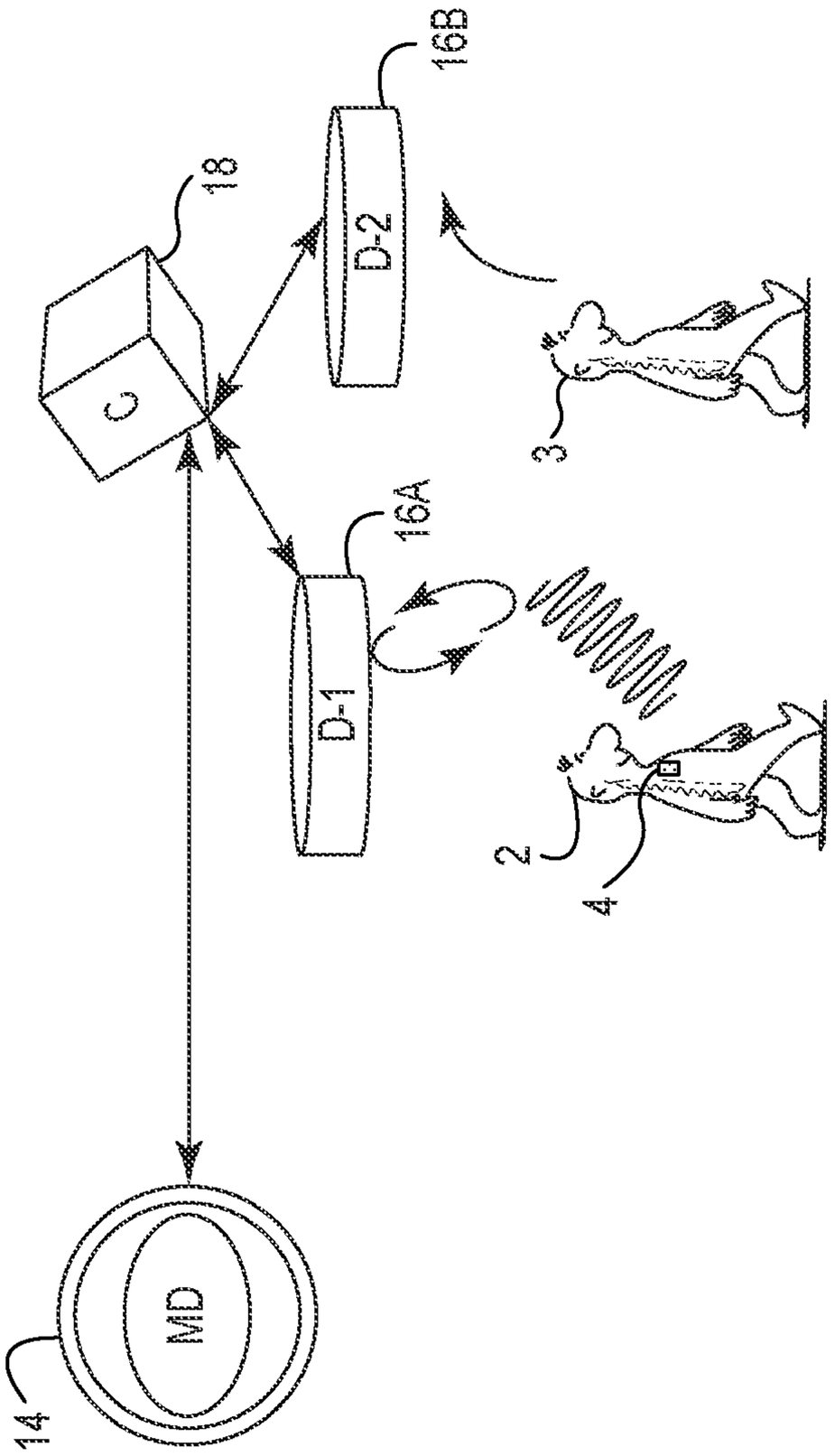

Fig. 5

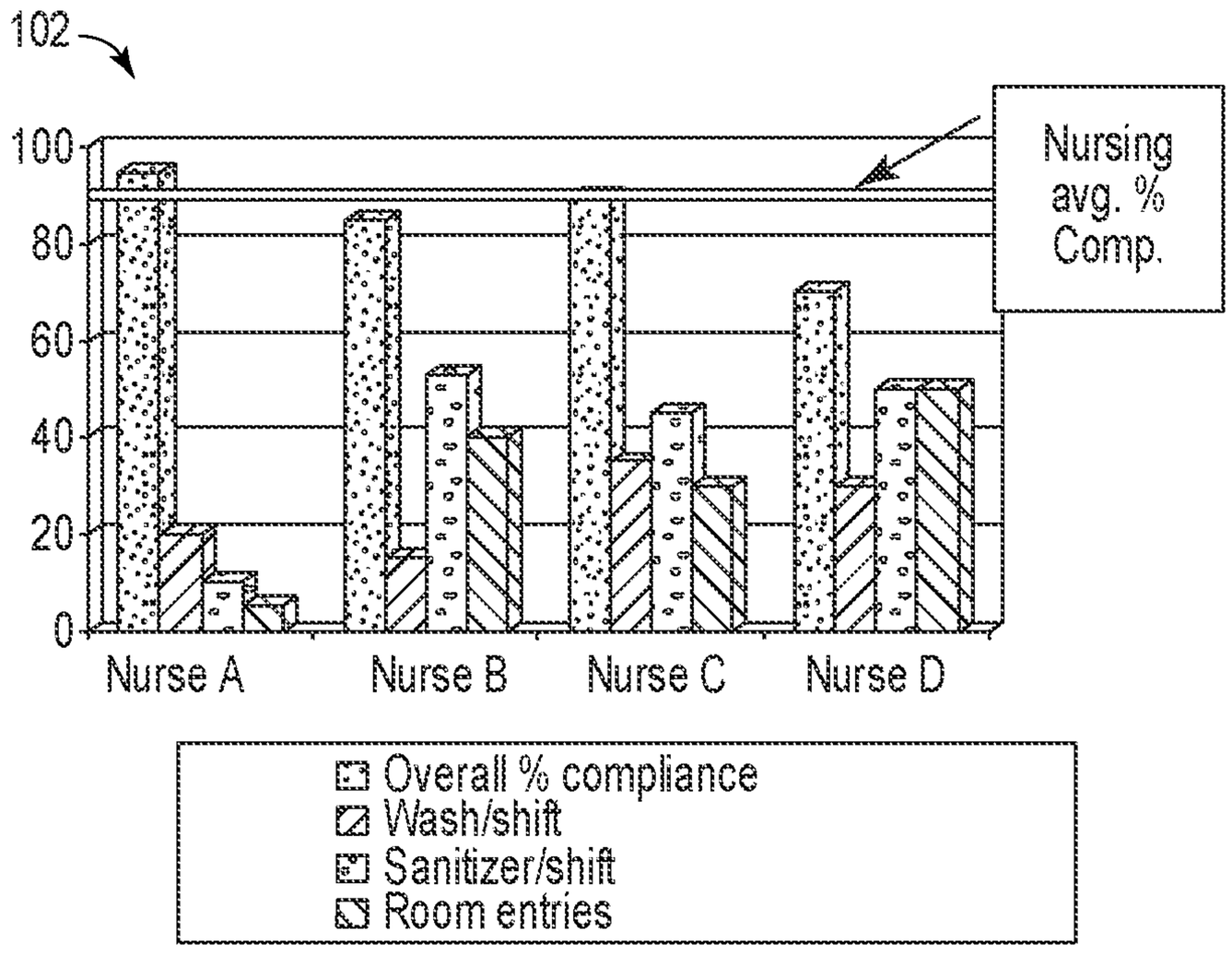
102
100
80
60
40
20
0
Nursing avg. % Comp.
Nurse A
Nurse B
Nurse C
Nurse D
Overall % compliance
Wash/shift
Sanitizer/shift
Room entries

Fig. 6A

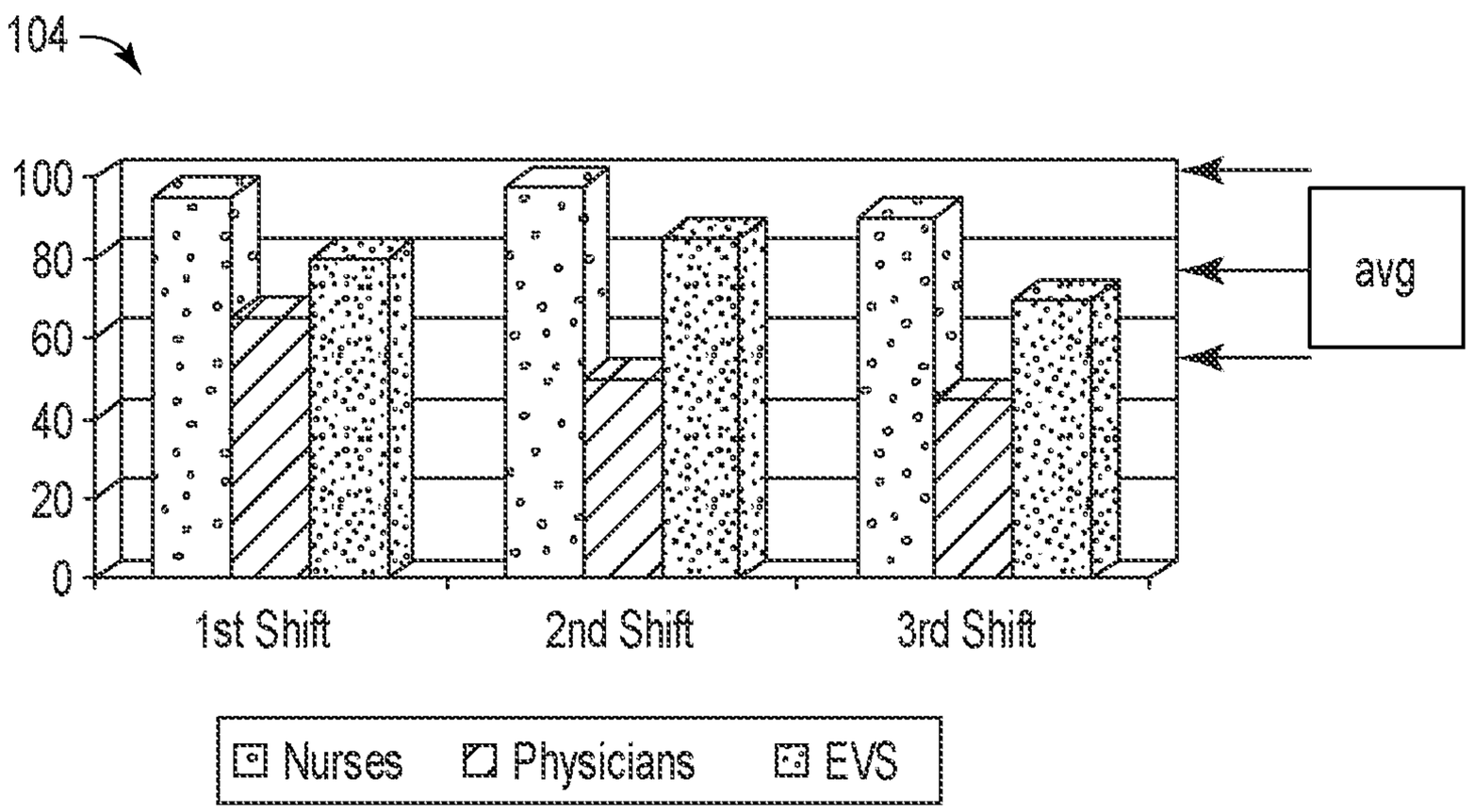
104
100
80
60
40
20
0
avg
1st Shift
2nd Shift
3rd Shift
Nurses
Physicians
EVS

Fig. 6B

106

Dispenser Location	Product Status	Product Type	Battery Status
W231	OK	QuikCare	Low
W255	Low	BactiStat	OK
W375	Low	QuikCare	Low
E515	Low	Endure 420	OK

Fig. 6C

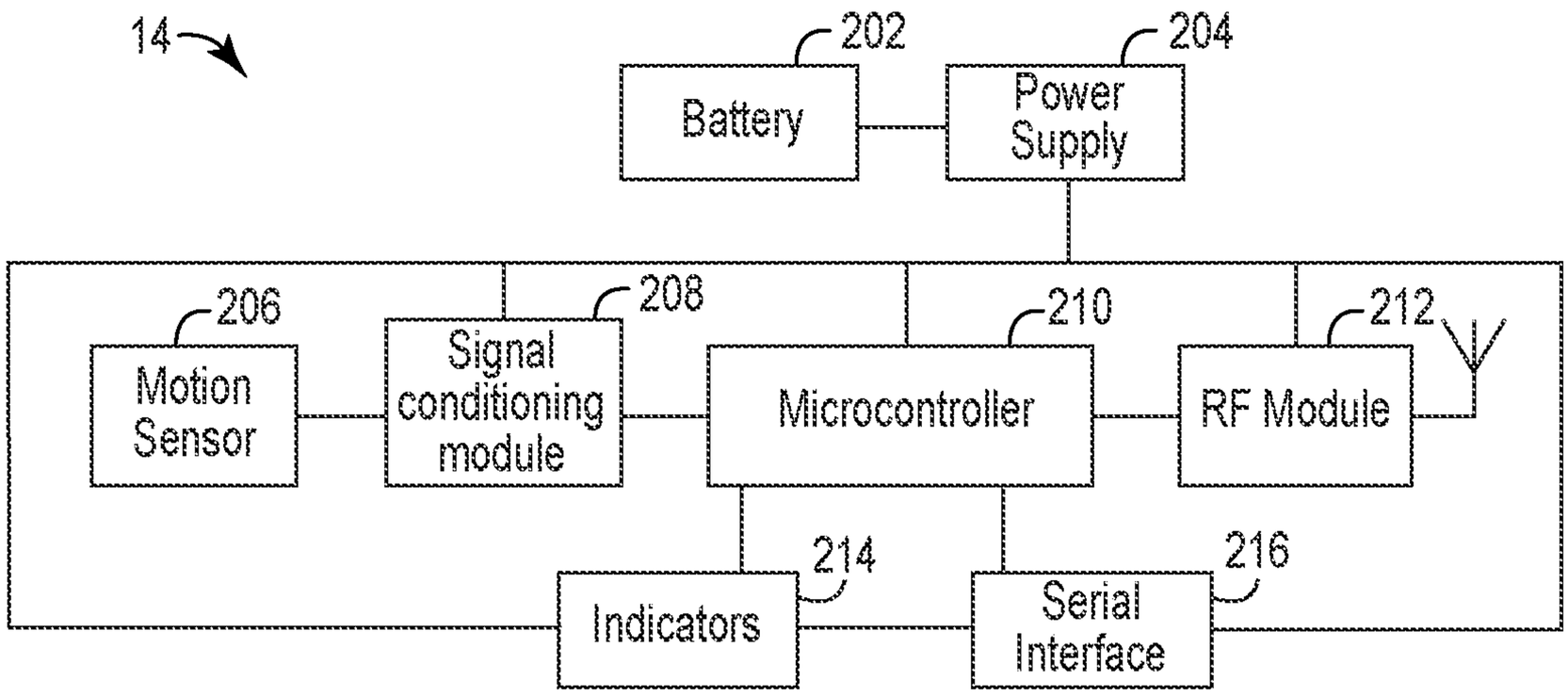
14
202
Battery
204
Power Supply
206
Motion Sensor
208
Signal conditioning module
210
Microcontroller
212
RF Module
214
Indicators
216
Serial Interface

Fig. 7

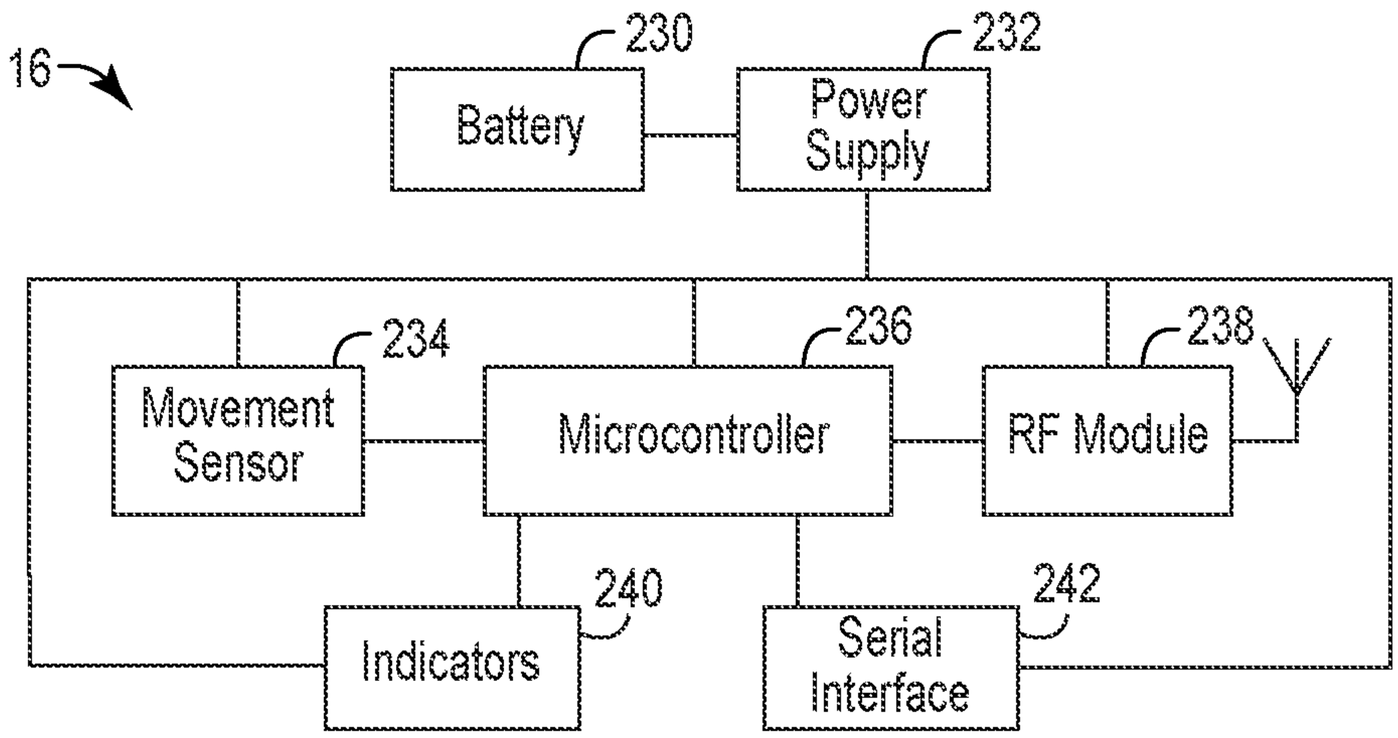
16
230
Battery
232
Power Supply
234
Movement Sensor
236
Microcontroller
238
RF Module
240
Indicators
242
Serial Interface

Fig. 8

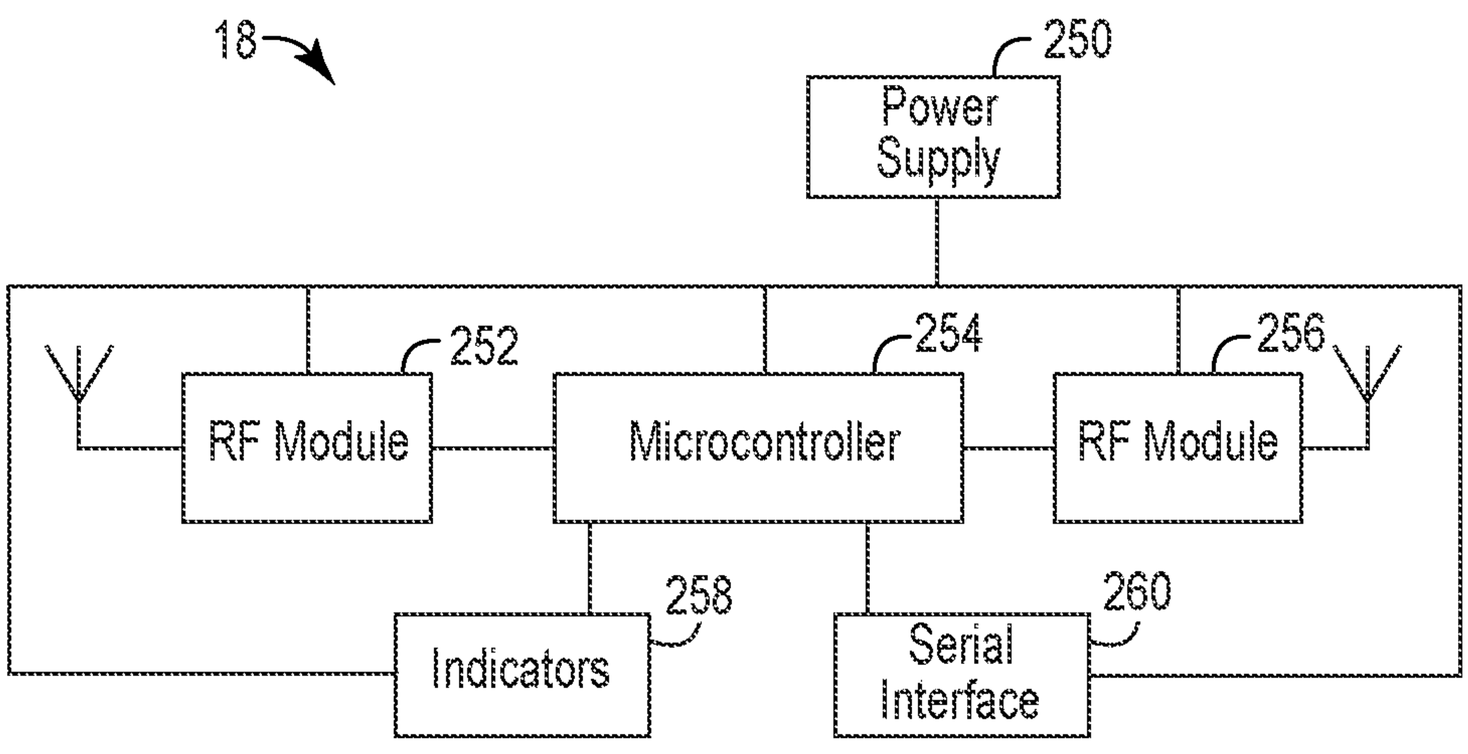
18
250
Power Supply
252
RF Module
254
Microcontroller
256
RF Module
258
Indicators
260
Serial Interface

Fig. 9

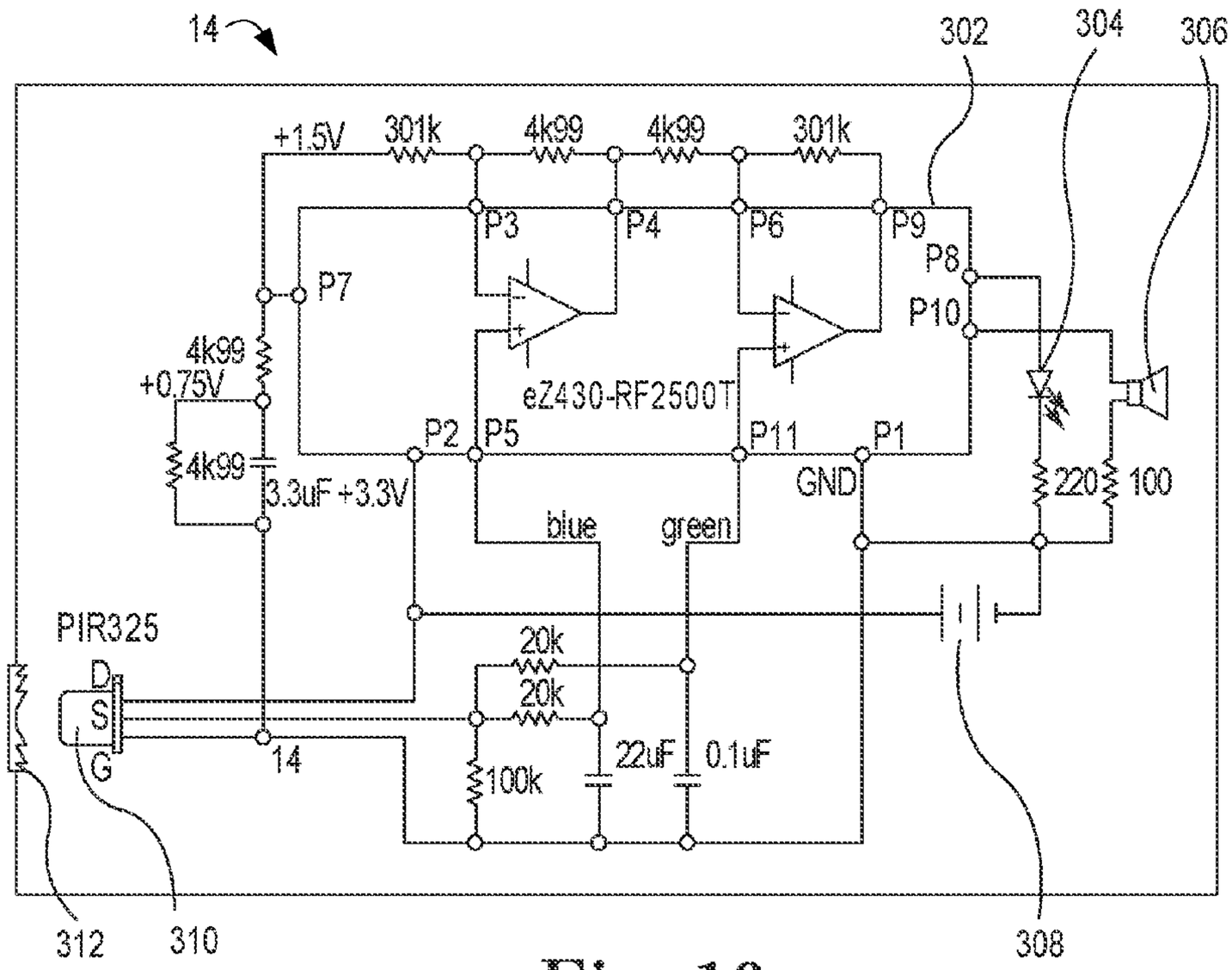
14
302
304
306
+1.5V
301k
4k99
4k99
301k
P3
P4
P6
P9
P8
P10
P7
4k99
+0.75V
eZ430-RF2500T
P2
P5
P11
P1
4k99
3.3uF
+3.3V
GND
220
100
blue
green
PIR325
20k
20k
D
S
G
14
22uF
0.1uF
100k
312
310
308

Fig. 10

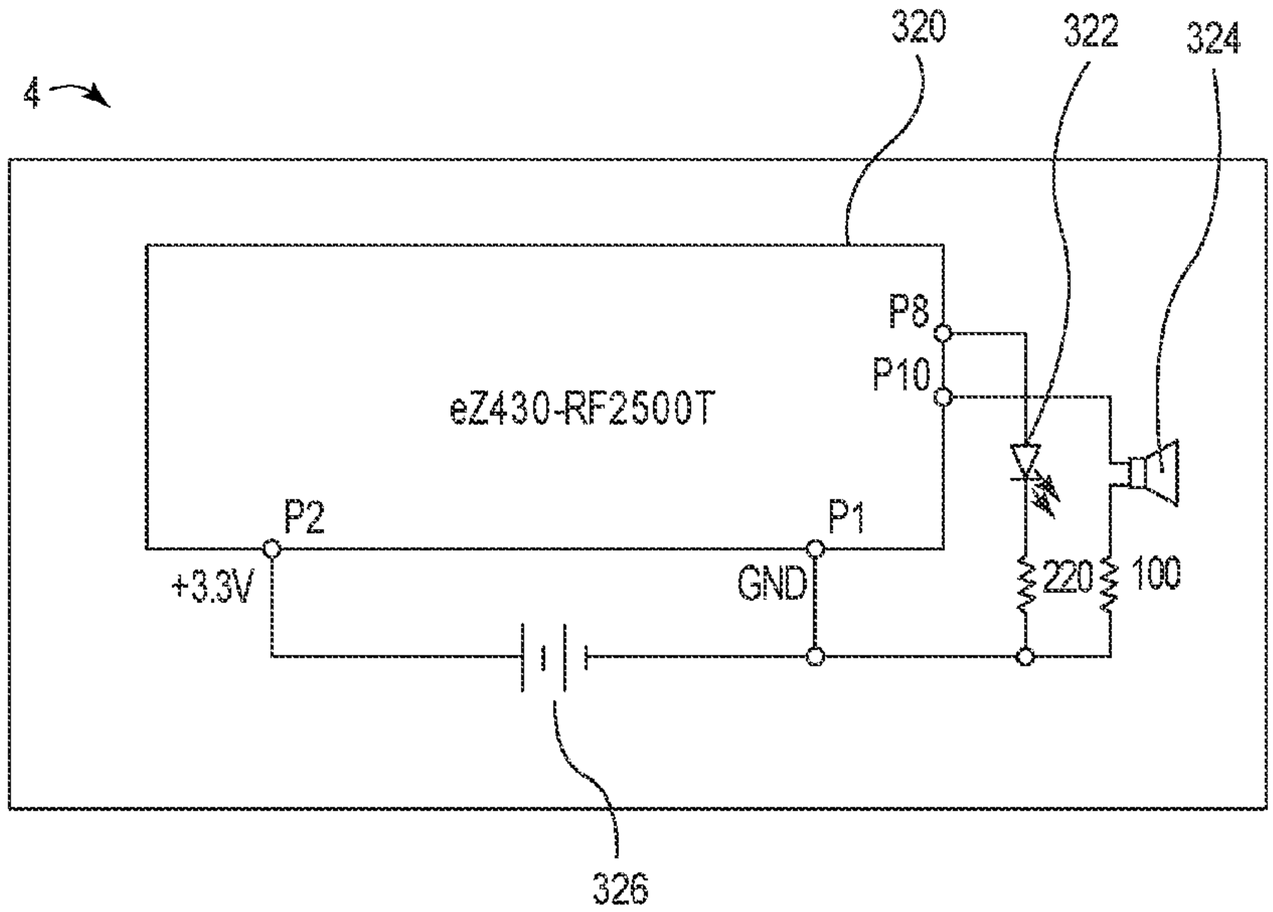
320
322
324
4
P8
P10
eZ430-RF2500T
P2
P1
+3.3V
GND
220
100
326

Fig. 11

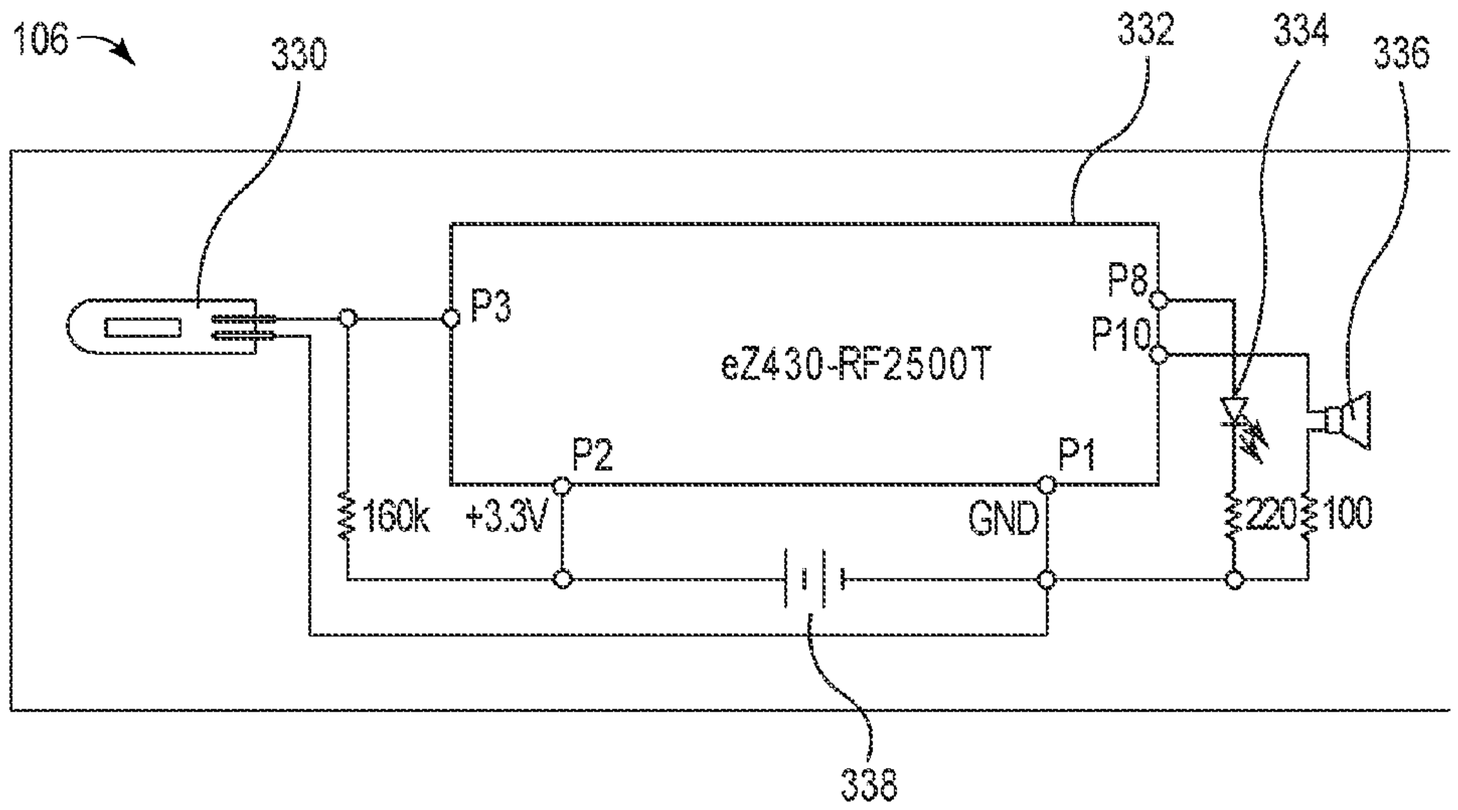
106
330
332
334
336
P3
P8
P10
eZ430-RF2500T
P2
P1
160k
+3.3V
GND
220
100
338

Fig. 12

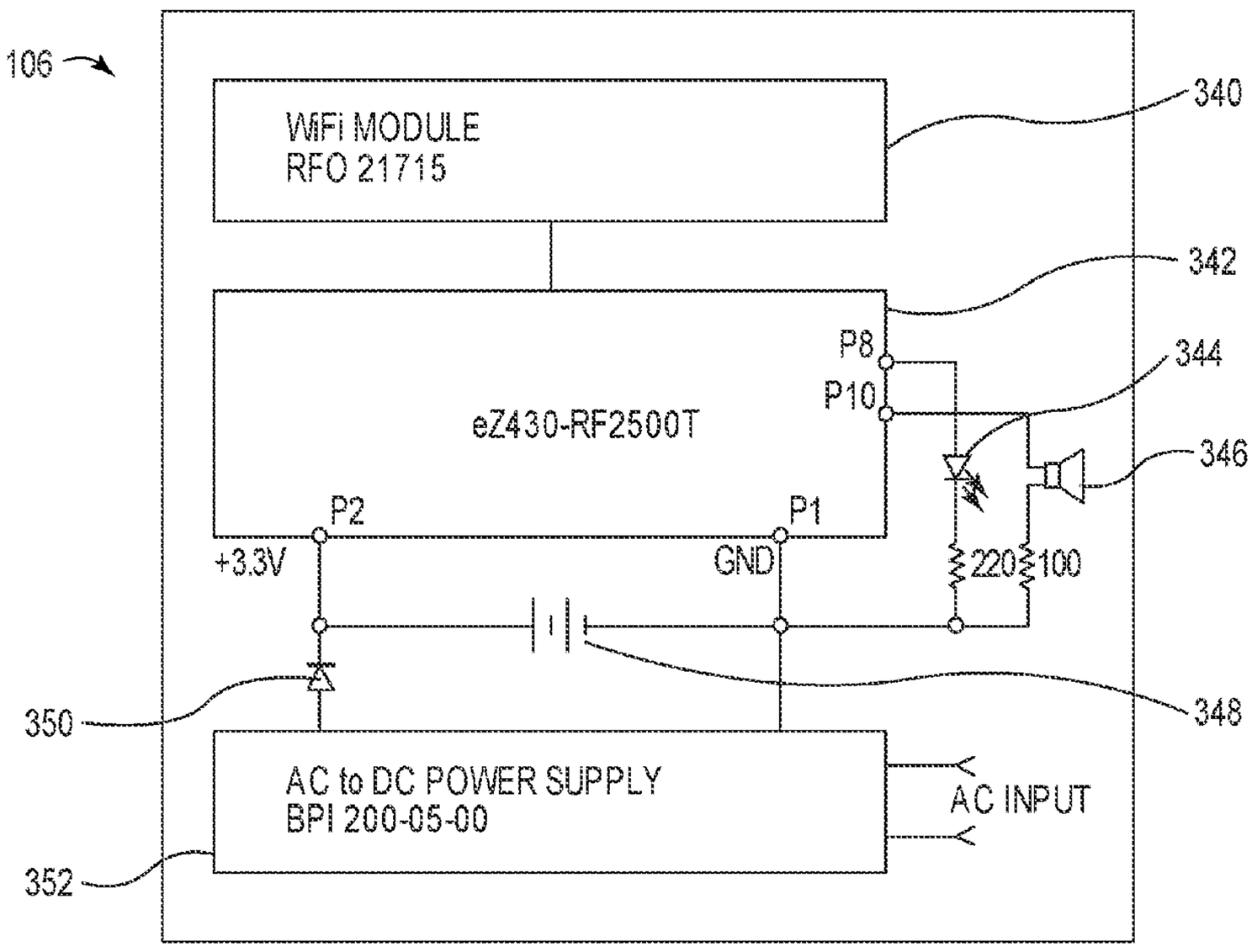
106
WiFi MODULE
RFO 21715
340
342
P8
P10
344
eZ430-RF2500T
346
P2
P1
+3.3V
GND
220
100
350
348
AC to DC POWER SUPPLY
BPI 200-05-00
AC INPUT
352

Fig. 13

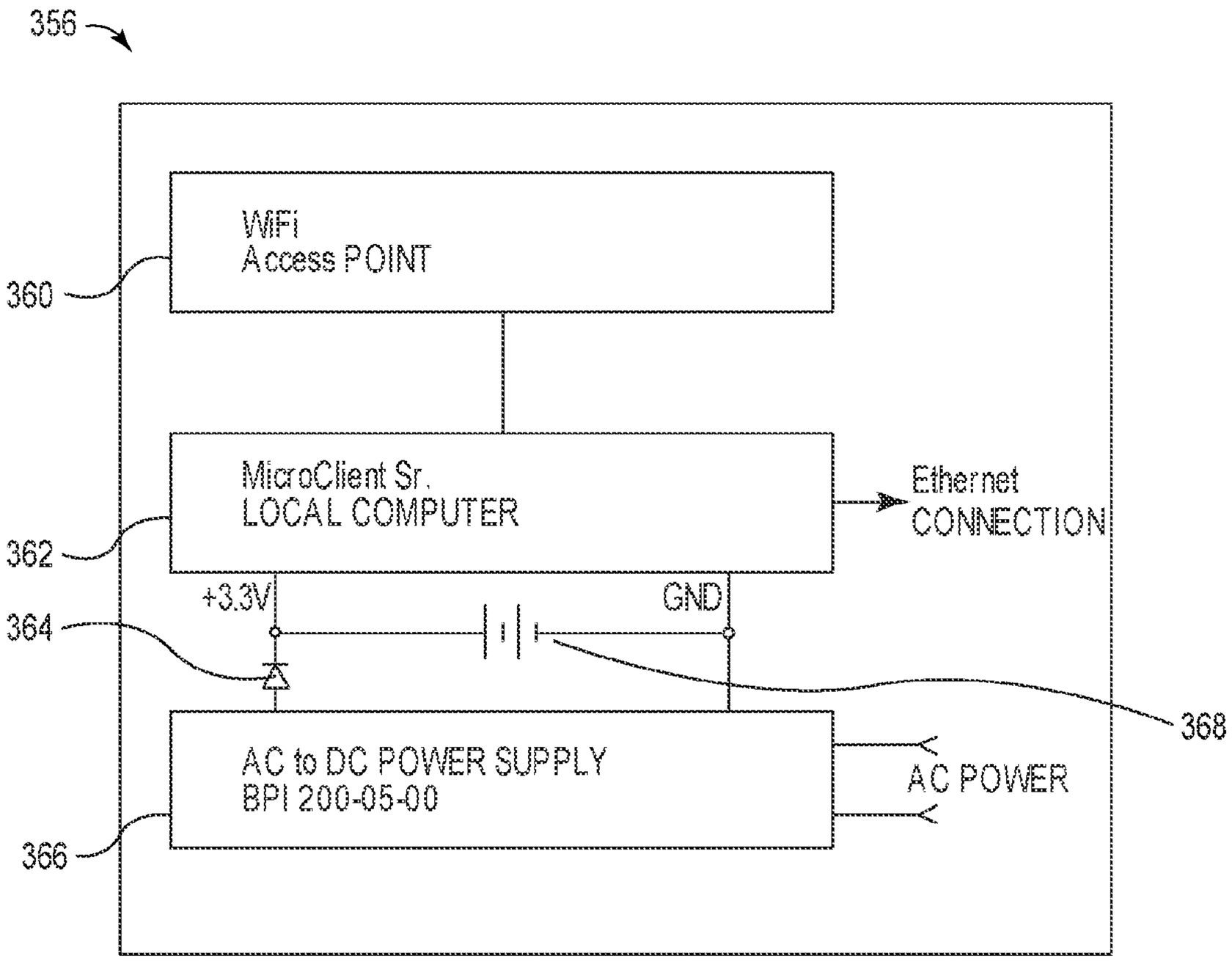
356
WIFI
Access POINT
360
MicroClient Sr.
LOCAL COMPUTER
362
Ethernet
CONNECTION
+3.3V
GND
364
368
AC to DC POWER SUPPLY
BPI 200-05-00
AC POWER
366

Fig. 14

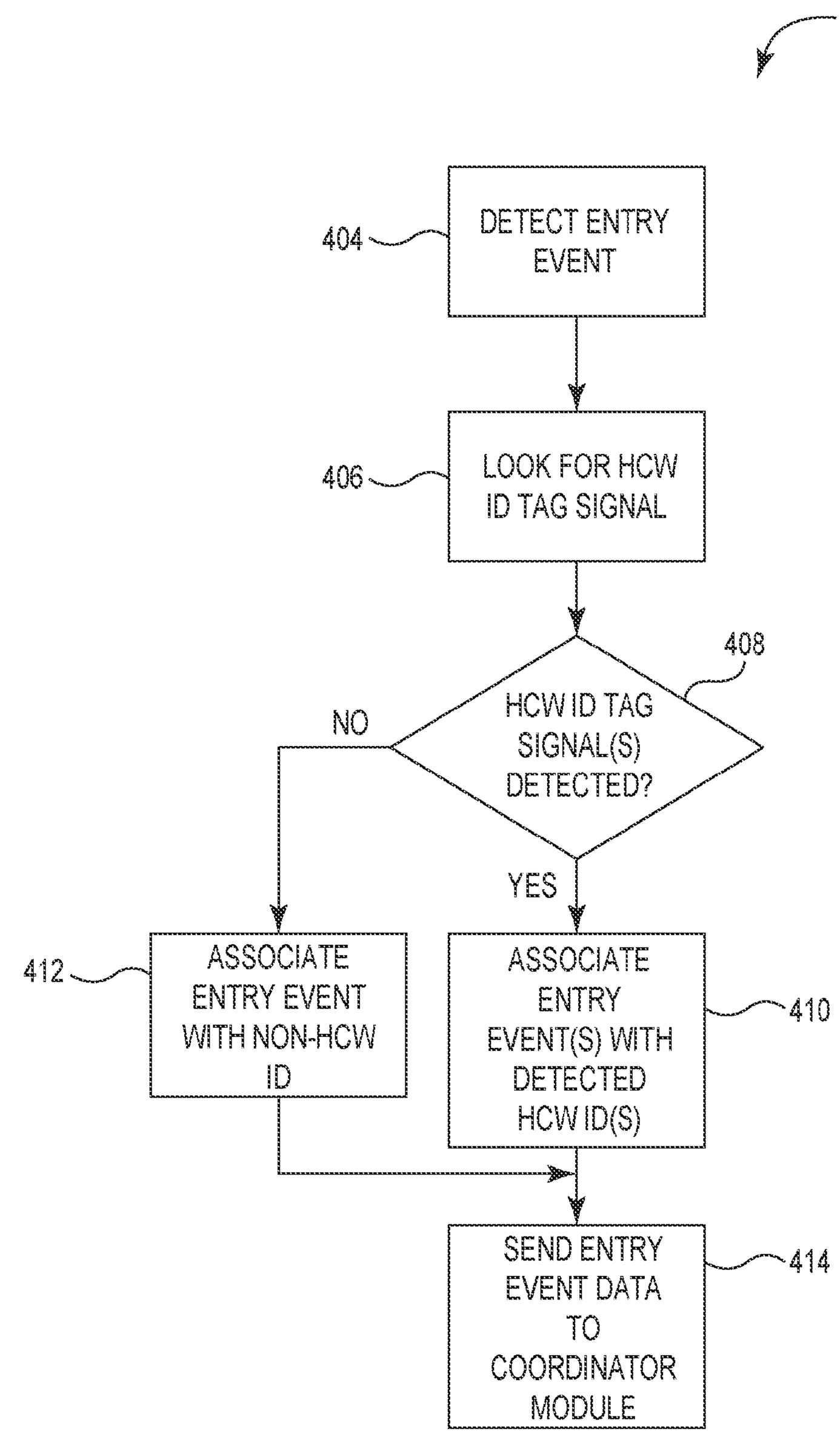
402
404
DETECT ENTRY EVENT
406
LOOK FOR HCW ID TAG SIGNAL
408
HCW ID TAG SIGNAL(S) DETECTED?
NO
YES
412
ASSOCIATE ENTRY EVENT WITH NON-HCW ID
ASSOCIATE ENTRY EVENT(S) WITH DETECTED HCW ID(S)
410
SEND ENTRY EVENT DATA TO COORDINATOR MODULE
414

Fig. 15

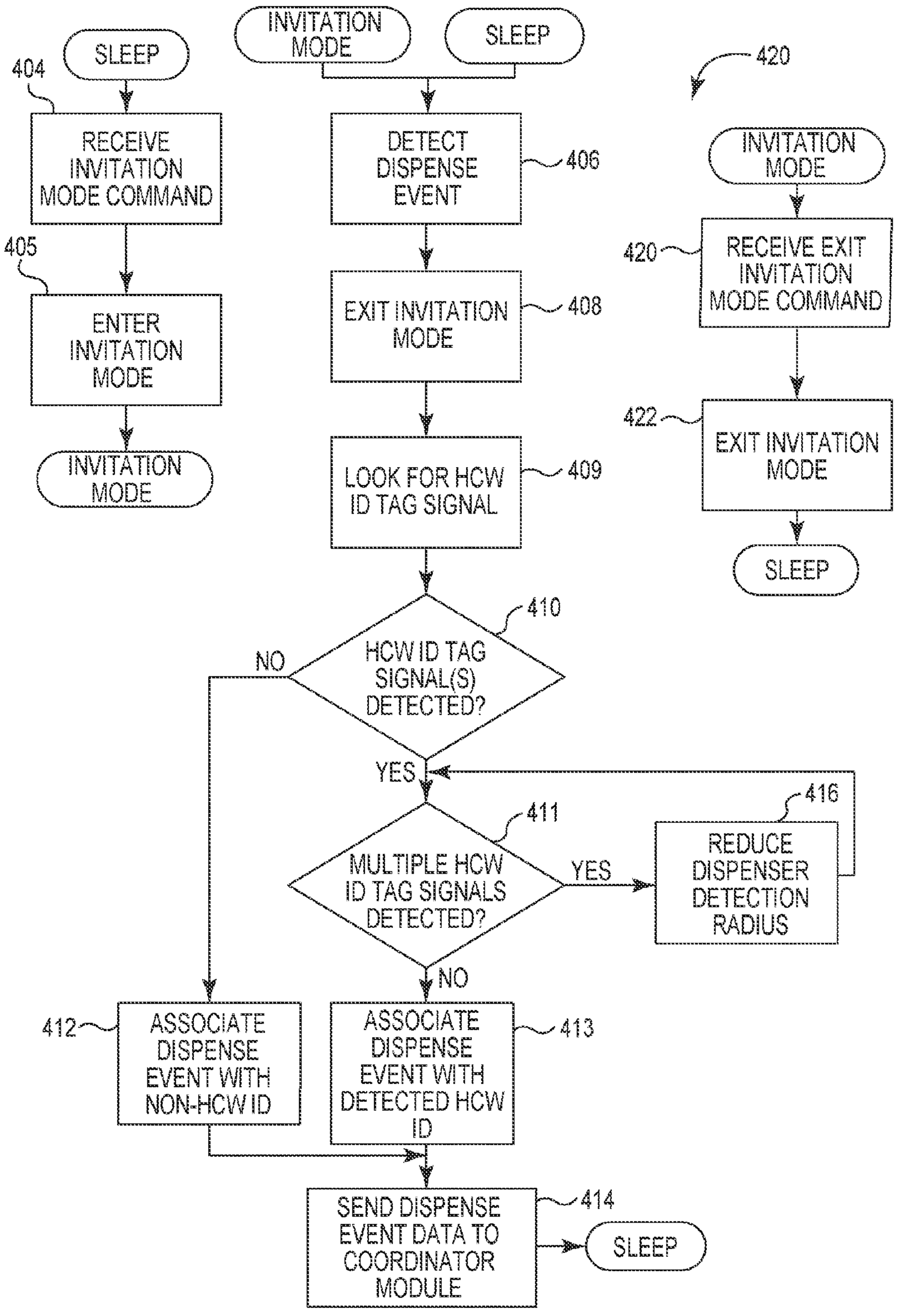
SLEEP
404
RECEIVE INVITATION MODE COMMAND
405
ENTER INVITATION MODE
INVITATION MODE
INVITATION MODE
SLEEP
DETECT DISPENSE EVENT
406
EXIT INVITATION MODE
408
LOOK FOR HCW ID TAG SIGNAL
409
HCW ID TAG SIGNAL(S) DETECTED?
410
NO
YES
MULTIPLE HCW ID TAG SIGNALS DETECTED?
411
YES
REDUCE DISPENSER DETECTION RADIUS
416
NO
ASSOCIATE DISPENSE EVENT WITH NON-HCW ID
412
ASSOCIATE DISPENSE EVENT WITH DETECTED HCW ID
413
SEND DISPENSE EVENT DATA TO COORDINATOR MODULE
414
SLEEP
420
INVITATION MODE
420
RECEIVE EXIT INVITATION MODE COMMAND
422
EXIT INVITATION MODE
SLEEP

Fig. 16

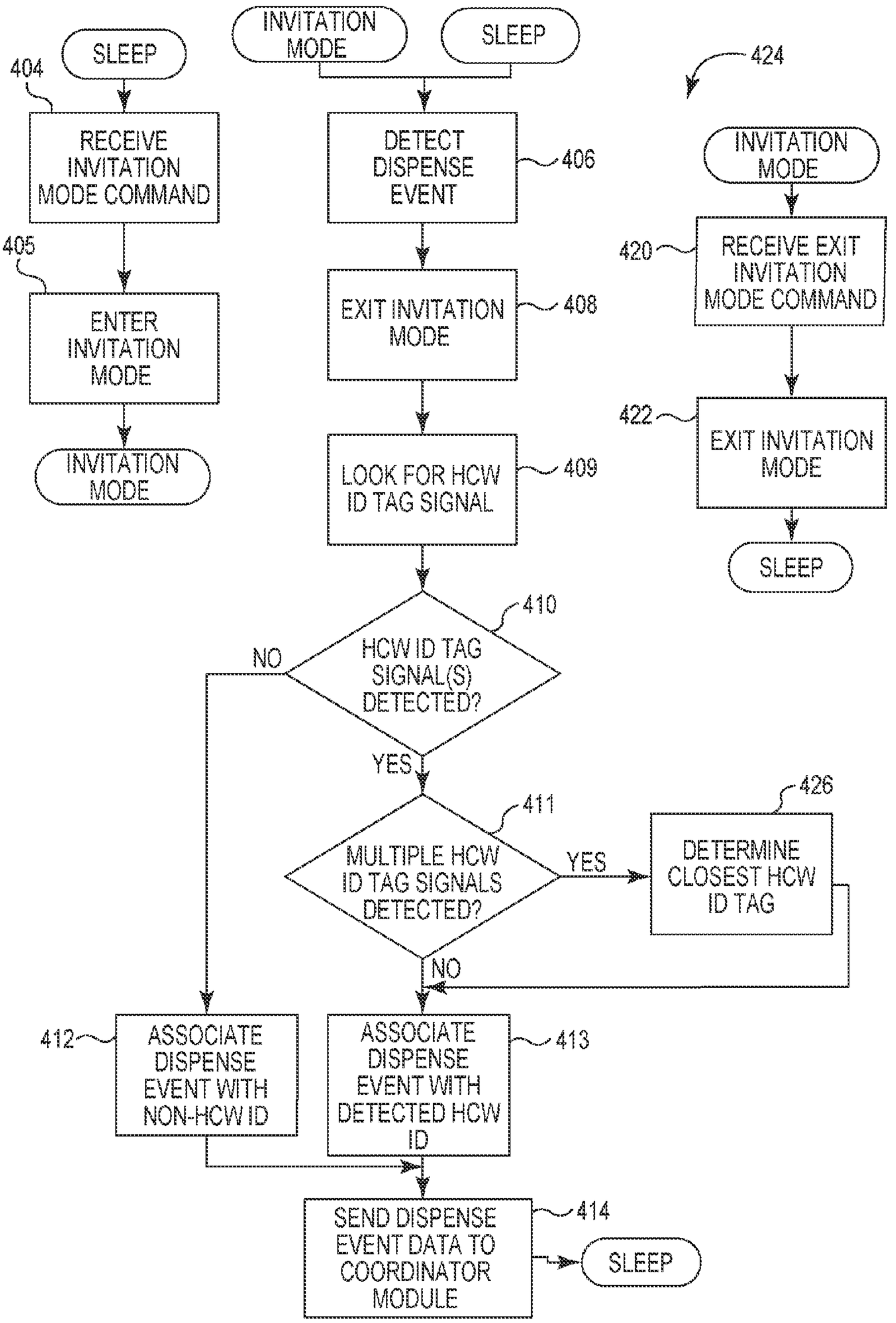
SLEEP
404
RECEIVE INVITATION MODE COMMAND
405
ENTER INVITATION MODE
INVITATION MODE
INVITATION MODE
SLEEP
DETECT DISPENSE EVENT
406
EXIT INVITATION MODE
408
LOOK FOR HCW ID TAG SIGNAL
409
410
HCW ID TAG SIGNAL(S) DETECTED?
NO
YES
411
MULTIPLE HCW ID TAG SIGNALS DETECTED?
YES
426
DETERMINE CLOSEST HCW ID TAG
NO
412
ASSOCIATE DISPENSE EVENT WITH NON-HCW ID
ASSOCIATE DISPENSE EVENT WITH DETECTED HCW ID
413
SEND DISPENSE EVENT DATA TO COORDINATOR MODULE
414
SLEEP
424
INVITATION MODE
420
RECEIVE EXIT INVITATION MODE COMMAND
422
EXIT INVITATION MODE
SLEEP

Fig. 17

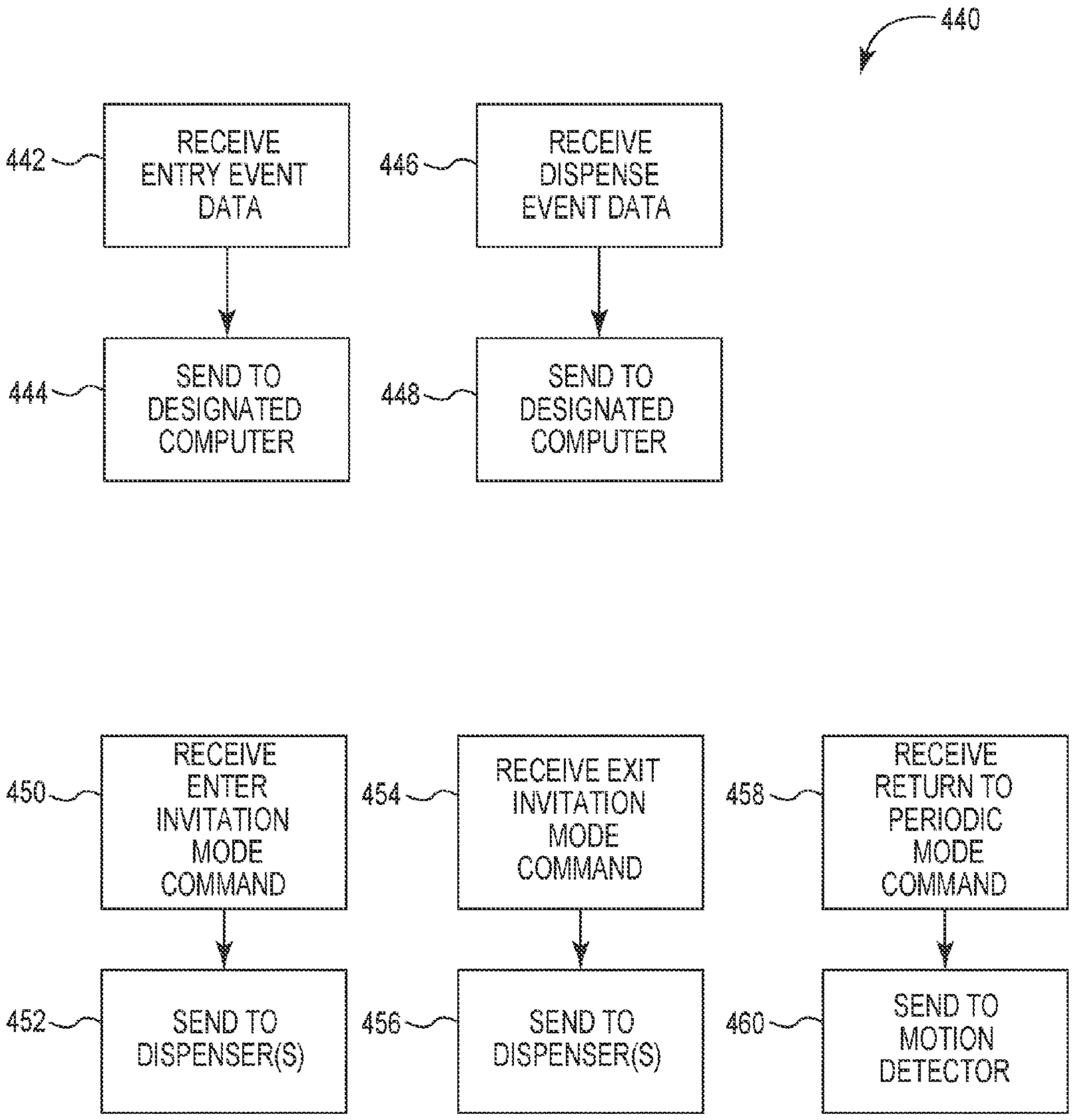
440
442
RECEIVE ENTRY EVENT DATA
444
SEND TO DESIGNATED COMPUTER
446
RECEIVE DISPENSE EVENT DATA
448
SEND TO DESIGNATED COMPUTER
450
RECEIVE ENTER INVITATION MODE COMMAND
452
SEND TO DISPENSER(S)
454
RECEIVE EXIT INVITATION MODE COMMAND
456
SEND TO DISPENSER(S)
458
RECEIVE RETURN TO PERIODIC MODE COMMAND
460
SEND TO MOTION DETECTOR

Fig. 18

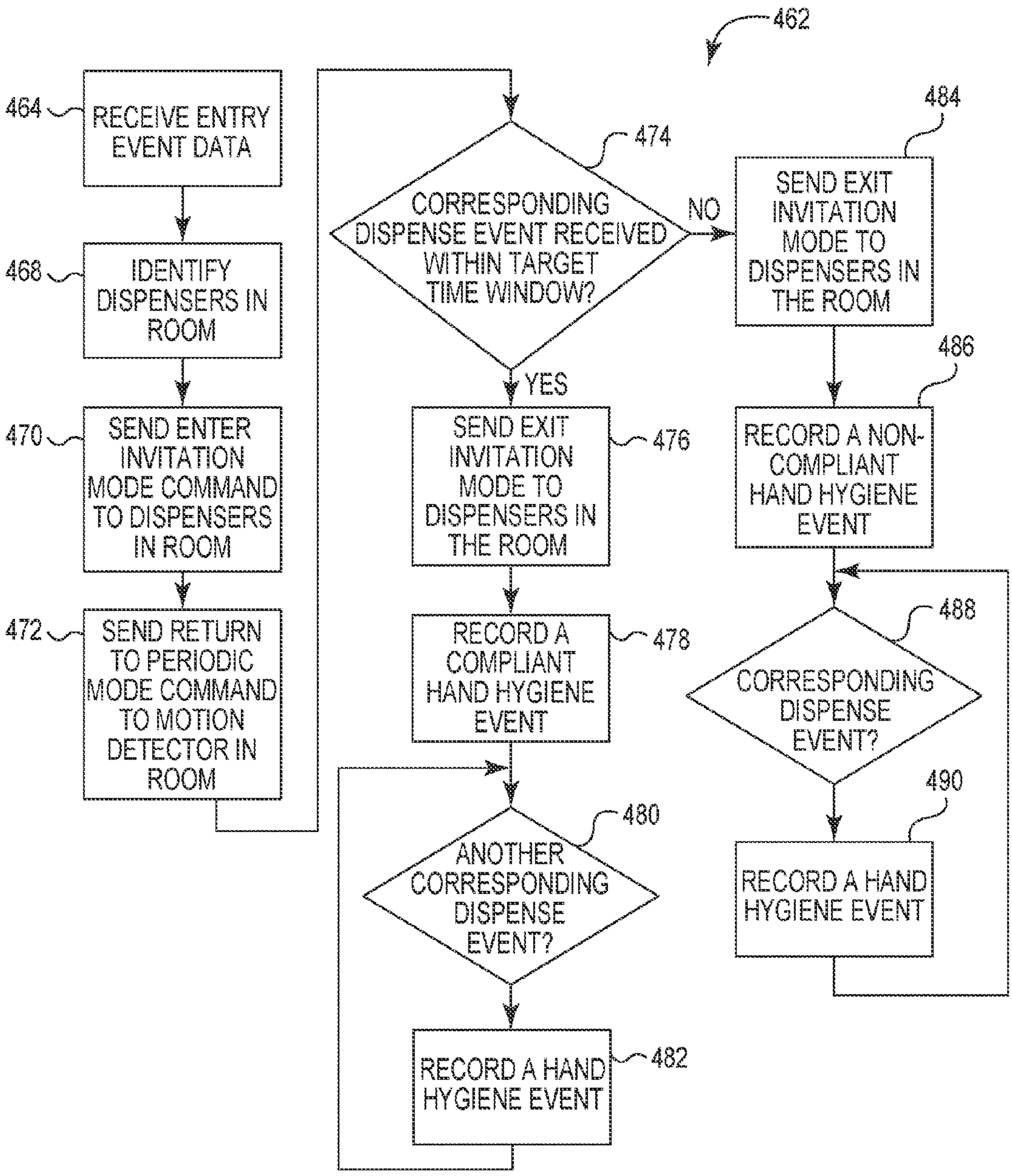
462
464
RECEIVE ENTRY EVENT DATA
468
IDENTIFY DISPENSERS IN ROOM
470
SEND ENTER INVITATION MODE COMMAND TO DISPENSERS IN ROOM
472
SEND RETURN TO PERIODIC MODE COMMAND TO MOTION DETECTOR IN ROOM
474
CORRESPONDING DISPENSE EVENT RECEIVED WITHIN TARGET TIME WINDOW?
NO
YES
476
SEND EXIT INVITATION MODE TO DISPENSERS IN THE ROOM
478
RECORD A COMPLIANT HAND HYGIENE EVENT
480
ANOTHER CORRESPONDING DISPENSE EVENT?
482
RECORD A HAND HYGIENE EVENT
484
SEND EXIT INVITATION MODE TO DISPENSERS IN THE ROOM
486
RECORD A NON-COMPLIANT HAND HYGIENE EVENT
488
CORRESPONDING DISPENSE EVENT?
490
RECORD A HAND HYGIENE EVENT

Fig. 19

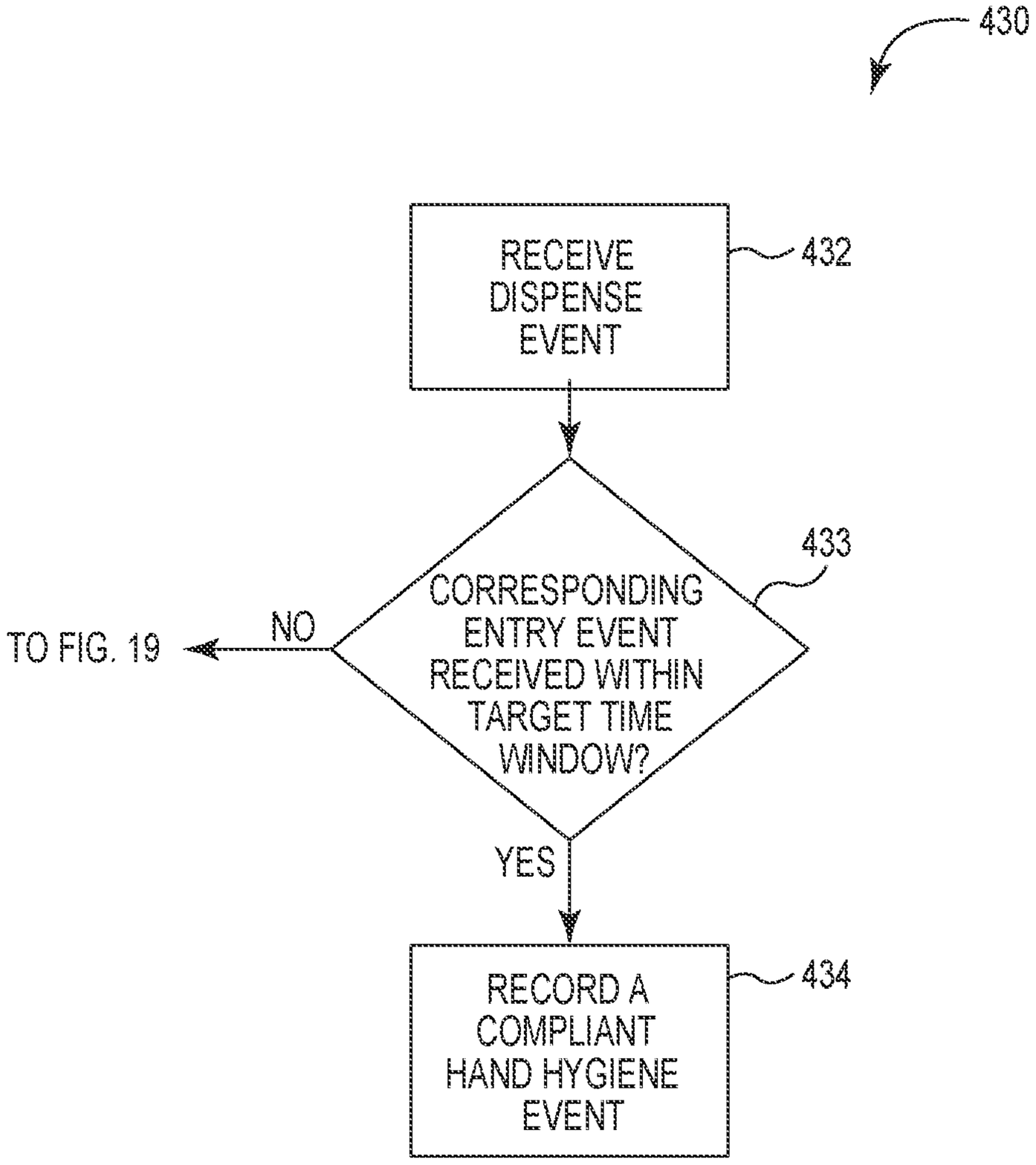
430
RECEIVE DISPENSE EVENT
432
CORRESPONDING ENTRY EVENT RECEIVED WITHIN TARGET TIME WINDOW?
433
NO
TO FIG. 19
YES
RECORD A COMPLIANT HAND HYGIENE EVENT
434

Fig. 20

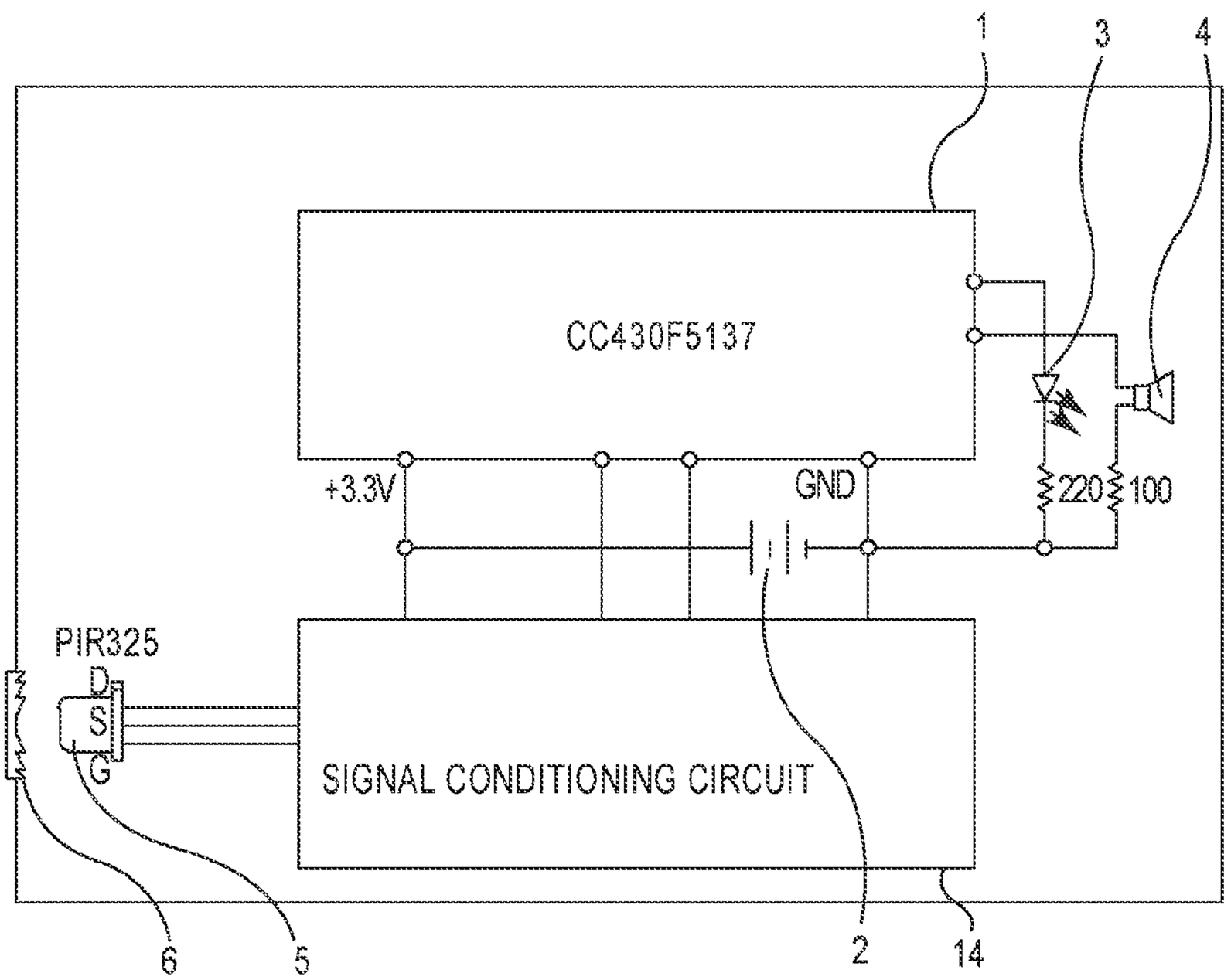
1
3
4
CC430F5137
+3.3V
GND
220
100
PIR325
D
S
G
SIGNAL CONDITIONING CIRCUIT
6
5
2
14

Fig. 21A

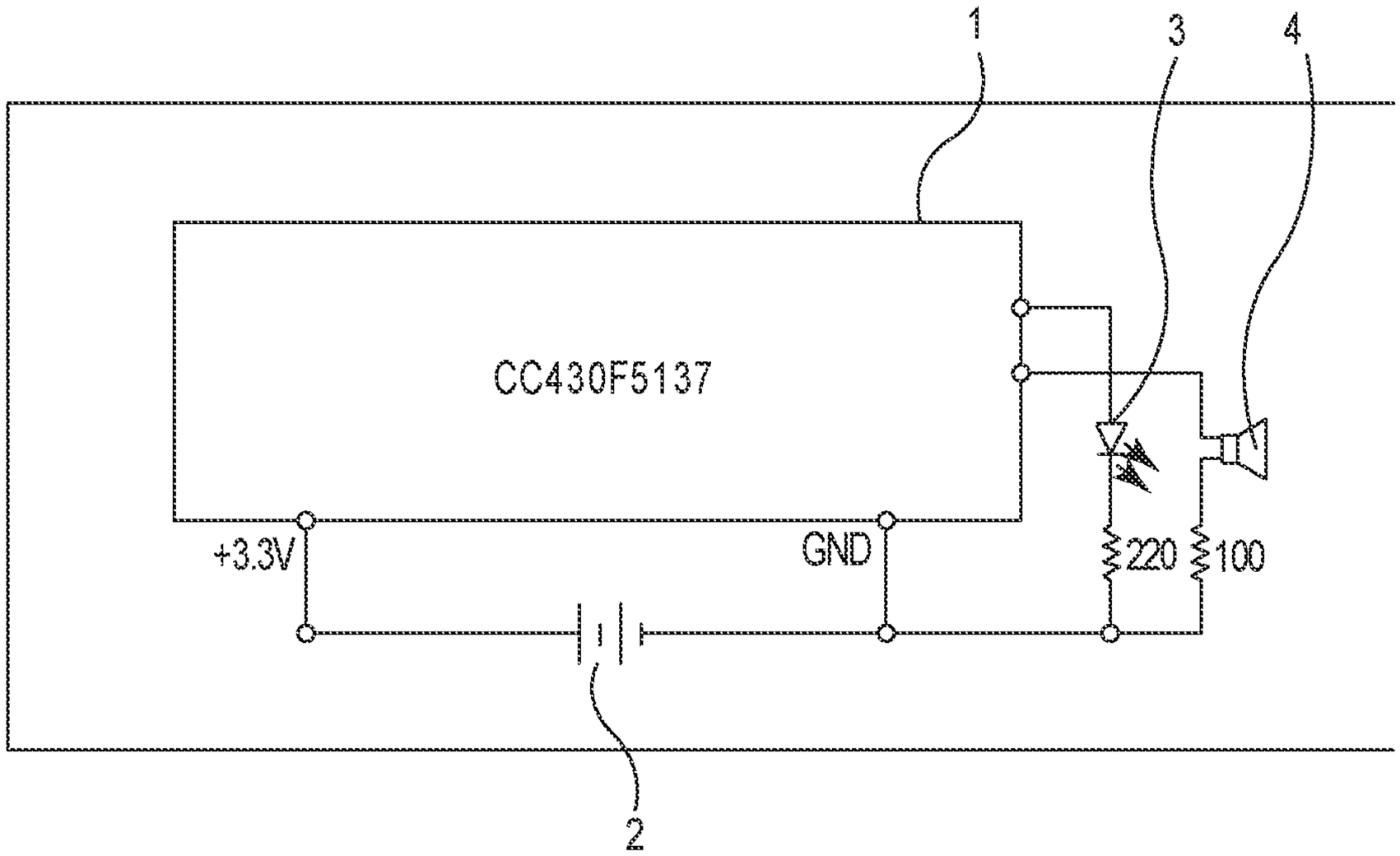

Fig. 21B

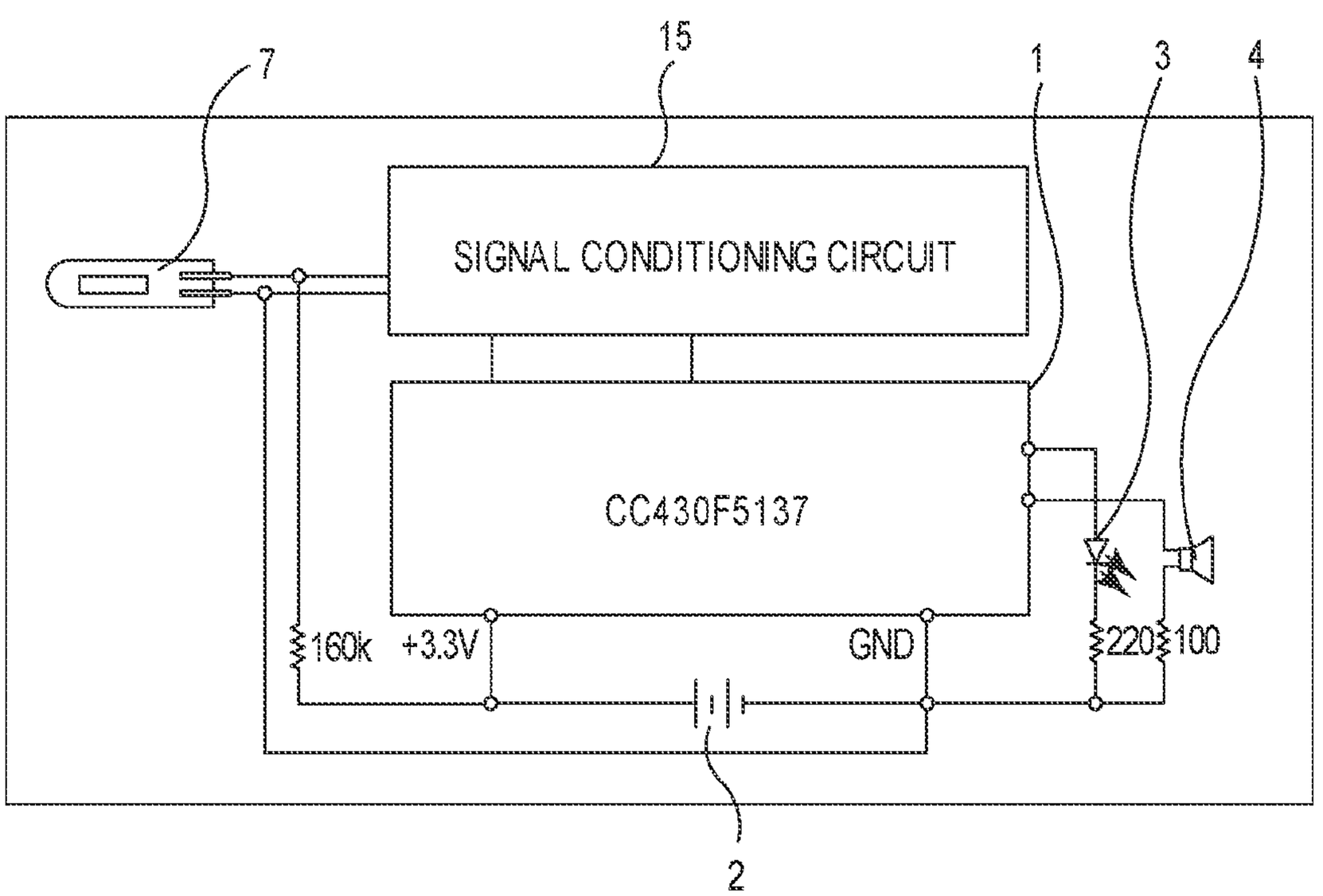
7
15
1
3
4
SIGNAL CONDITIONING CIRCUIT
CC430F5137
160k
+3.3V
GND
220
100
2

Fig. 21C

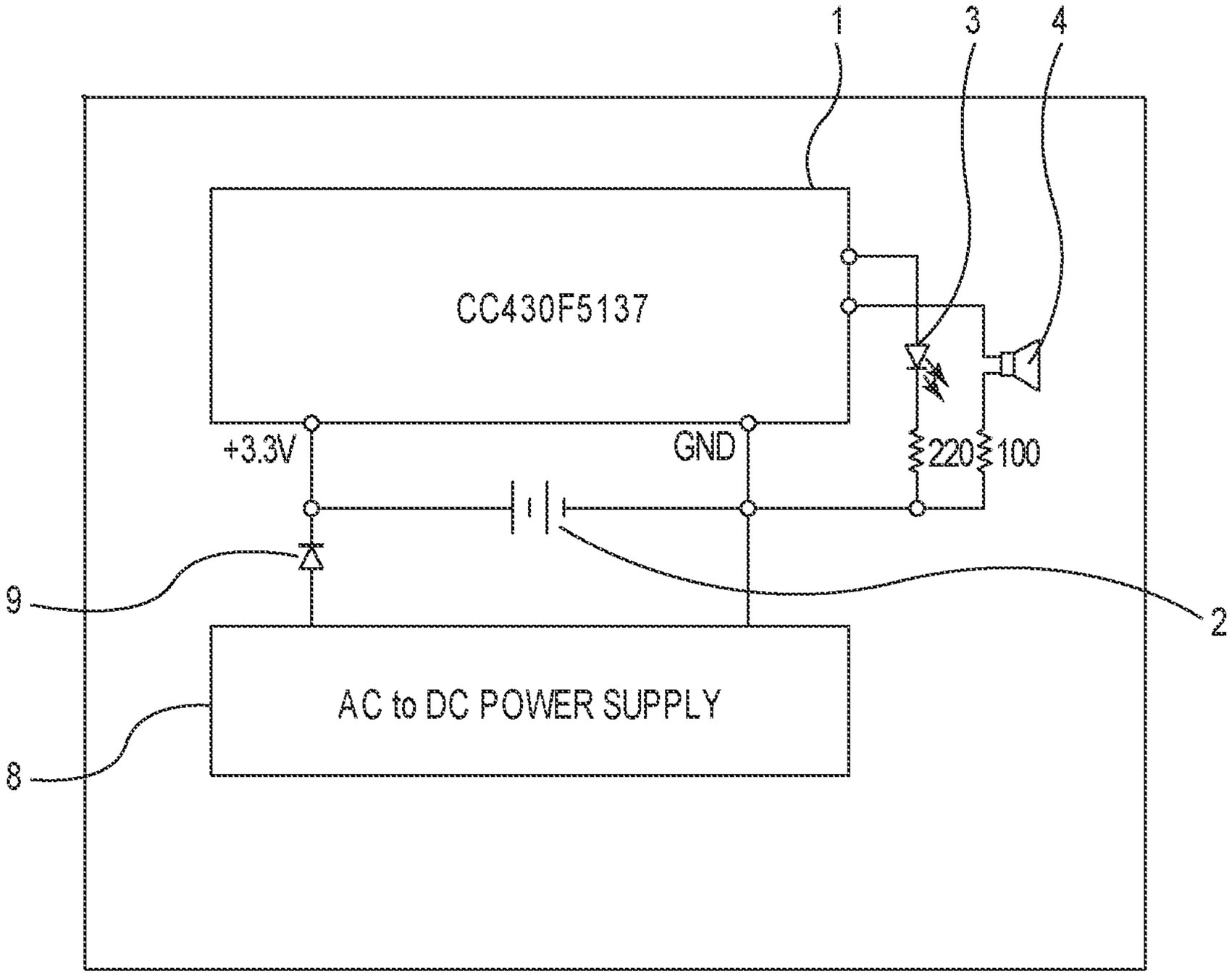

Fig. 21D

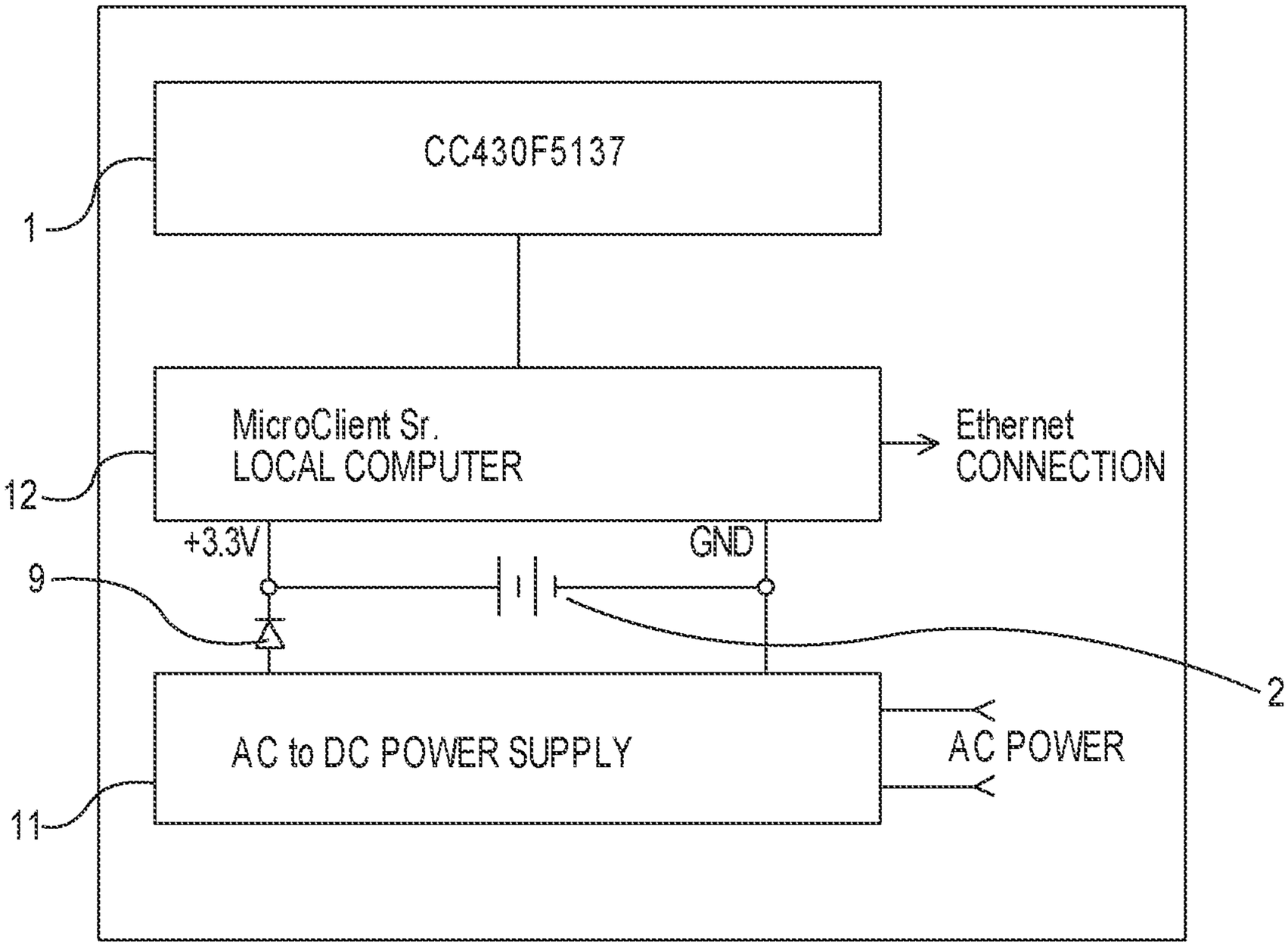
CC430F5137
1
MicroClient Sr.
LOCAL COMPUTER
12
Ethernet
CONNECTION
+3.3V
GND
9
2
AC to DC POWER SUPPLY
AC POWER
11

Fig. 21E

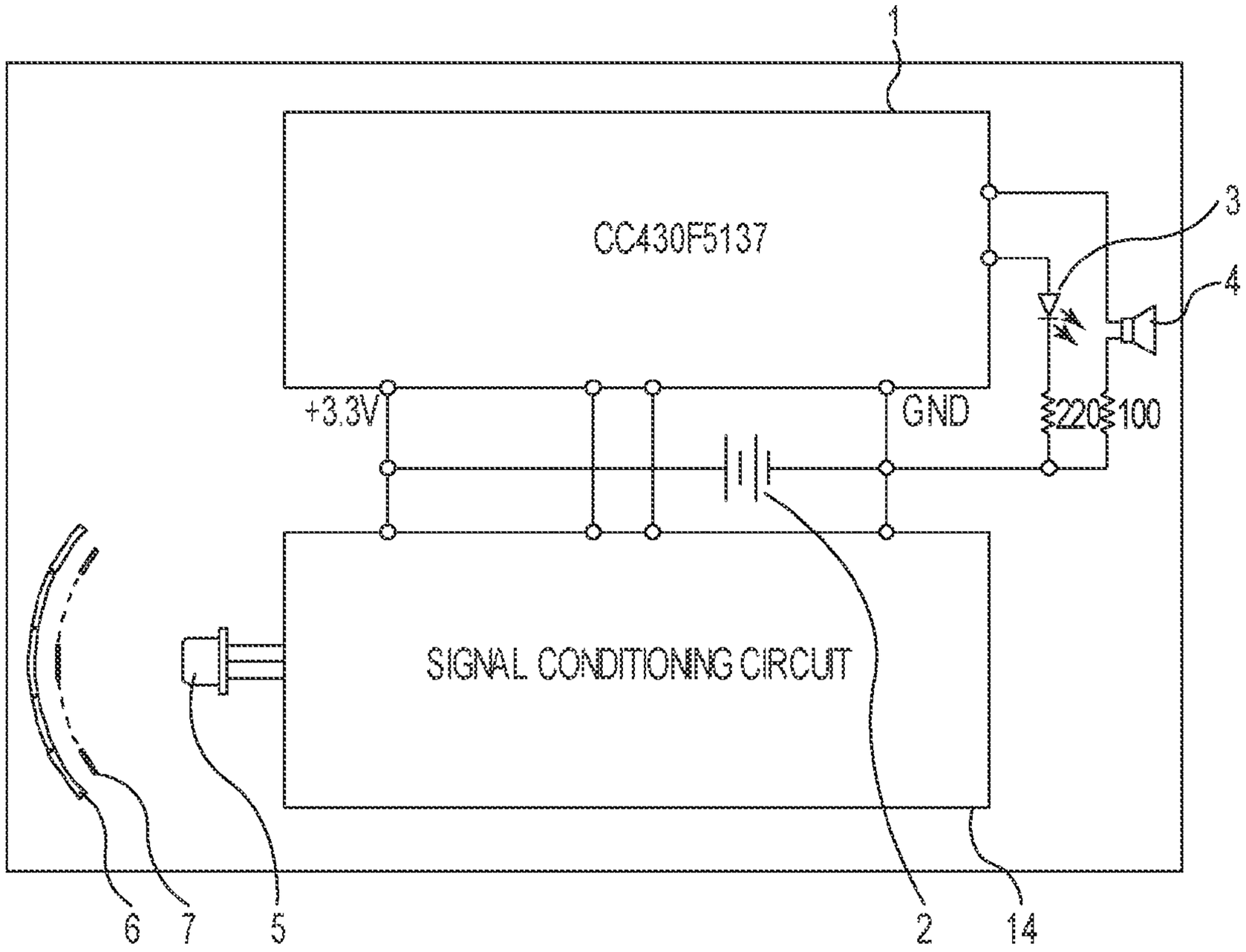
CC430F5137
3
4
+3.3V
GND
220
100
SIGNAL CONDITIONING CIRCUIT
6
7
5
2
14

Fig. 21F

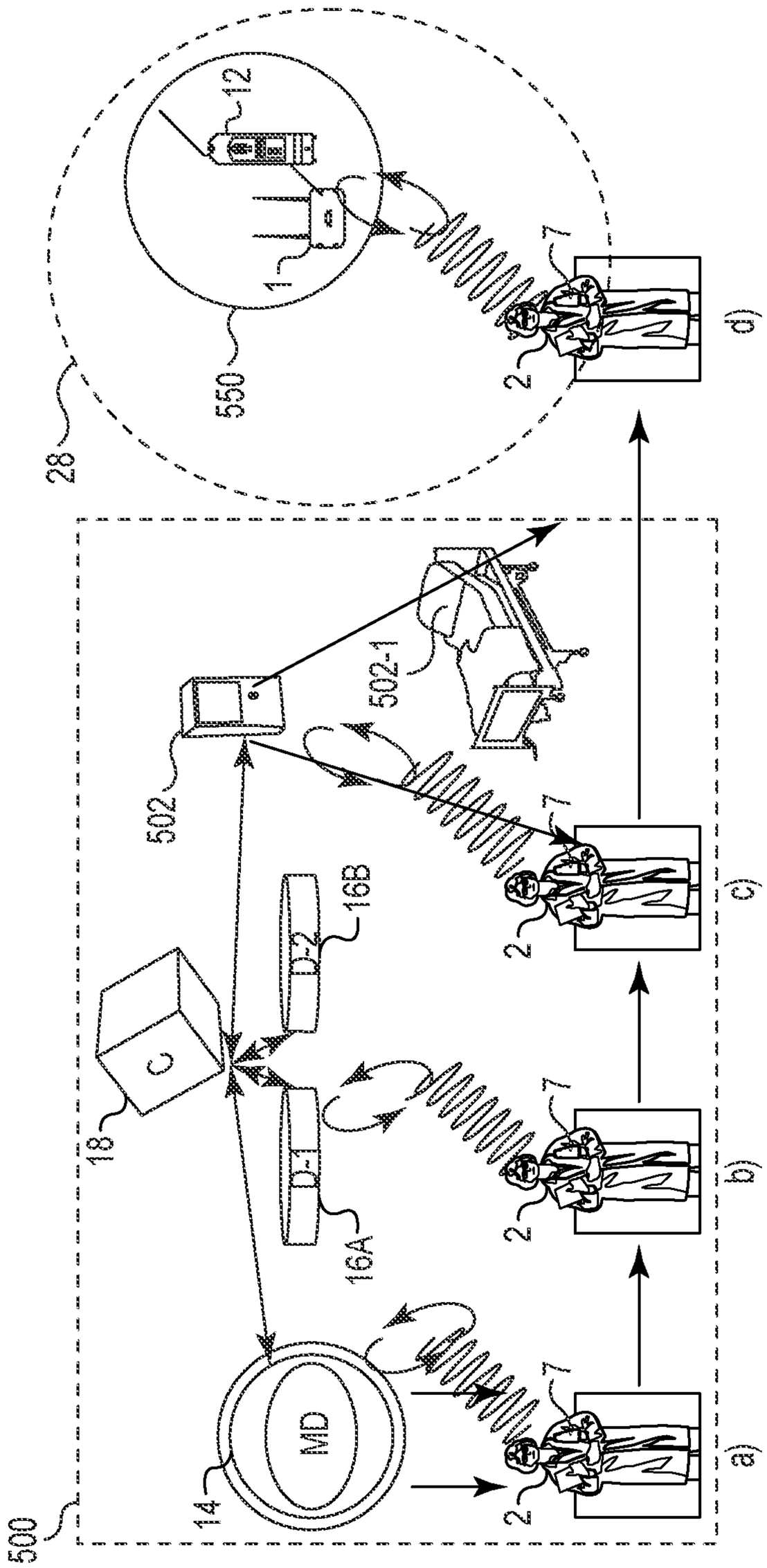

Fig. 22A

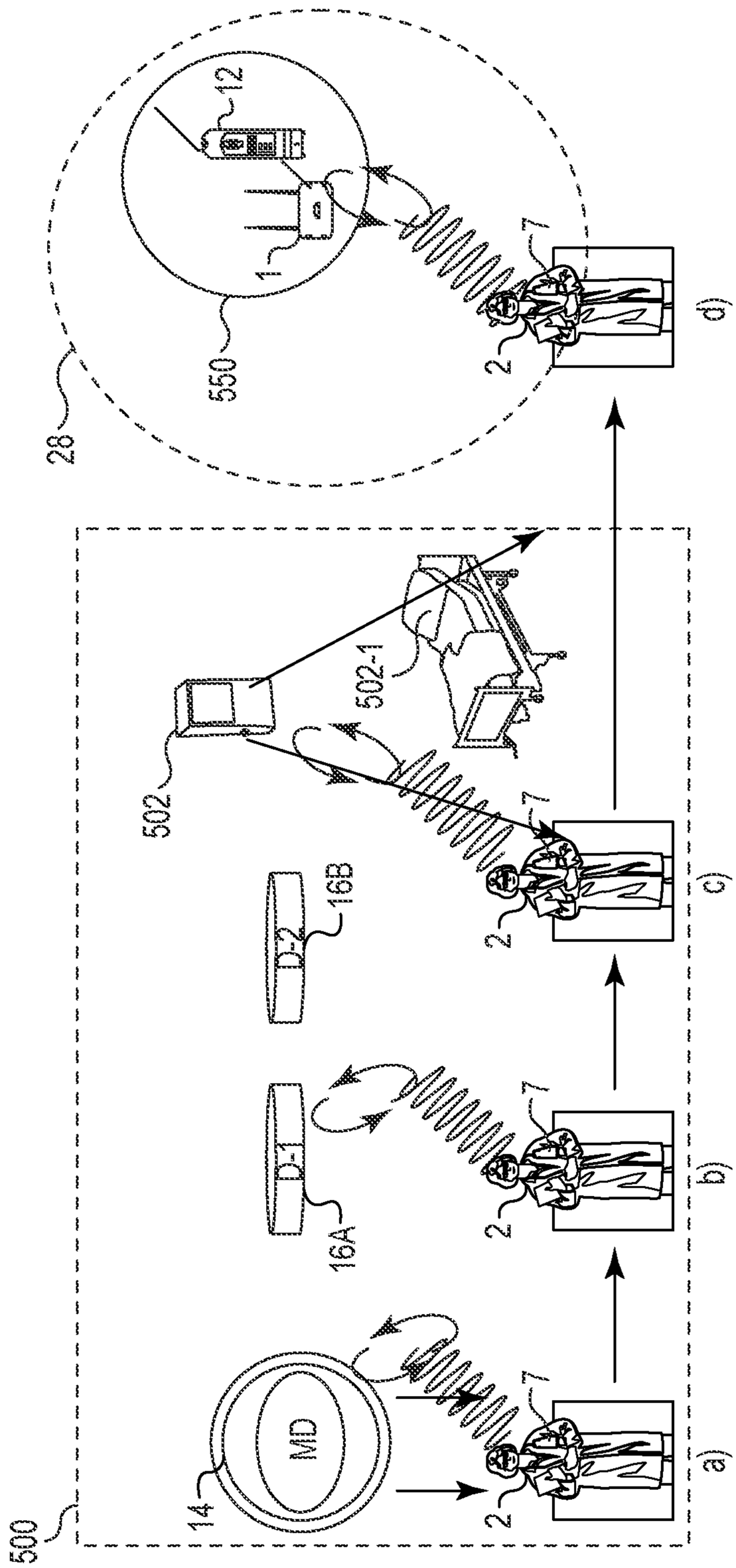

Fig. 22B

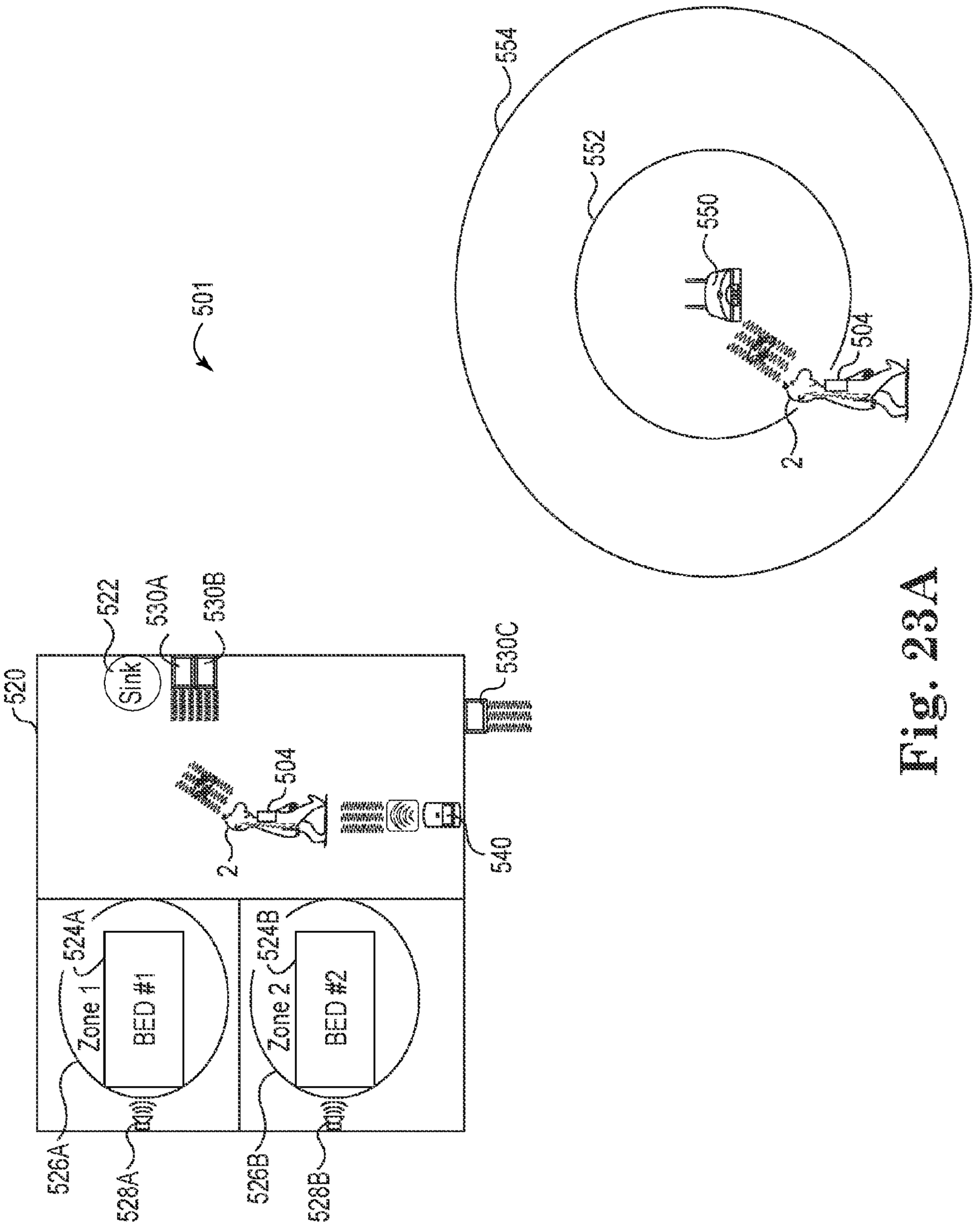
554
552
550
504
2
501
520
Sink
522
530A
530B
530C
504
2
540
524A
Zone 1
BED #1
524B
Zone 2
BED #2
526A
528A
526B
528B

Fig. 23A

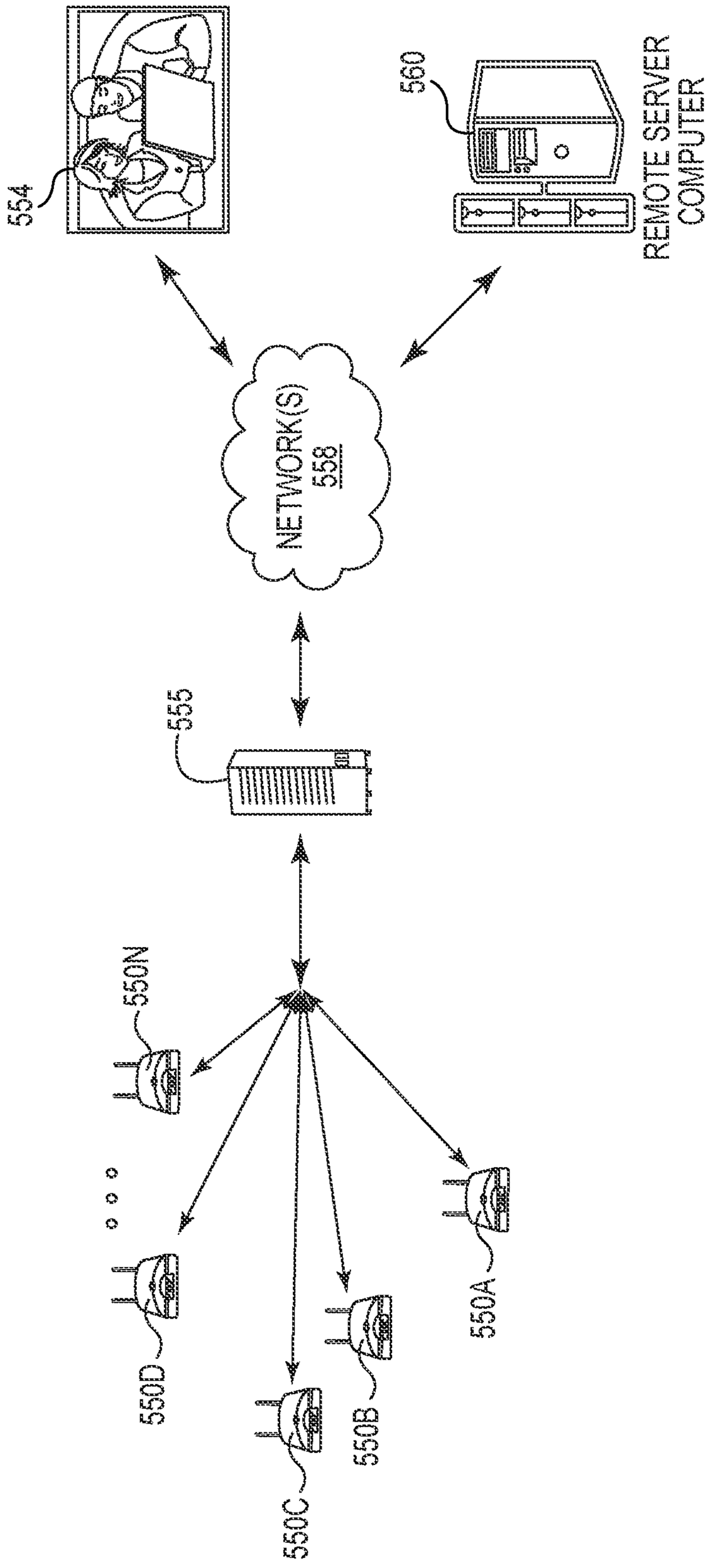
554
560
REMOTE SERVER COMPUTER
NETWORK(S)
558
501
555
550N
550D
550C
550B
550A

Fig. 23B

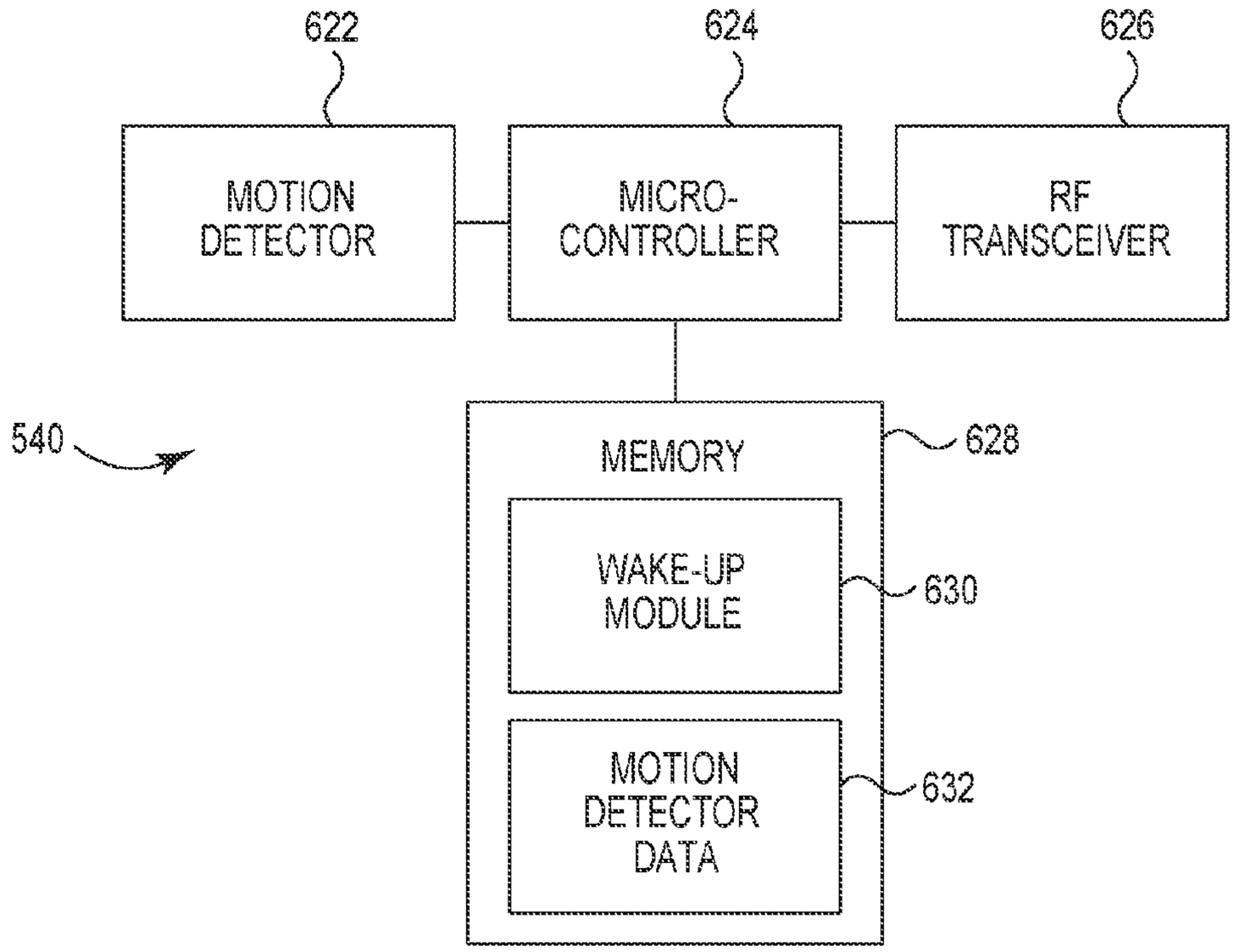
622
624
626
MOTION DETECTOR
MICRO-CONTROLLER
RF TRANSCEIVER
540
MEMORY
628
WAKE-UP MODULE
630
MOTION DETECTOR DATA
632

Fig. 24

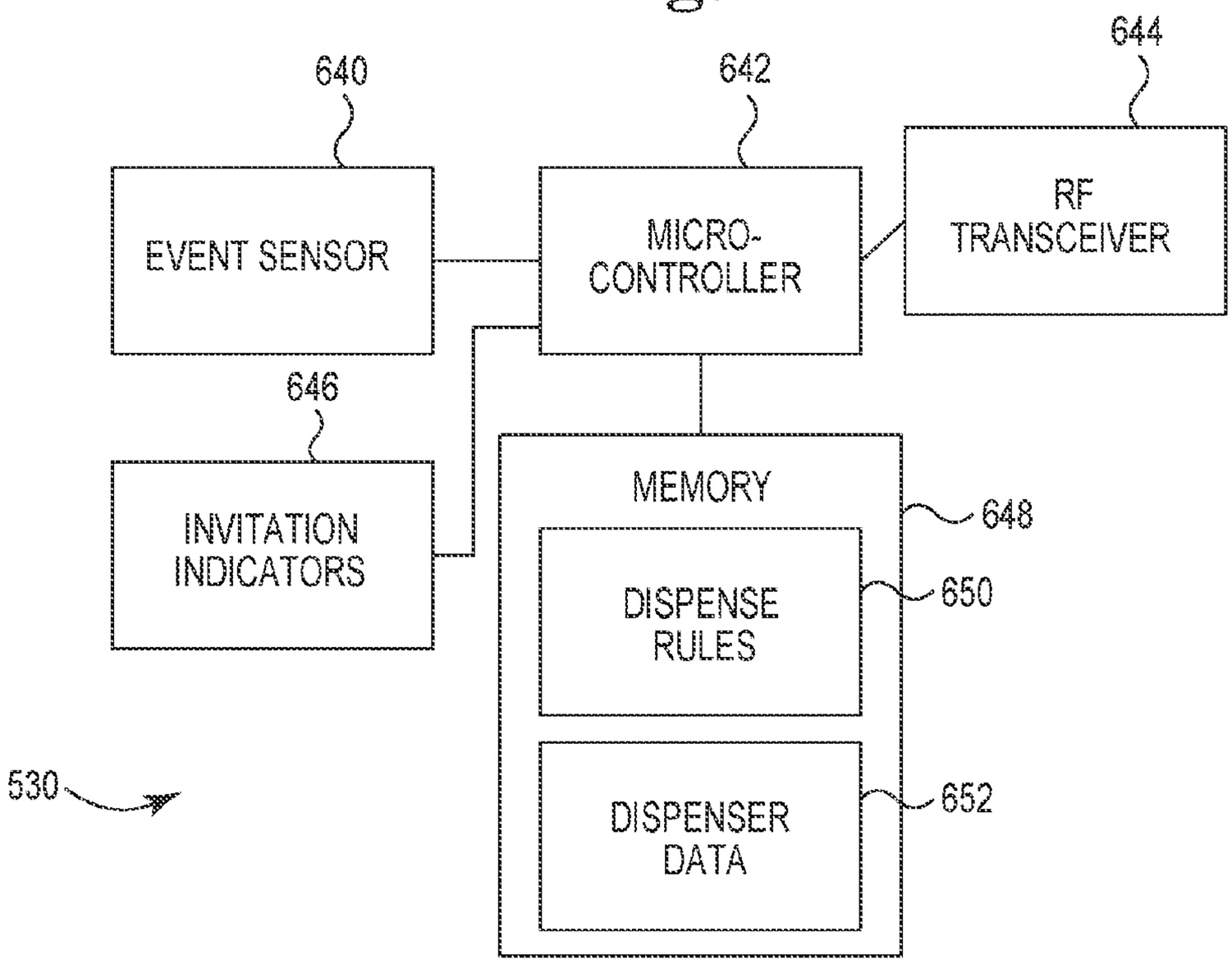
640
642
644
EVENT SENSOR
MICRO-CONTROLLER
RF TRANSCEIVER
646
INVITATION INDICATORS
MEMORY
648
DISPENSE RULES
650
DISPENSER DATA
652
530

Fig. 25

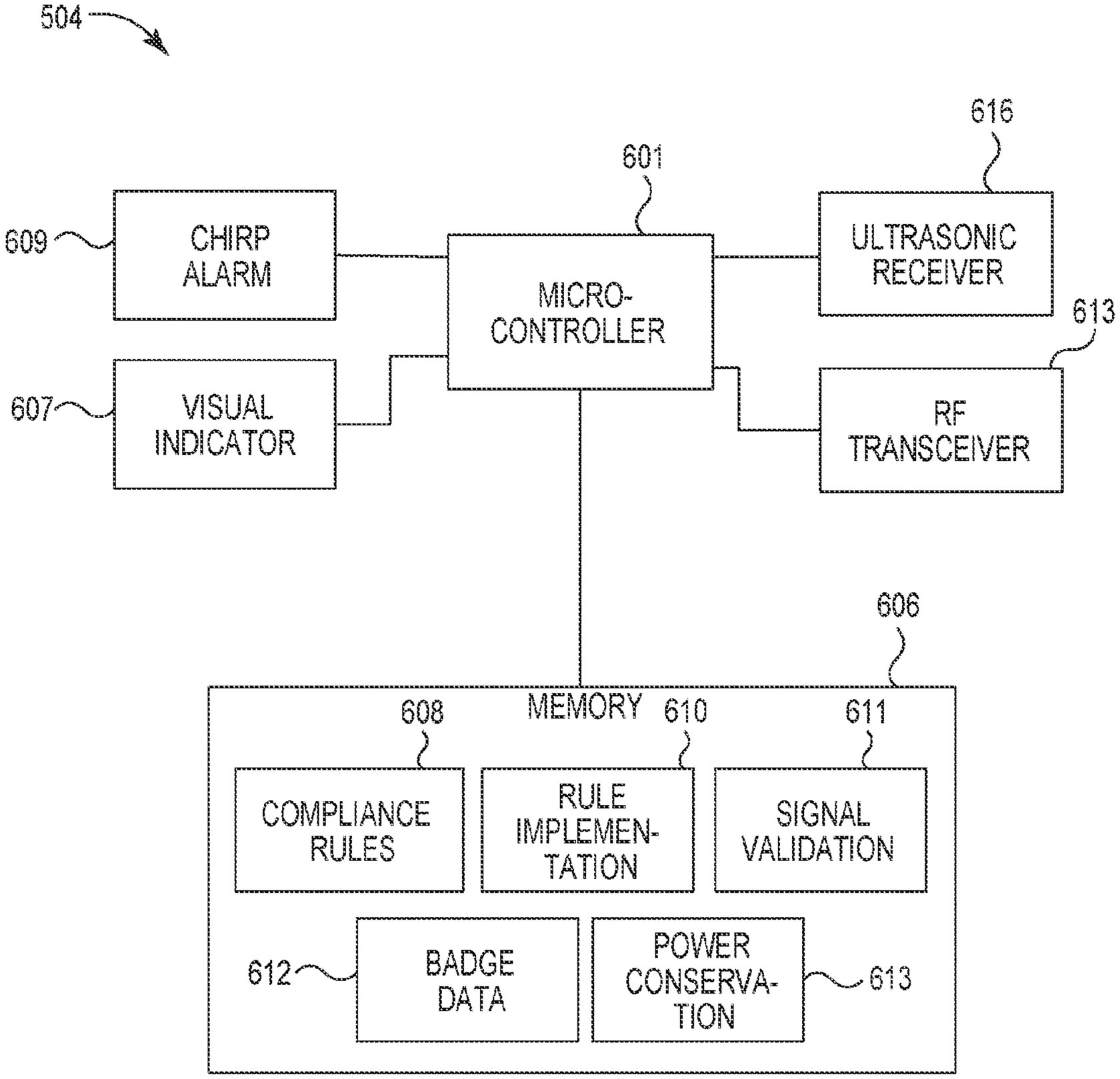
504
601
609
CHIRP ALARM
MICRO-CONTROLLER
616
ULTRASONIC RECEIVER
613
607
VISUAL INDICATOR
RF TRANSCEIVER
606
MEMORY
608
610
611
COMPLIANCE RULES
RULE IMPLEMEN-TATION
SIGNAL VALIDATION
612
BADGE DATA
POWER CONSERVA-TION
613

Fig. 26

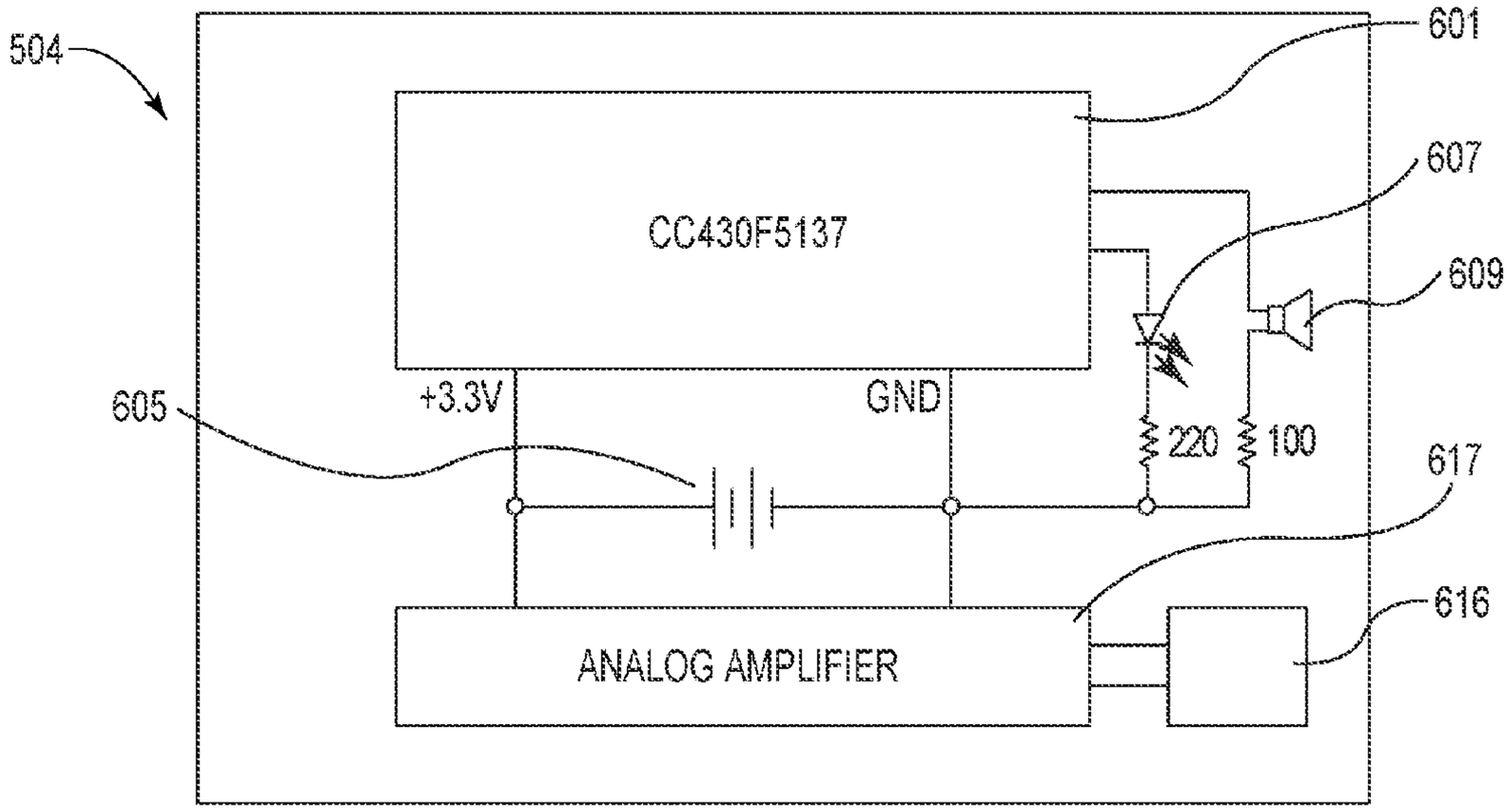
504
601
CC430F5137
607
609
605
+3.3V
GND
220
100
617
616
ANALOG AMPLIFIER

Fig. 27

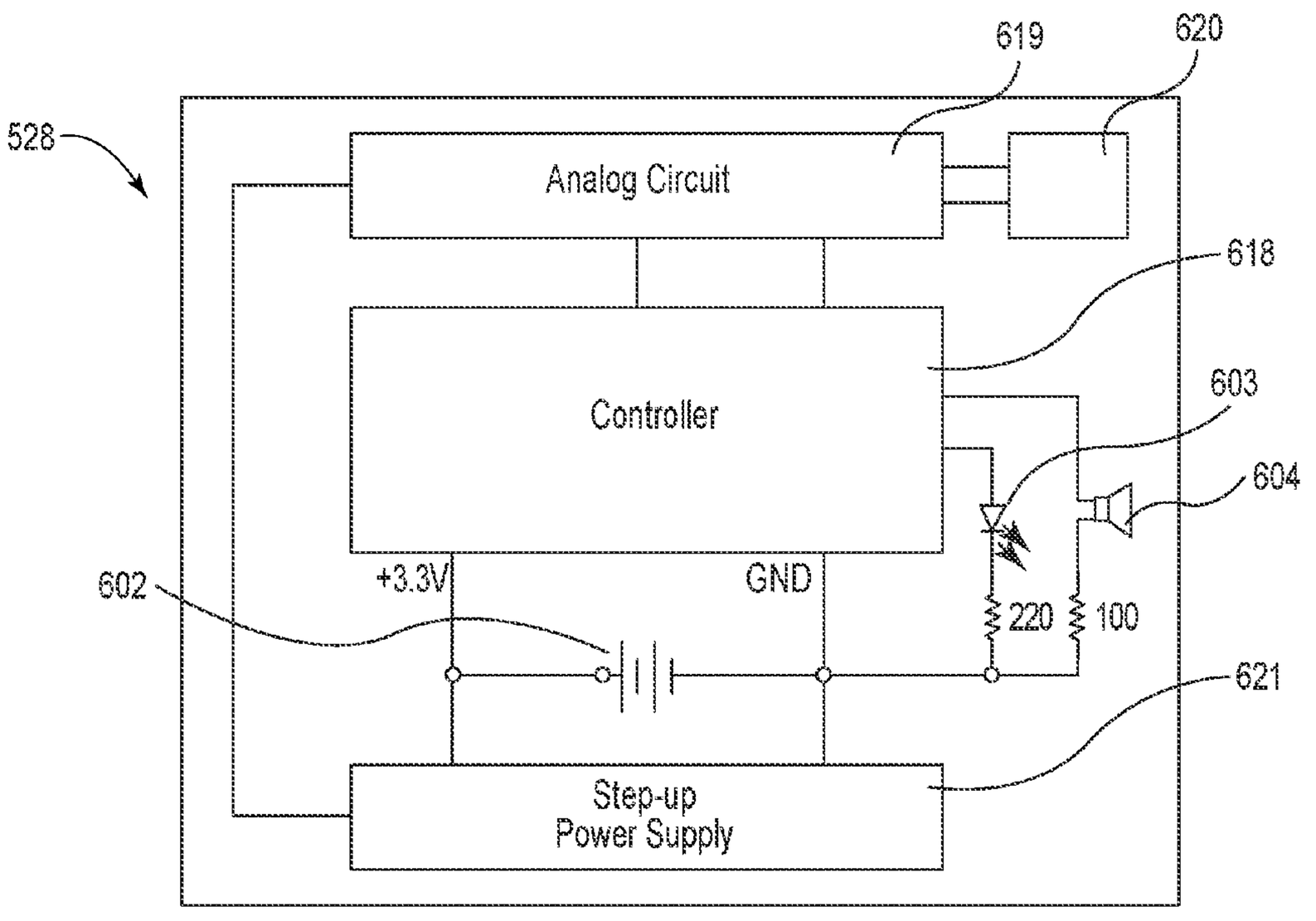
619
620
528
Analog Circuit
618
Controller
603
604
602
+3.3V
GND
220
100
621
Step-up
Power Supply

Fig. 28

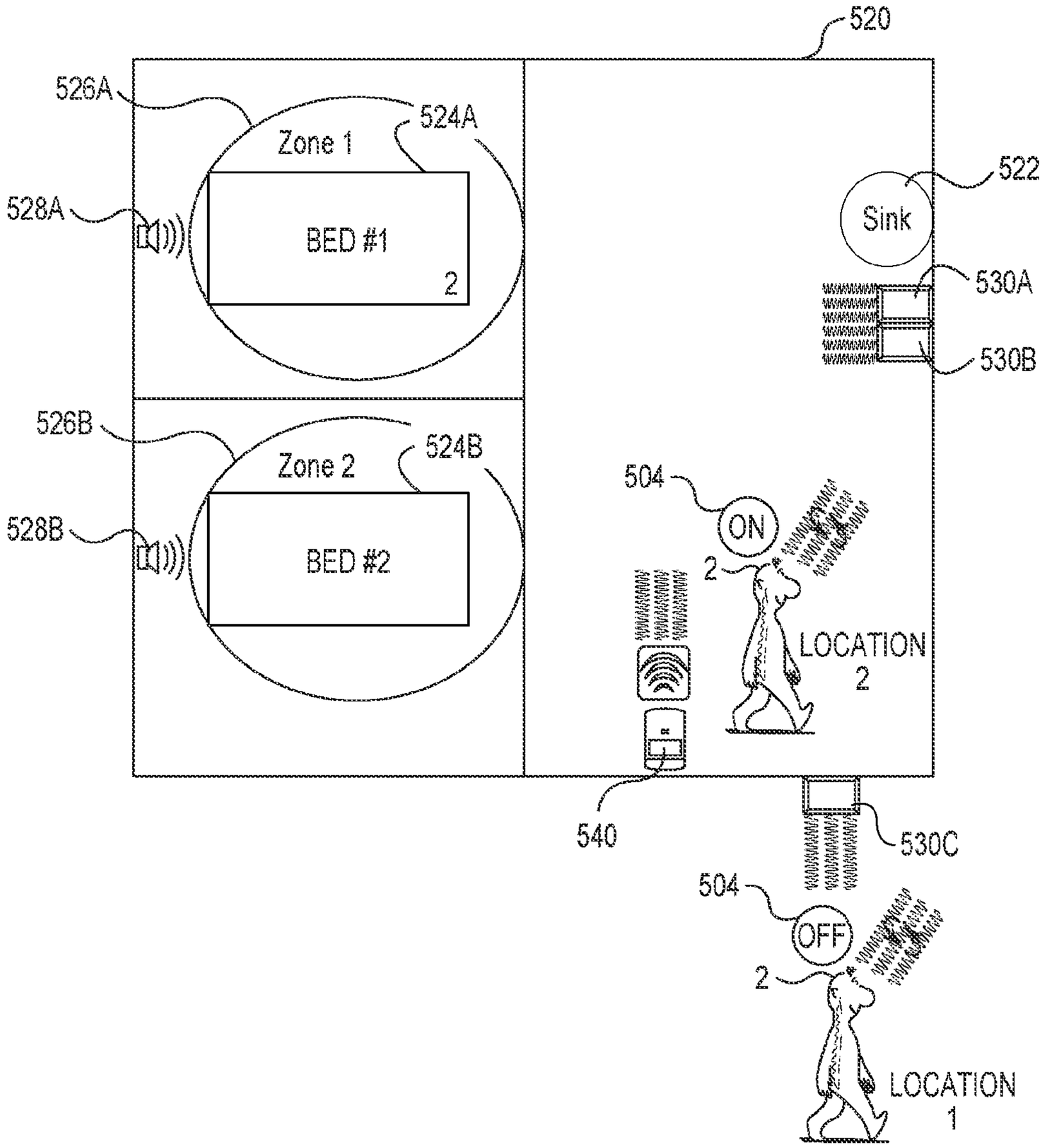
520
526A
524A
Zone 1
528A
BED #1
2
522
Sink
530A
530B
526B
524B
Zone 2
528B
BED #2
504
ON
2
LOCATION
2
540
530C
504
OFF
2
LOCATION
1

Fig. 29

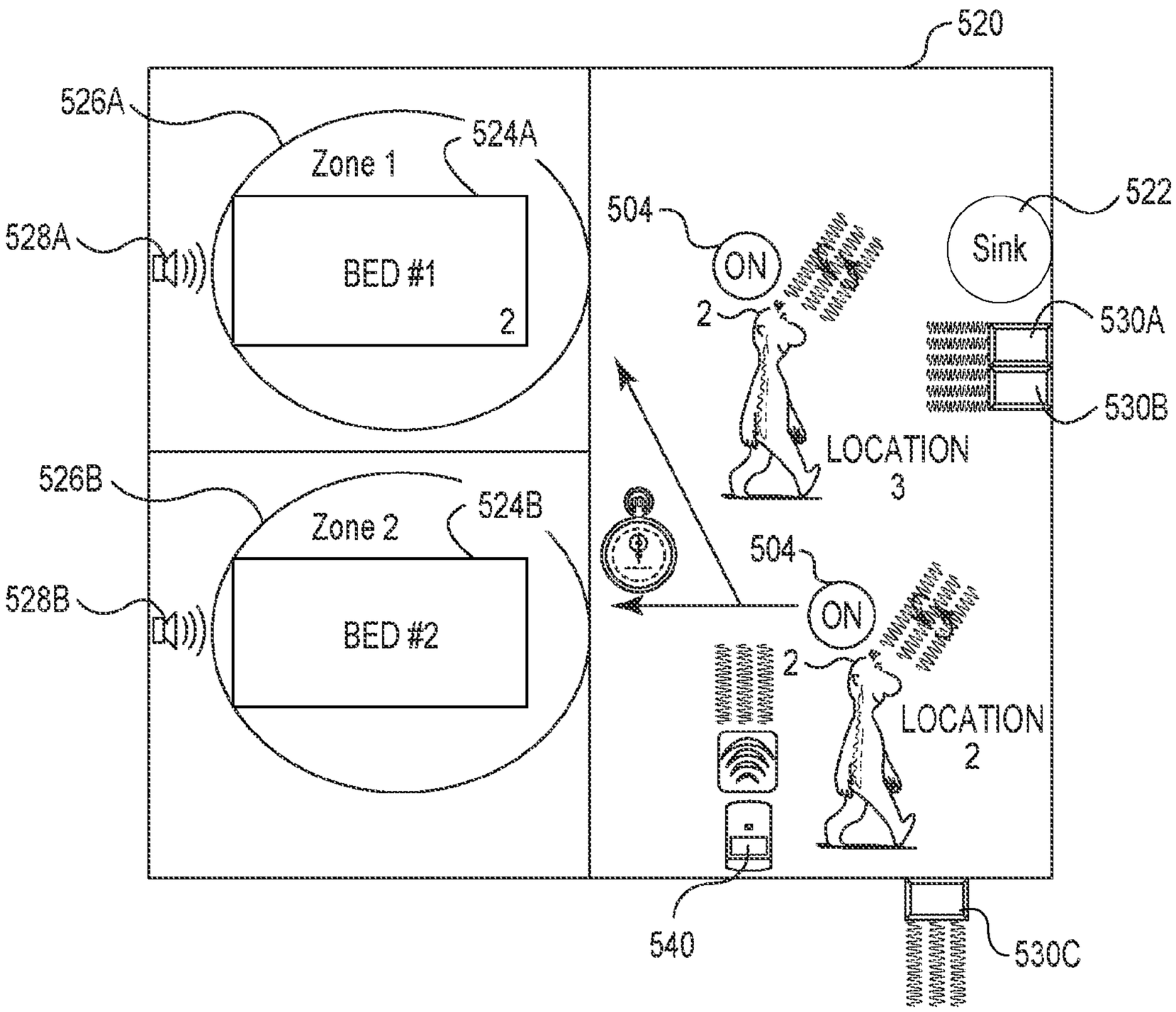
520
526A
524A
Zone 1
528A
BED #1
2
504
ON
2
522
Sink
530A
530B
LOCATION
3
526B
524B
Zone 2
528B
BED #2
504
ON
2
LOCATION
2
540
530C

Fig. 30

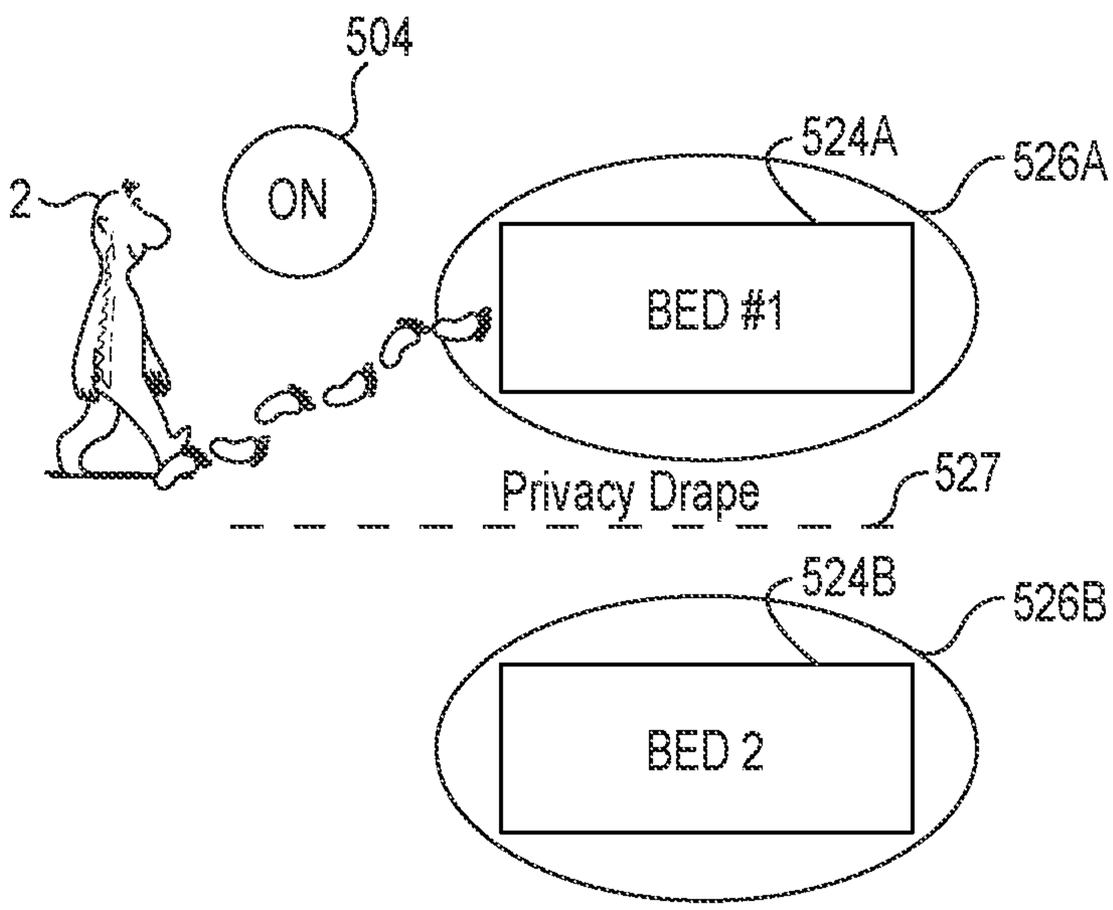
504
ON
2
524A
526A
BED #1
Privacy Drape
527
524B
526B
BED 2

Fig. 31

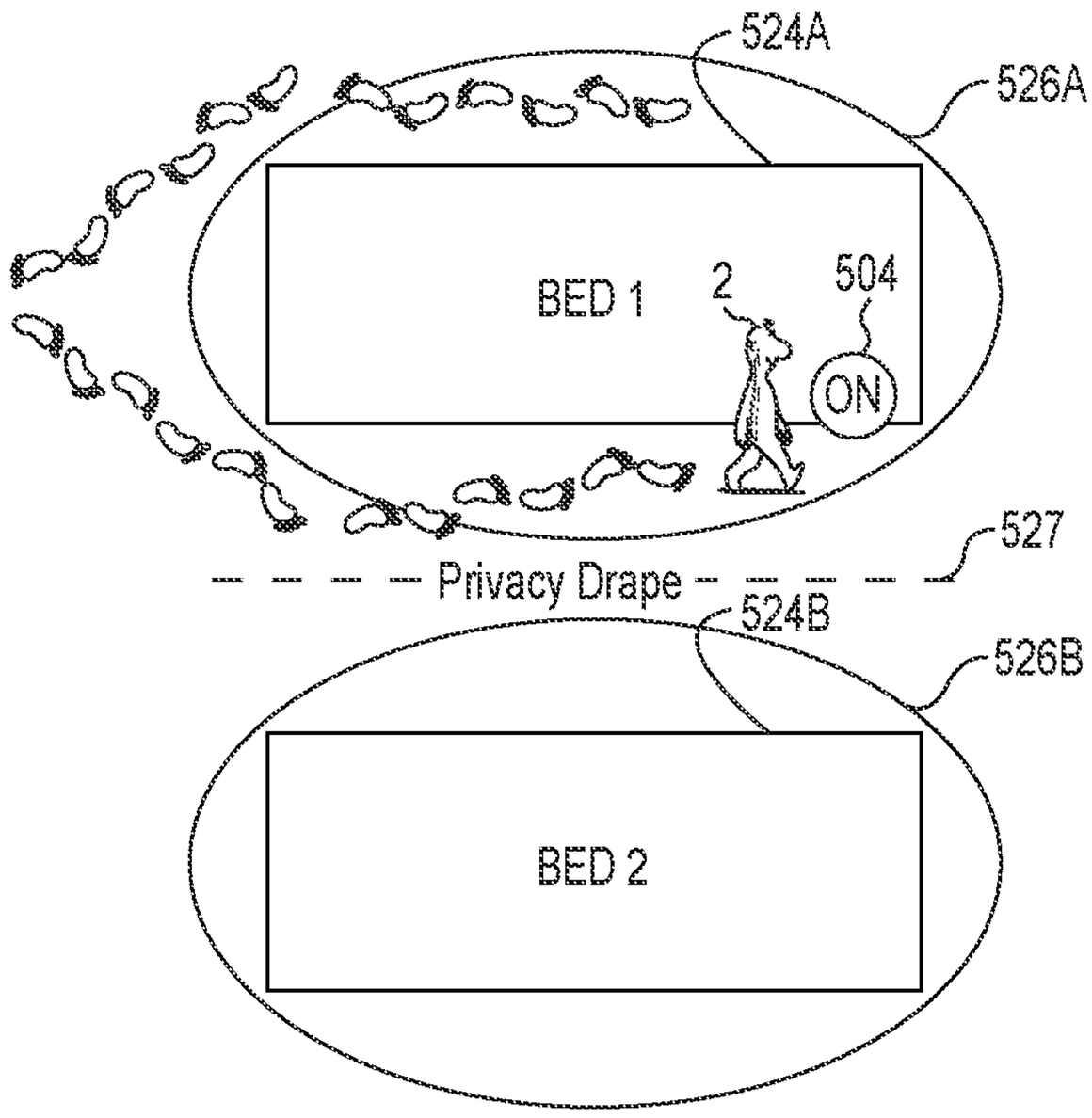
524A
526A
BED 1
2
504
ON
Privacy Drape
527
524B
526B
BED 2

Fig. 32

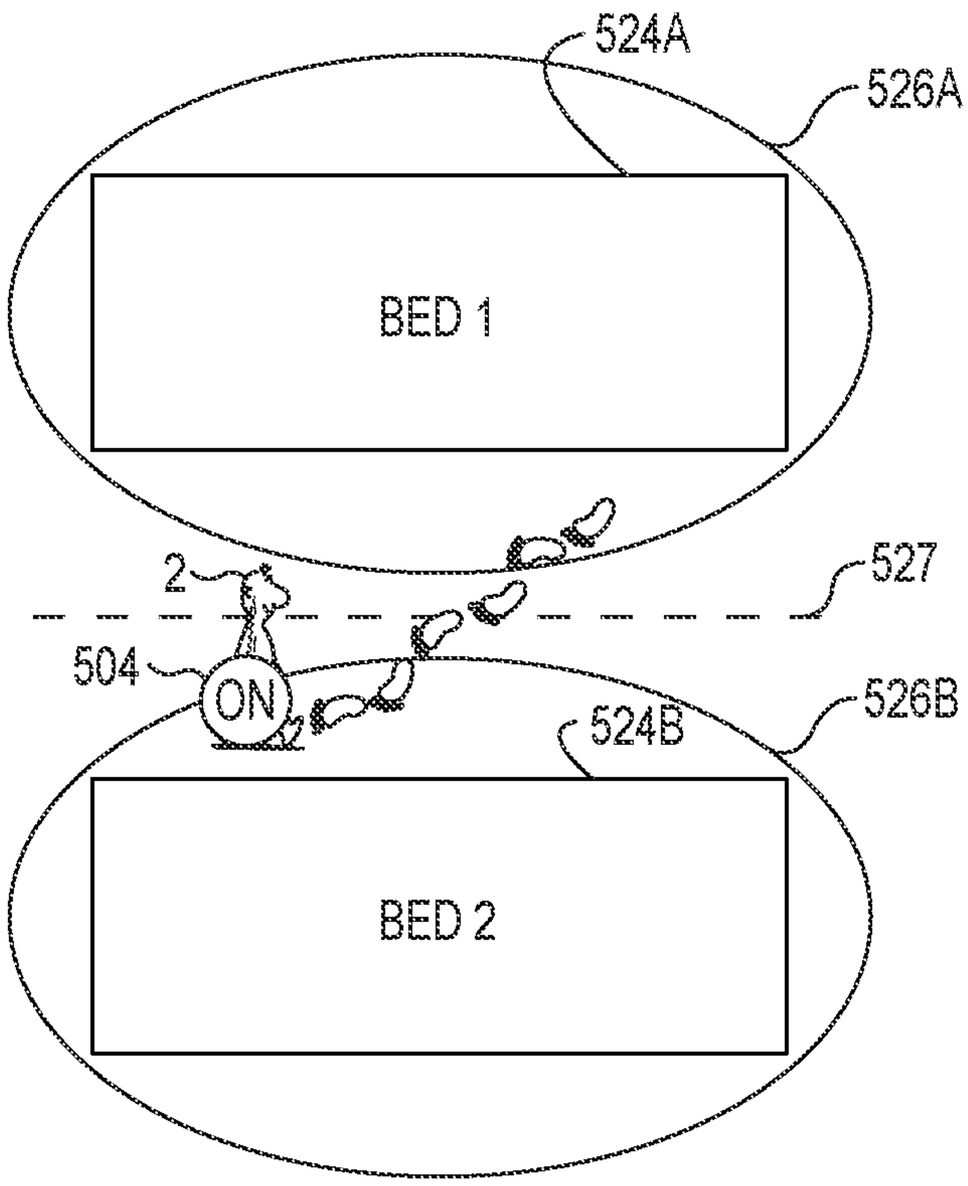

Fig. 33

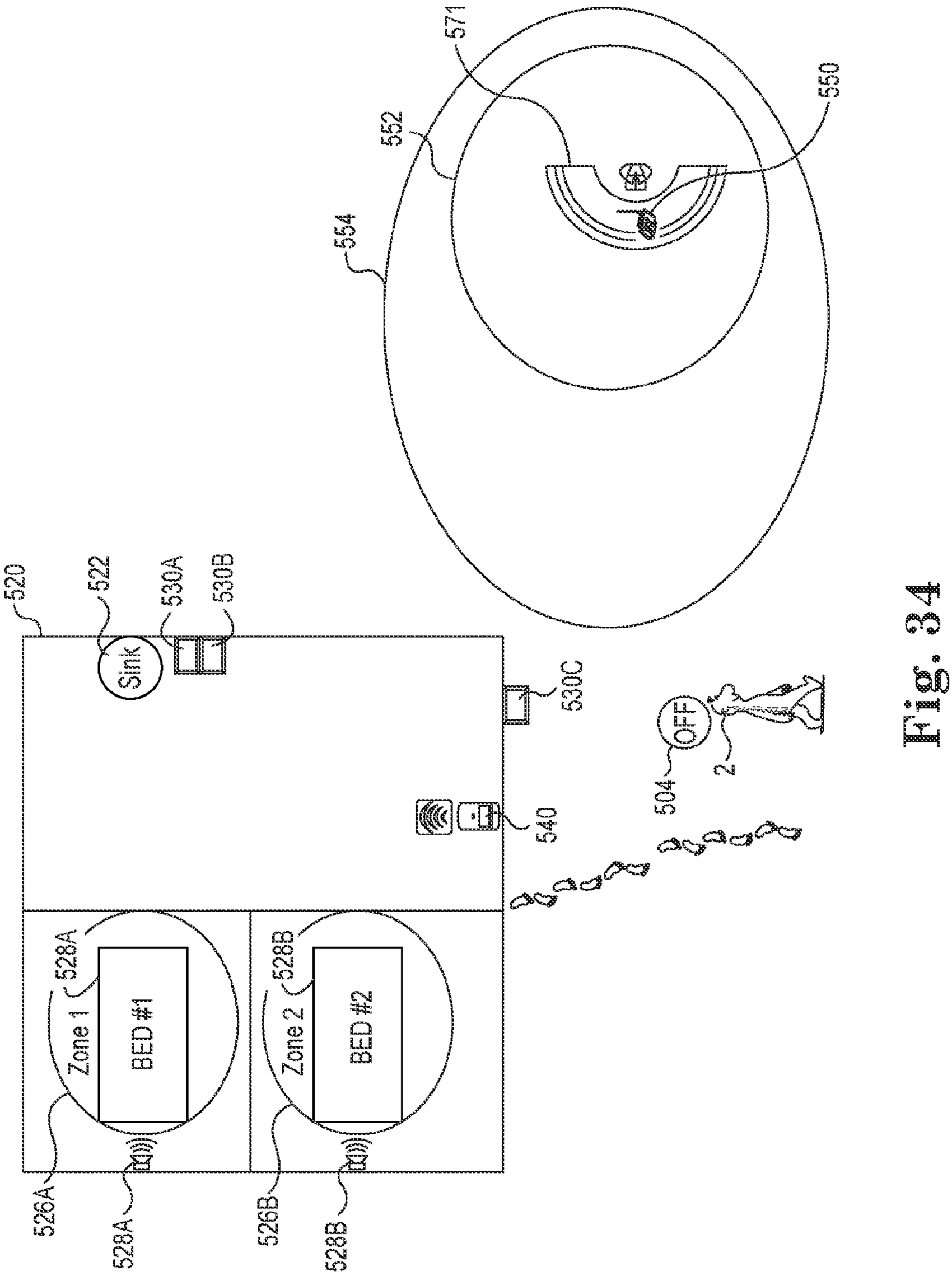
571
550
552
554
520
522
530A
530B
530C
Sink
540
504
OFF
2
528A
528B
Zone 1
Zone 2
BED #1
BED #2
526A
526B
528A
528B

Fig. 34

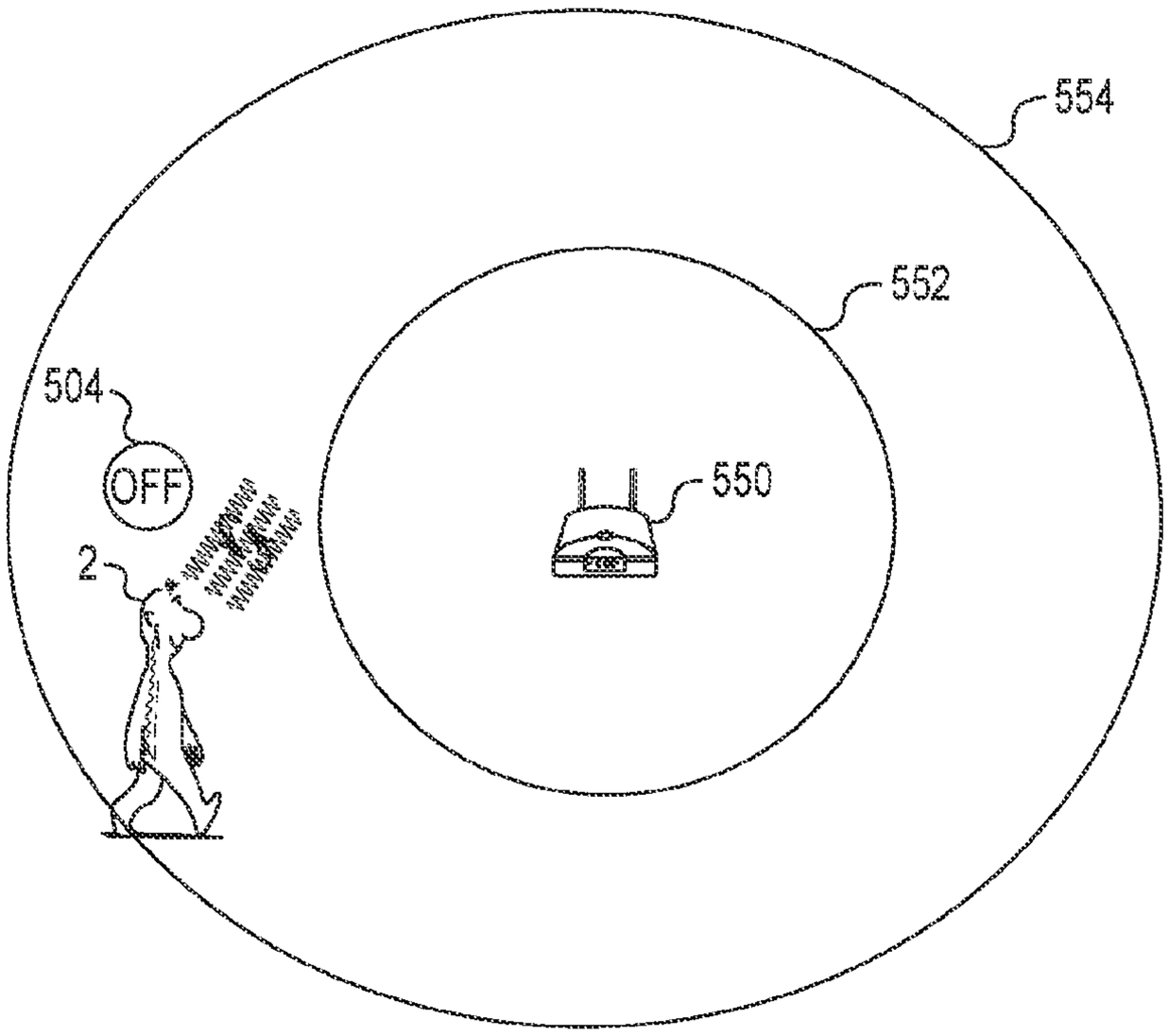

Fig. 35

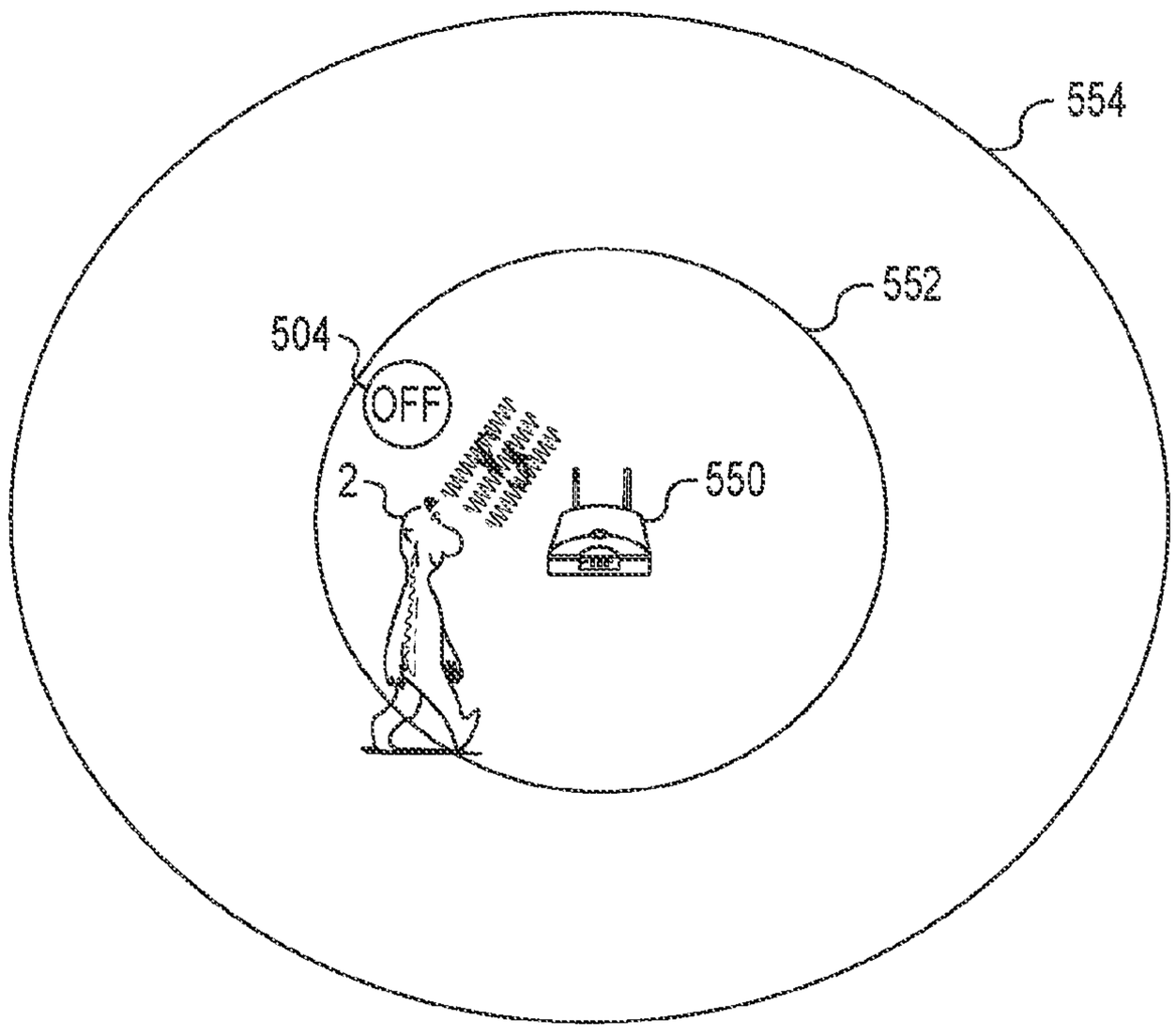

Fig. 36

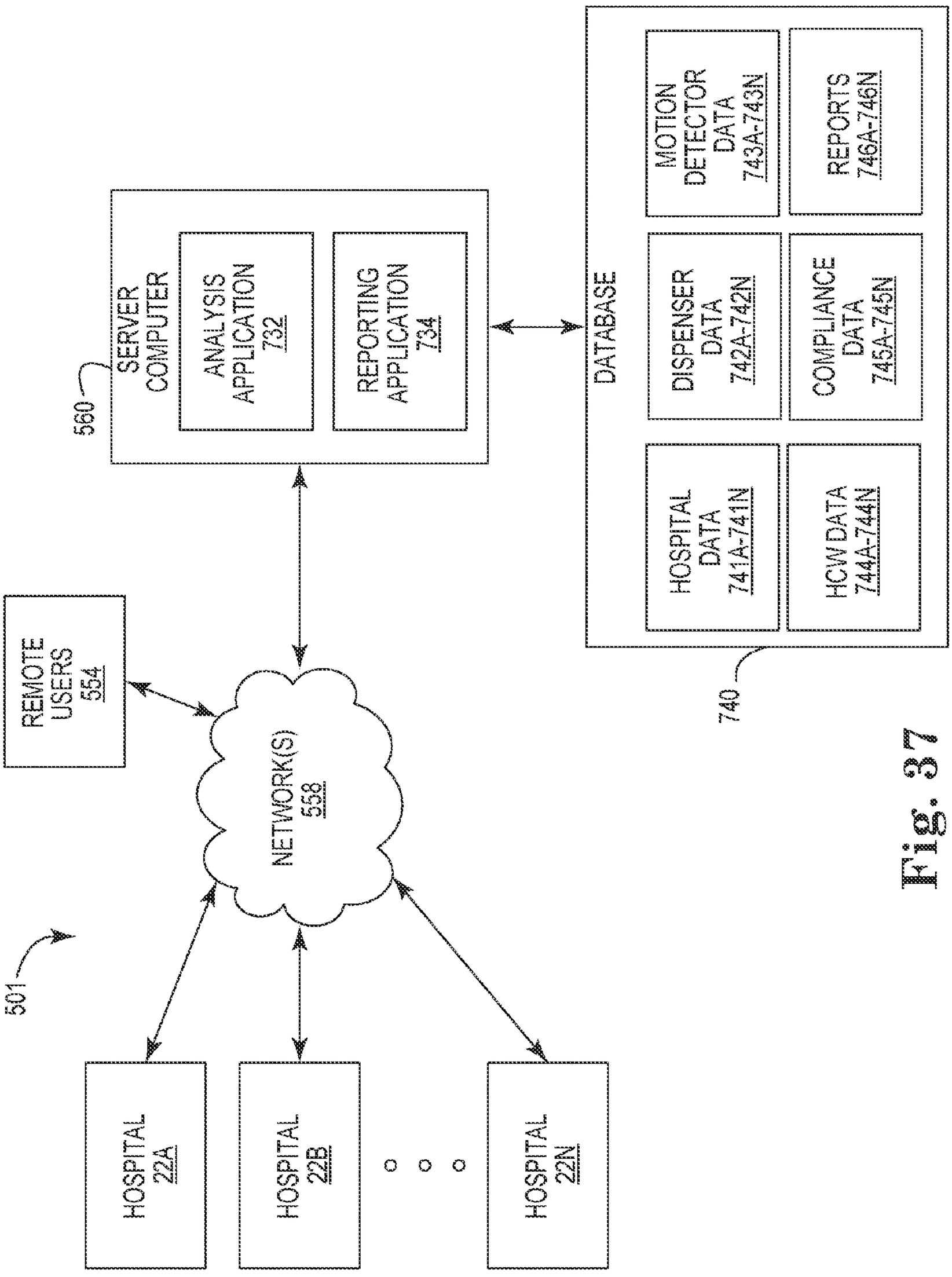
HOSPITAL 22A
HOSPITAL 22B
HOSPITAL 22N
501
REMOTE USERS 554
NETWORK(S) 558
SERVER COMPUTER
560
ANALYSIS APPLICATION 732
REPORTING APPLICATION 734
DATABASE
740
HOSPITAL DATA 741A-741N
DISPENSER DATA 742A-742N
HCW DATA 744A-744N
COMPLIANCE DATA 745A-745N
MOTION DETECTOR DATA 743A-743N
REPORTS 746A-746N

Fig. 37

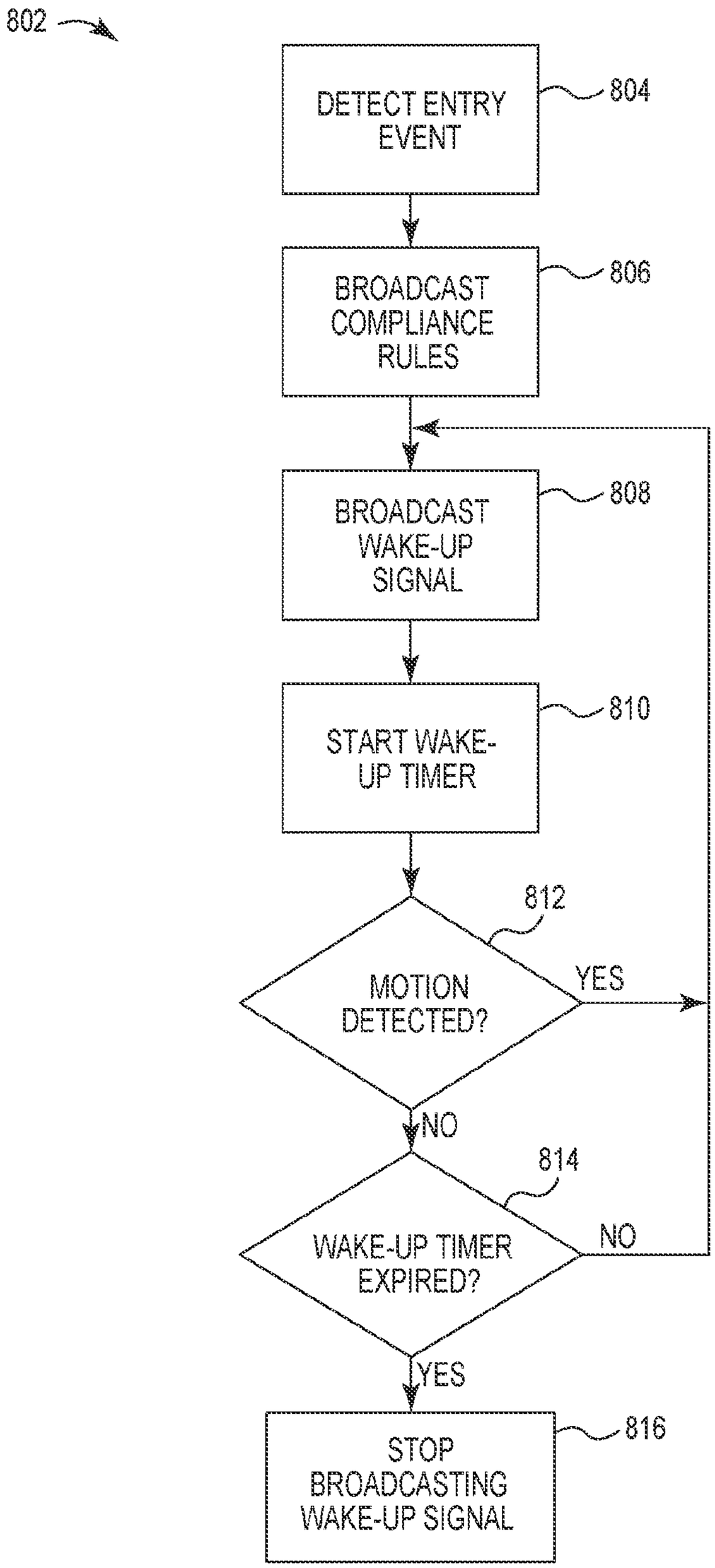
802
DETECT ENTRY EVENT
804
BROADCAST COMPLIANCE RULES
806
BROADCAST WAKE-UP SIGNAL
808
START WAKE-UP TIMER
810
MOTION DETECTED?
812
YES
NO
WAKE-UP TIMER EXPIRED?
814
NO
YES
STOP BROADCASTING WAKE-UP SIGNAL
816

Fig. 38

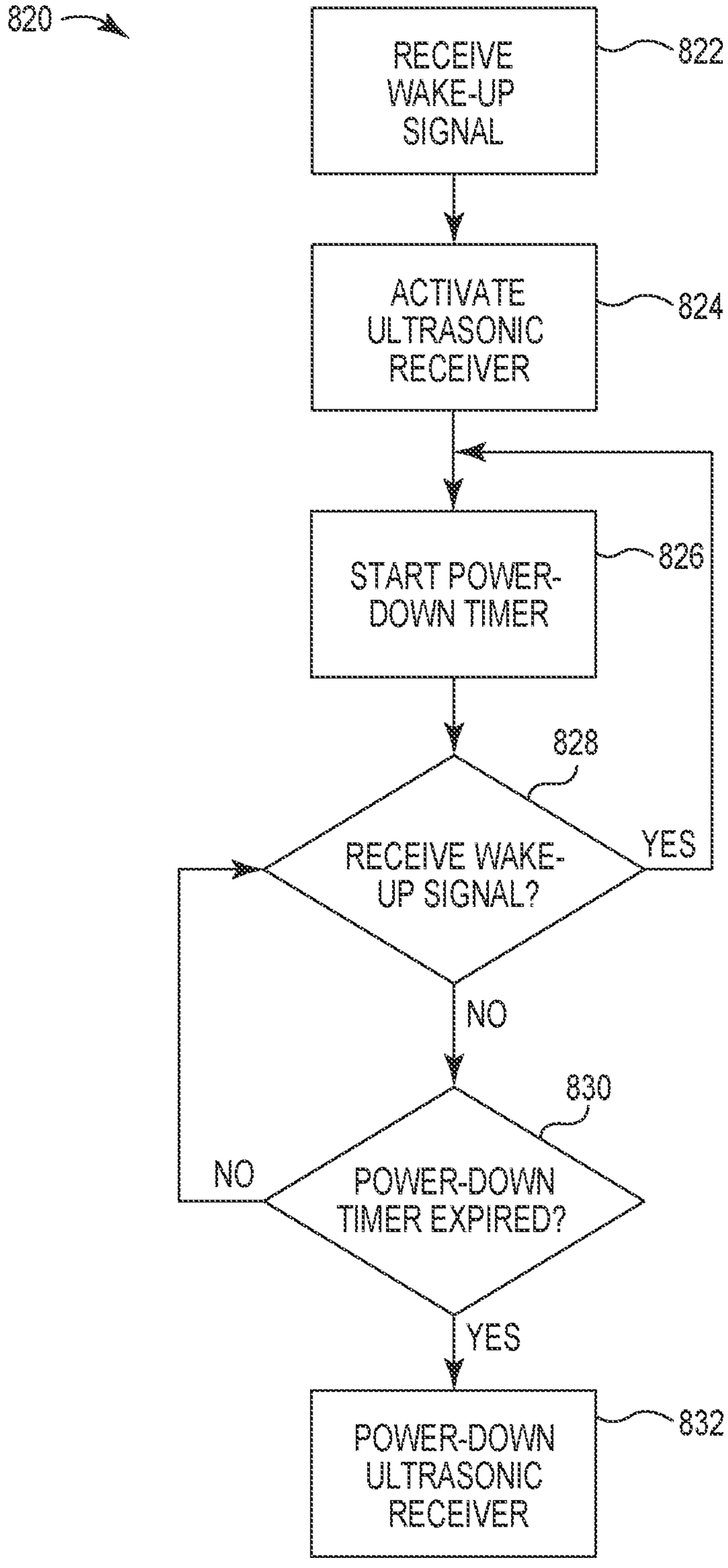
820
RECEIVE WAKE-UP SIGNAL
822
ACTIVATE ULTRASONIC RECEIVER
824
START POWER-DOWN TIMER
826
828
RECEIVE WAKE-UP SIGNAL?
YES
NO
830
POWER-DOWN TIMER EXPIRED?
NO
YES
POWER-DOWN ULTRASONIC RECEIVER
832

Fig. 39

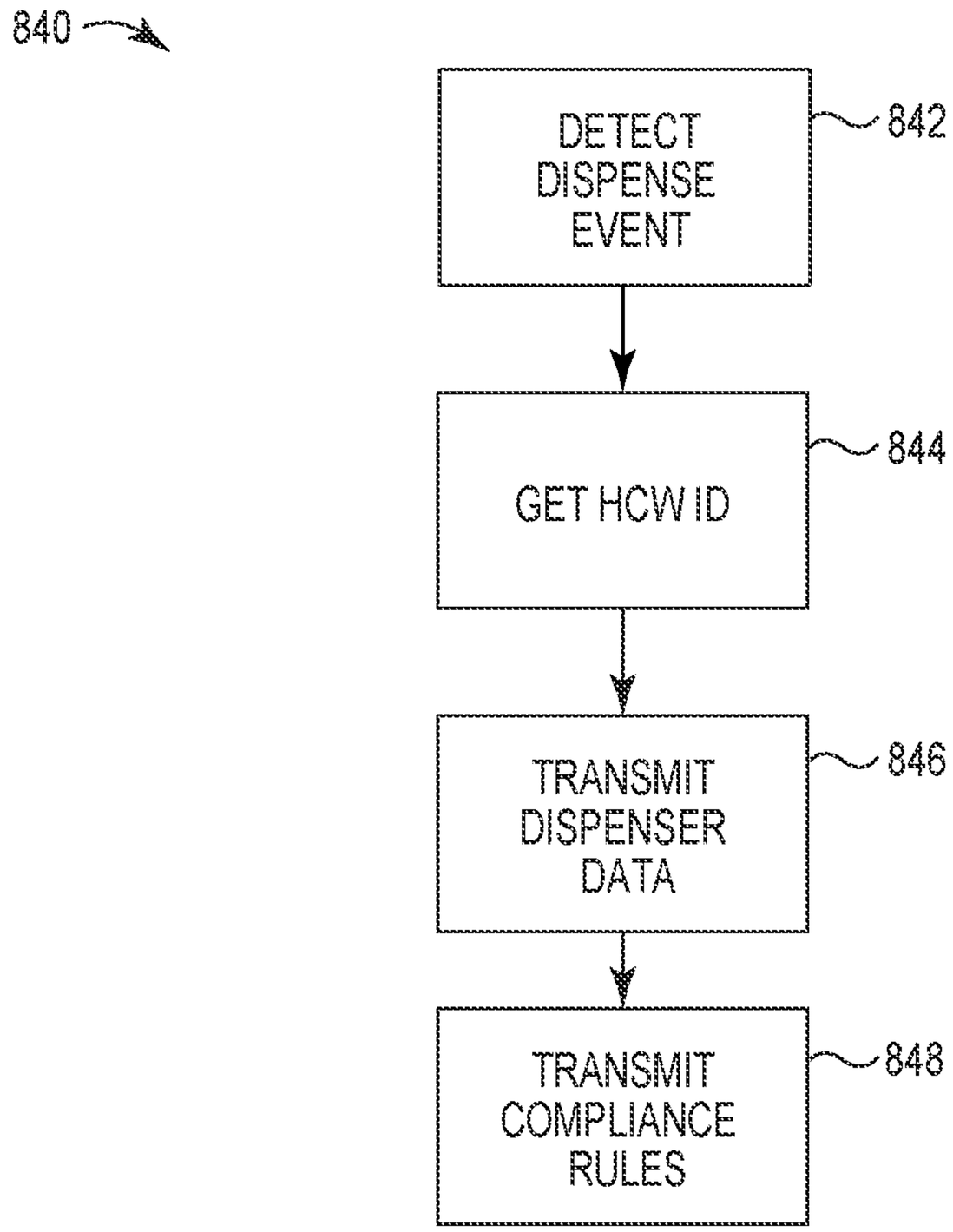
840
DETECT DISPENSE EVENT
842
GET HCW ID
844
TRANSMIT DISPENSER DATA
846
TRANSMIT COMPLIANCE RULES
848

Fig. 40

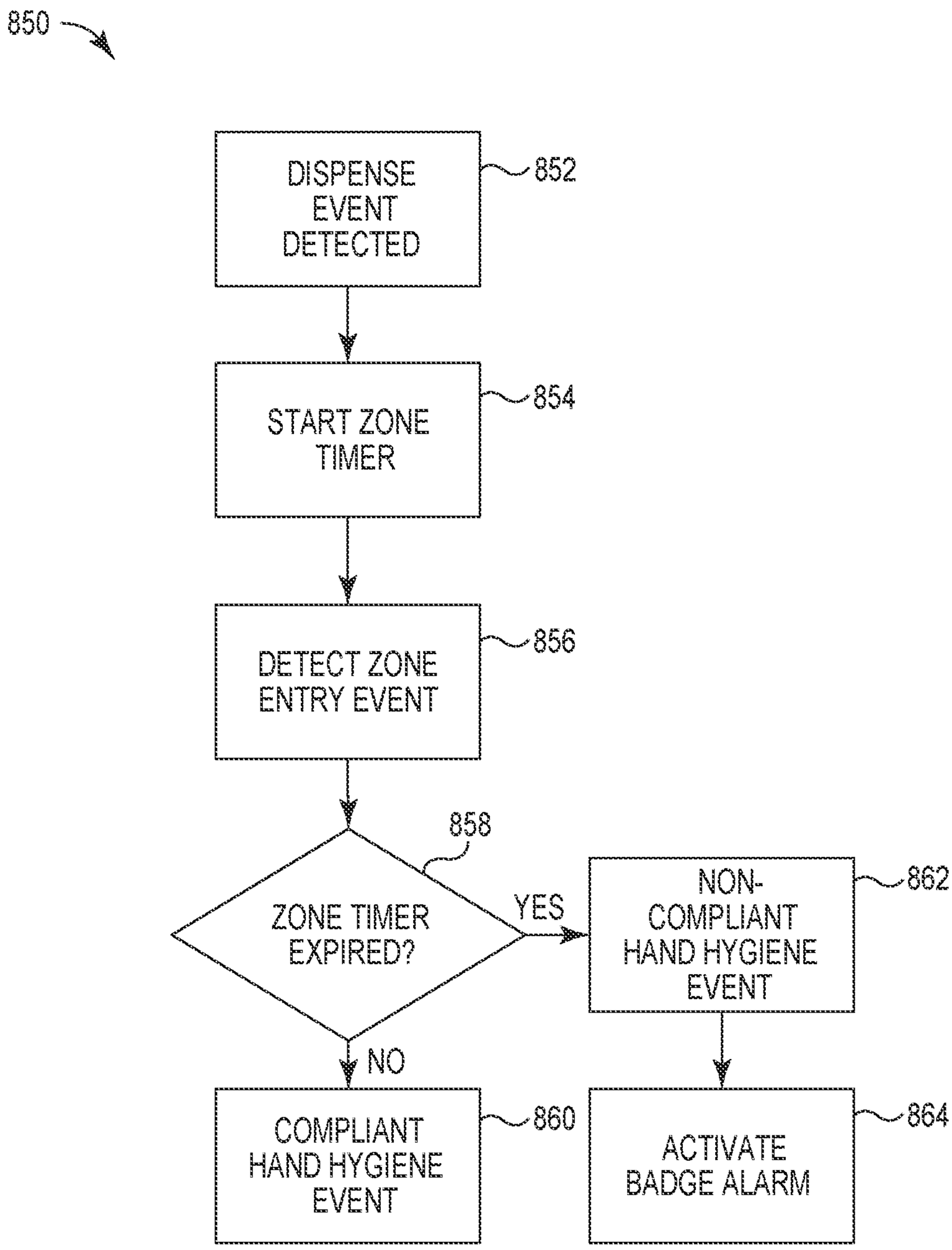
850
DISPENSE EVENT DETECTED
852
START ZONE TIMER
854
DETECT ZONE ENTRY EVENT
856
ZONE TIMER EXPIRED?
858
YES
NO
NON-COMPLIANT HAND HYGIENE EVENT
862
COMPLIANT HAND HYGIENE EVENT
860
ACTIVATE BADGE ALARM
864

Fig. 41

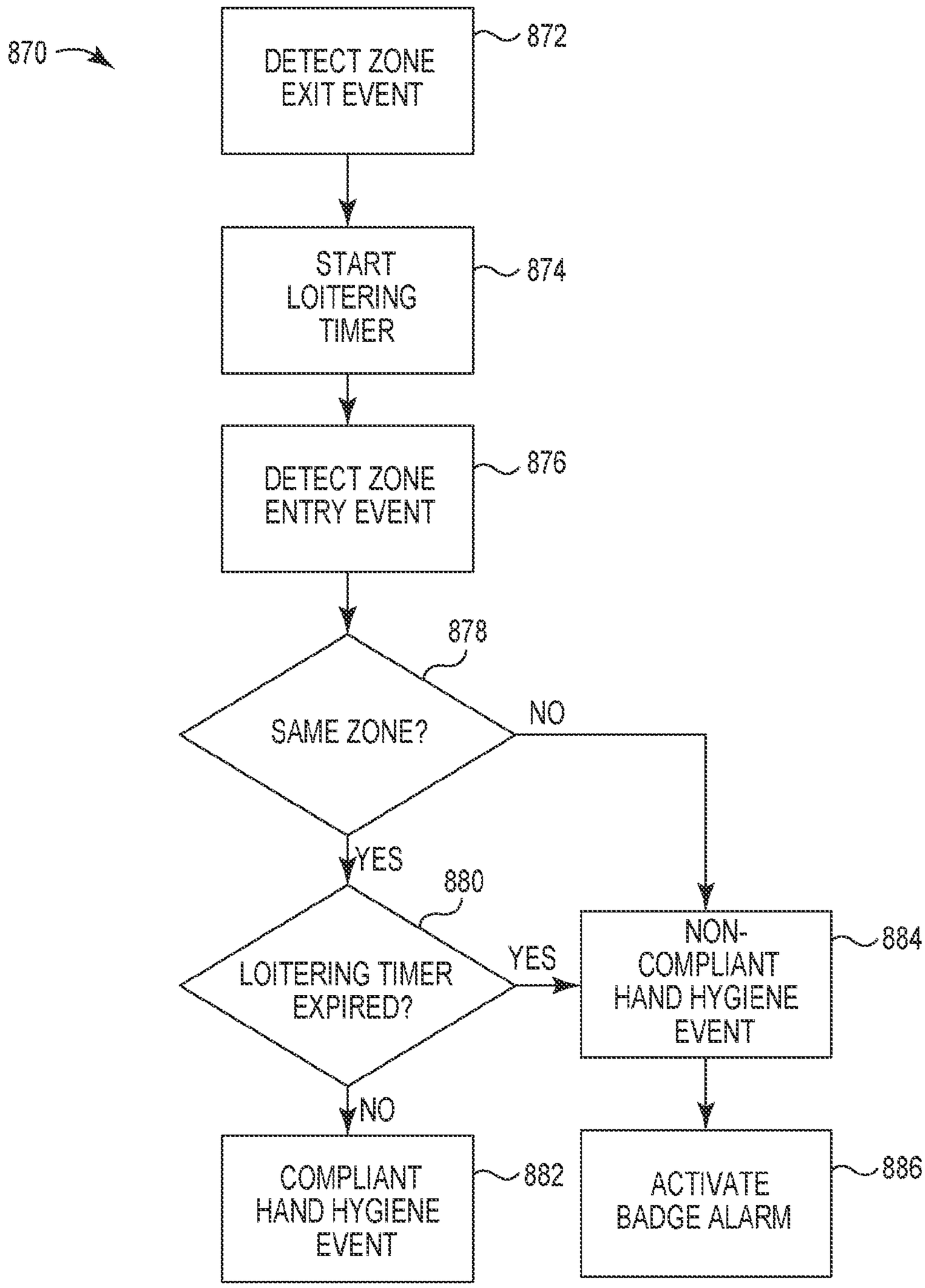
870
DETECT ZONE EXIT EVENT
872
START LOITERING TIMER
874
DETECT ZONE ENTRY EVENT
876
SAME ZONE?
878
NO
YES
LOITERING TIMER EXPIRED?
880
YES
NO
COMPLIANT HAND HYGIENE EVENT
882
NON-COMPLIANT HAND HYGIENE EVENT
884
ACTIVATE BADGE ALARM
886

Fig. 42

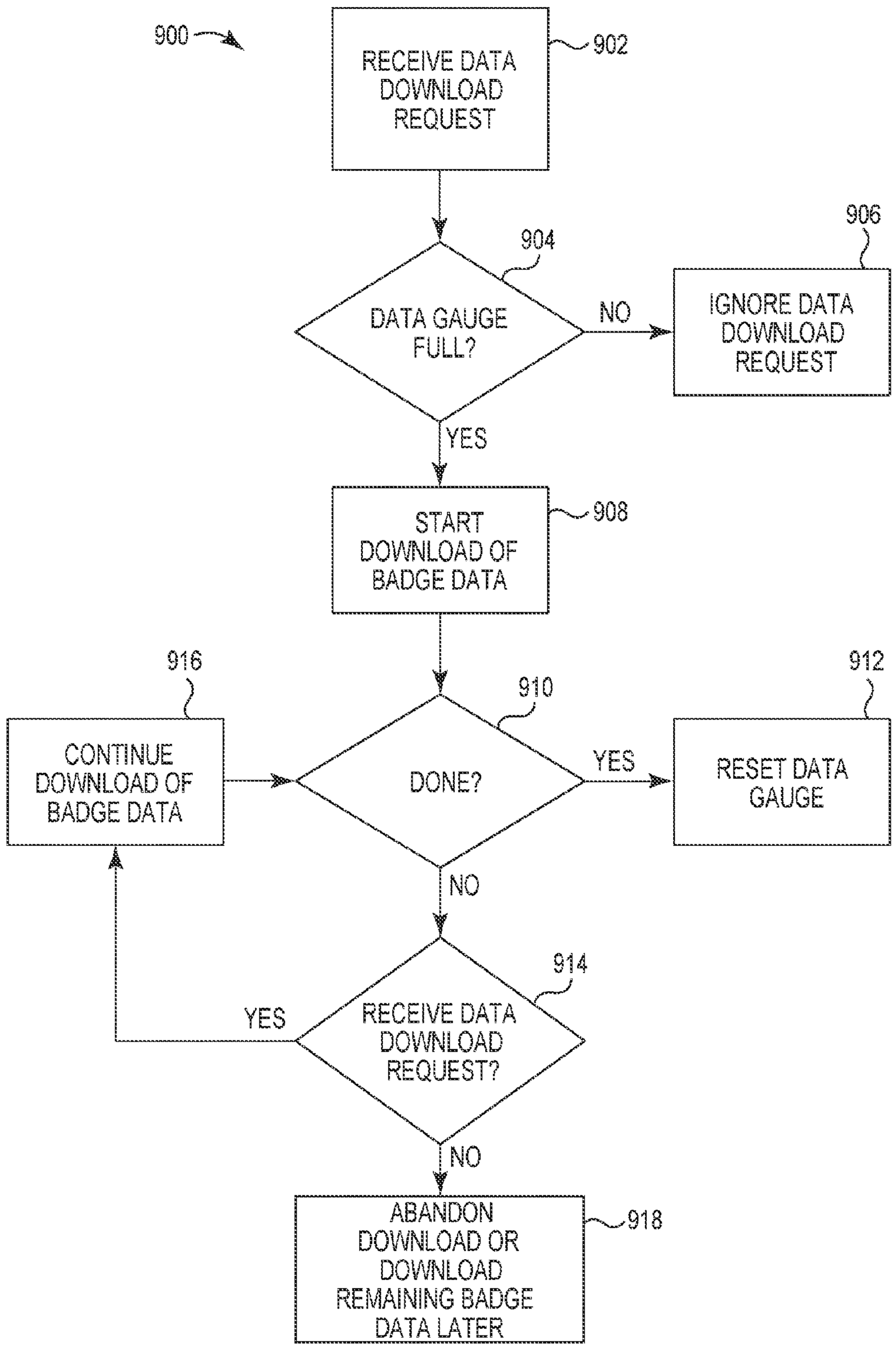
900
RECEIVE DATA DOWNLOAD REQUEST
902
DATA GAUGE FULL?
904
NO
IGNORE DATA DOWNLOAD REQUEST
906
YES
START DOWNLOAD OF BADGE DATA
908
DONE?
910
YES
RESET DATA GAUGE
912
NO
CONTINUE DOWNLOAD OF BADGE DATA
916
RECEIVE DATA DOWNLOAD REQUEST?
914
YES
NO
ABANDON DOWNLOAD OR DOWNLOAD REMAINING BADGE DATA LATER
918

Fig. 43

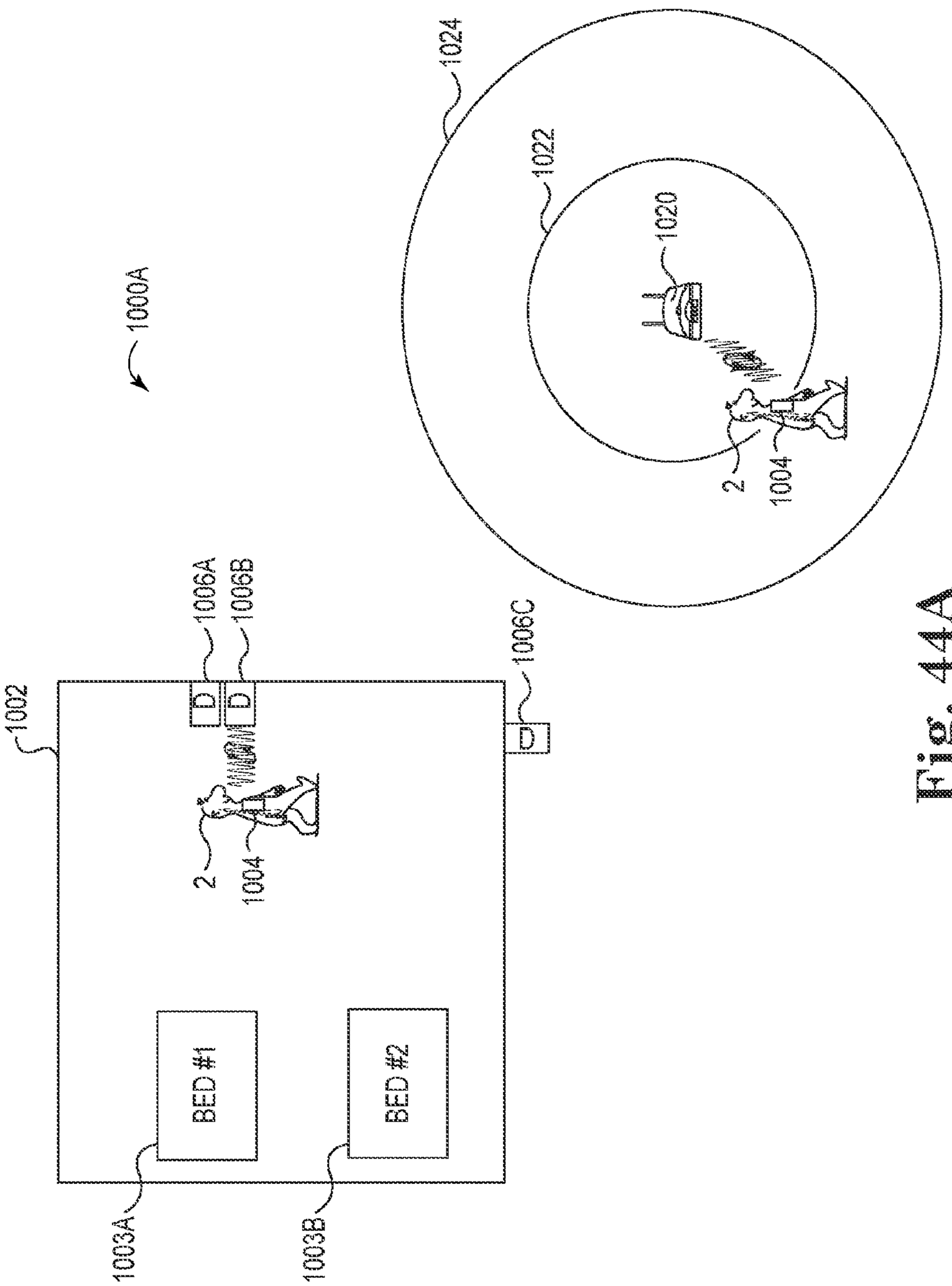
1000A
1002
1003A
1003B
BED #1
BED #2
1004
2
1006A
1006B
1006C
D
1020
1022
1024

Fig. 44A

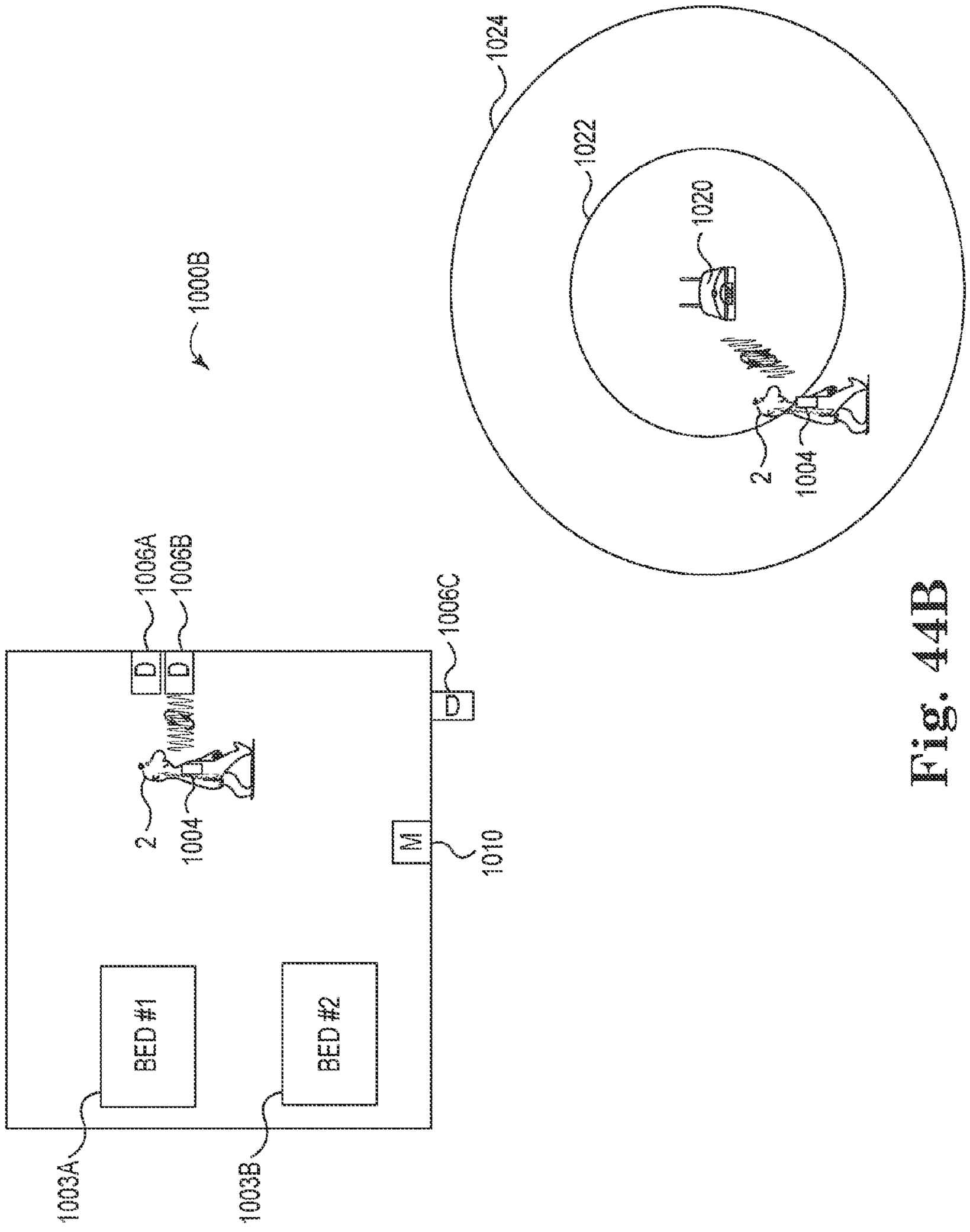
1000B
1024
1022
1020
1004
2
1006A
1006B
1006C
D
D
D
M
1010
BED #1
BED #2
1003A
1003B

Fig. 44B

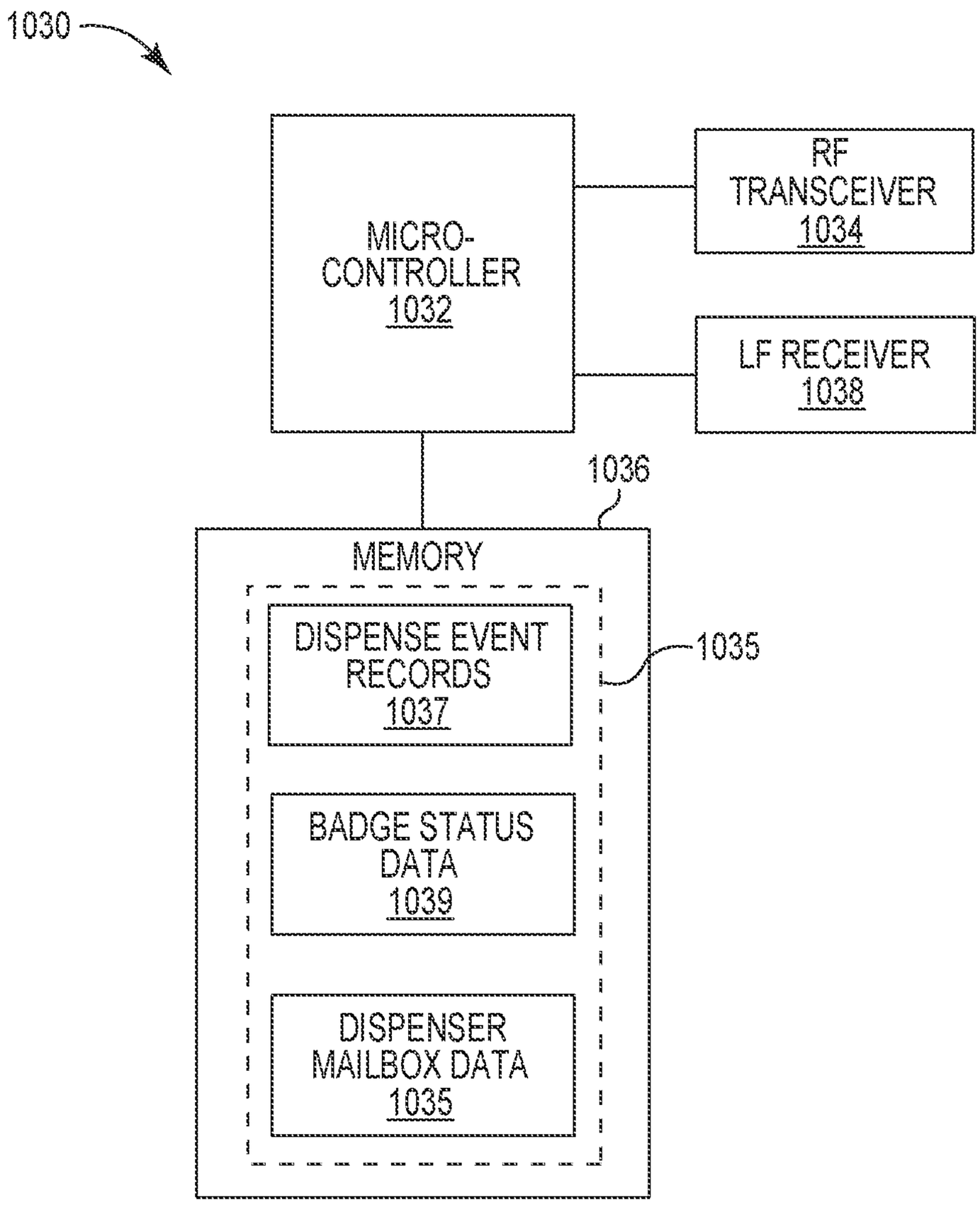
1030
MICRO-CONTROLLER 1032
RF TRANSCEIVER 1034
LF RECEIVER 1038
1036
MEMORY
DISPENSE EVENT RECORDS 1037
1035
BADGE STATUS DATA 1039
DISPENSER MAILBOX DATA 1035

Fig. 45

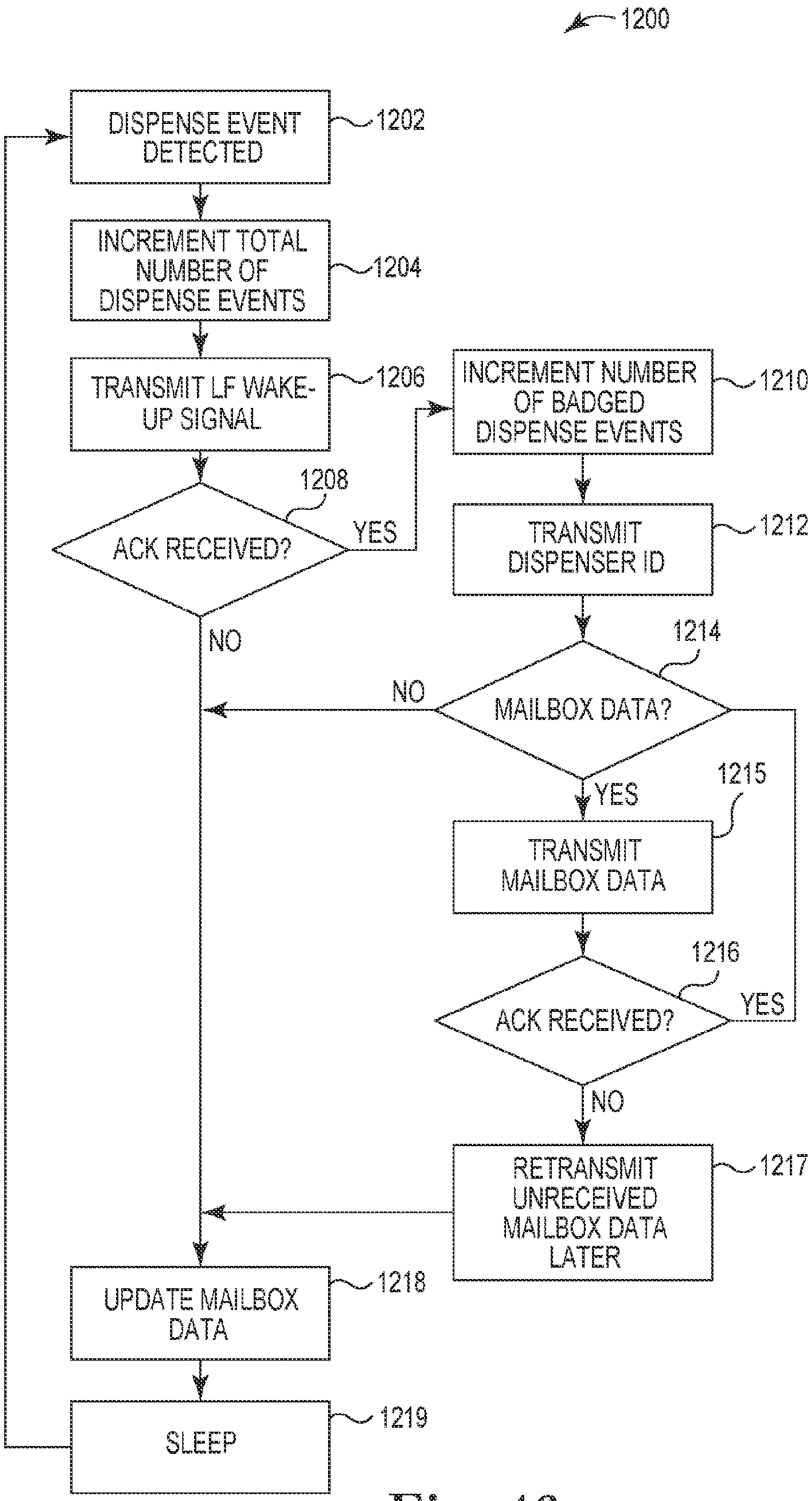
1200
DISPENSE EVENT DETECTED
1202
INCREMENT TOTAL NUMBER OF DISPENSE EVENTS
1204
TRANSMIT LF WAKE-UP SIGNAL
1206
ACK RECEIVED?
1208
YES
NO
INCREMENT NUMBER OF BADGED DISPENSE EVENTS
1210
TRANSMIT DISPENSER ID
1212
MAILBOX DATA?
1214
NO
YES
TRANSMIT MAILBOX DATA
1215
ACK RECEIVED?
1216
YES
NO
RETRANSMIT UNRECEIVED MAILBOX DATA LATER
1217
UPDATE MAILBOX DATA
1218
SLEEP
1219

Fig. 46

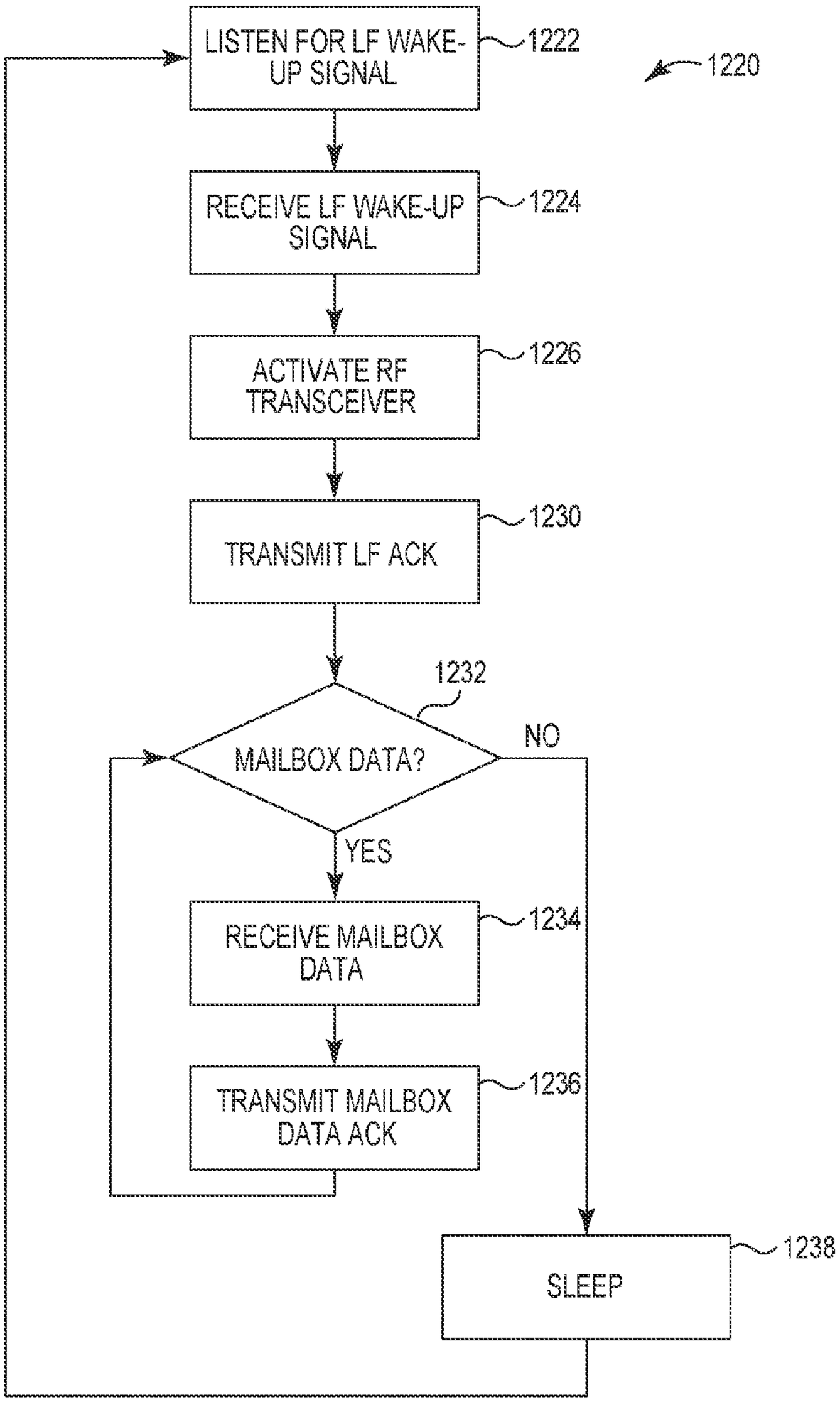
LISTEN FOR LF WAKE-UP SIGNAL
1222
1220
RECEIVE LF WAKE-UP SIGNAL
1224
ACTIVATE RF TRANSCEIVER
1226
TRANSMIT LF ACK
1230
1232
MAILBOX DATA?
NO
YES
RECEIVE MAILBOX DATA
1234
TRANSMIT MAILBOX DATA ACK
1236
SLEEP
1238

Fig. 47

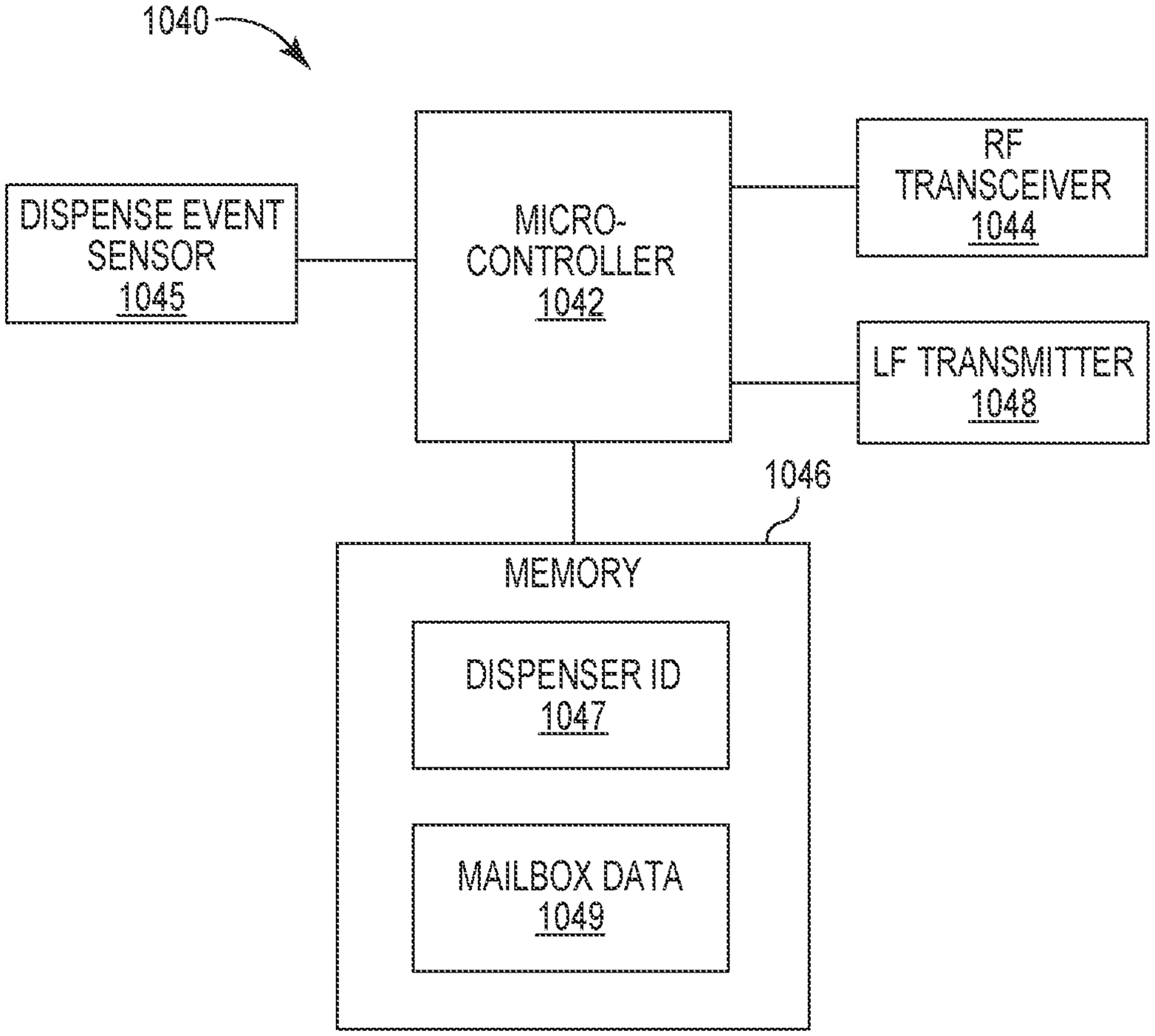
1040
DISPENSE EVENT SENSOR 1045
MICRO-CONTROLLER 1042
RF TRANSCEIVER 1044
LF TRANSMITTER 1048
1046
MEMORY
DISPENSER ID 1047
MAILBOX DATA 1049

Fig. 48

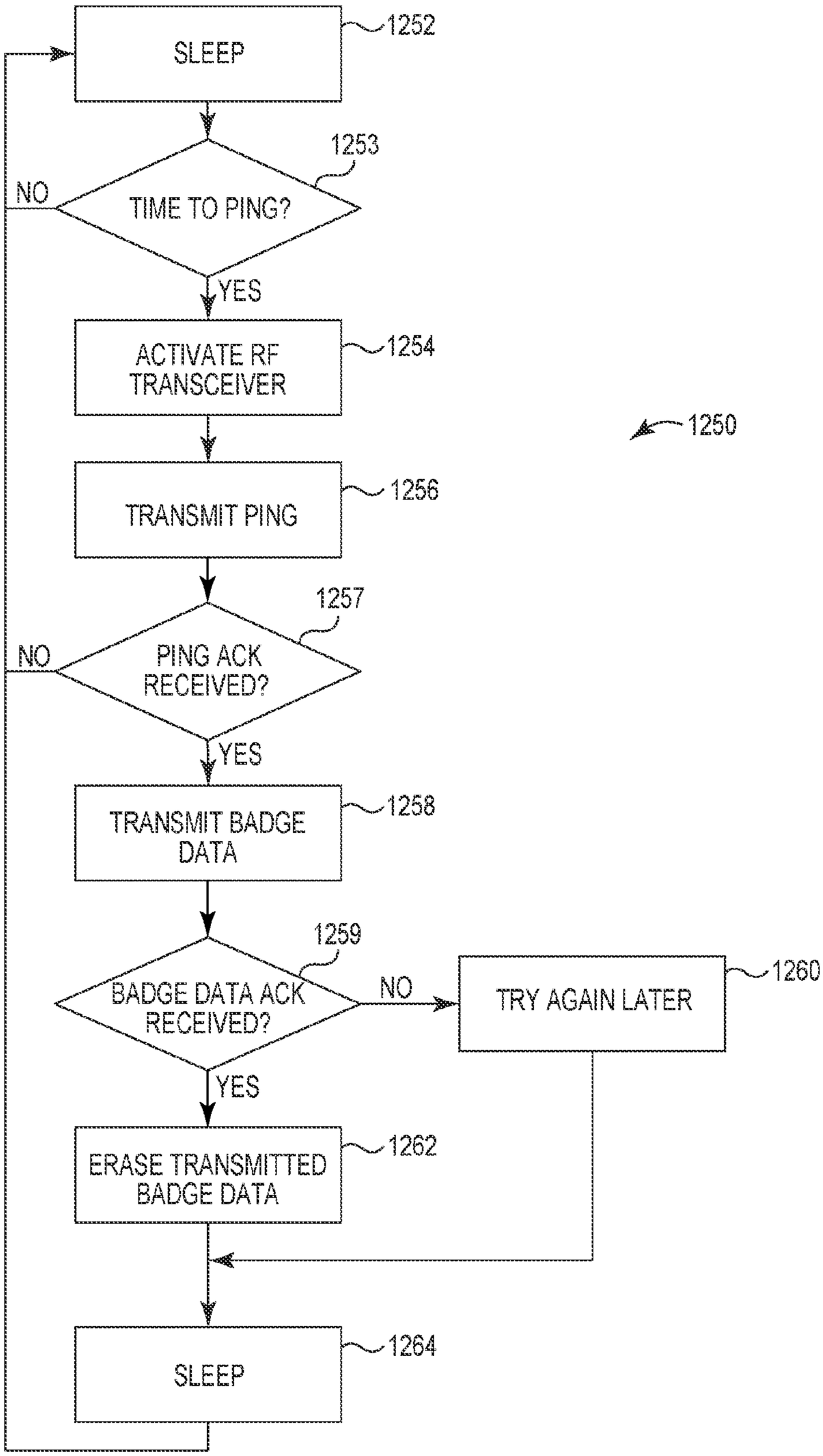
1250
SLEEP
1252
1253
TIME TO PING?
NO
YES
ACTIVATE RF TRANSCEIVER
1254
TRANSMIT PING
1256
1257
PING ACK RECEIVED?
NO
YES
TRANSMIT BADGE DATA
1258
1259
BADGE DATA ACK RECEIVED?
NO
TRY AGAIN LATER
1260
YES
ERASE TRANSMITTED BADGE DATA
1262
SLEEP
1264

Fig. 49

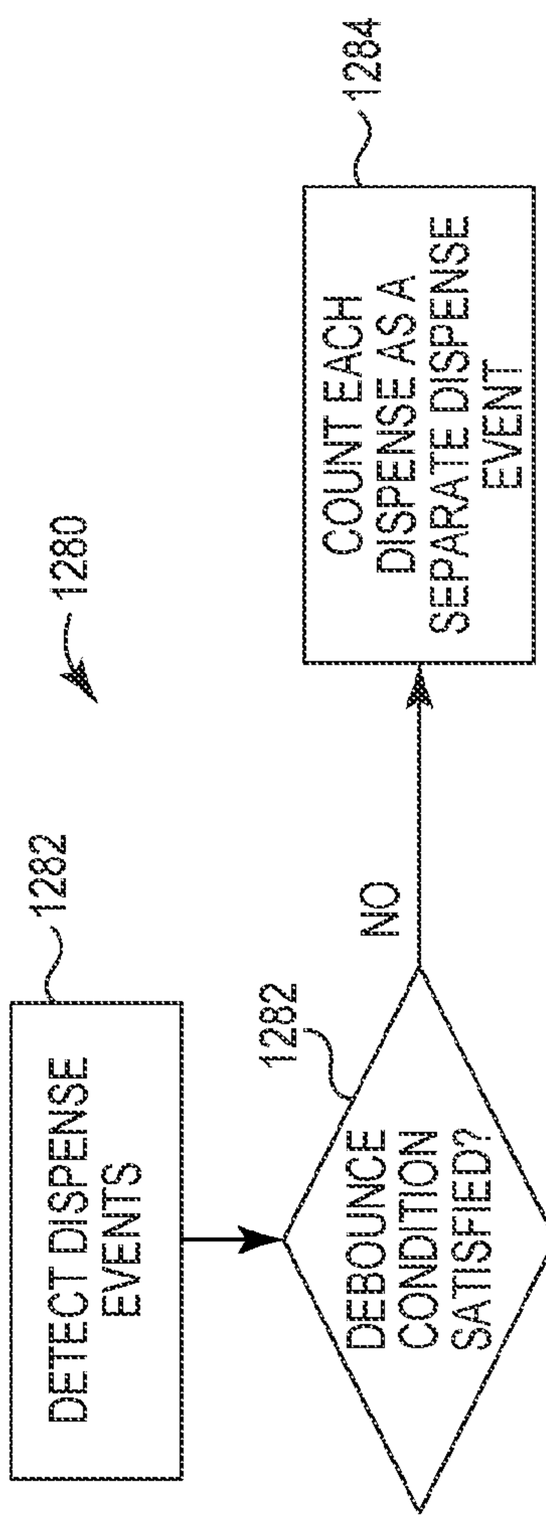
1280
1282
DETECT DISPENSE EVENTS
1282
DEBOUNCE CONDITION SATISFIED?
NO
YES
1284
COUNT EACH DISPENSE AS A SEPARATE DISPENSE EVENT
1286
COUNT AS A SINGLE DISPENSE EVENT

Fig. 51

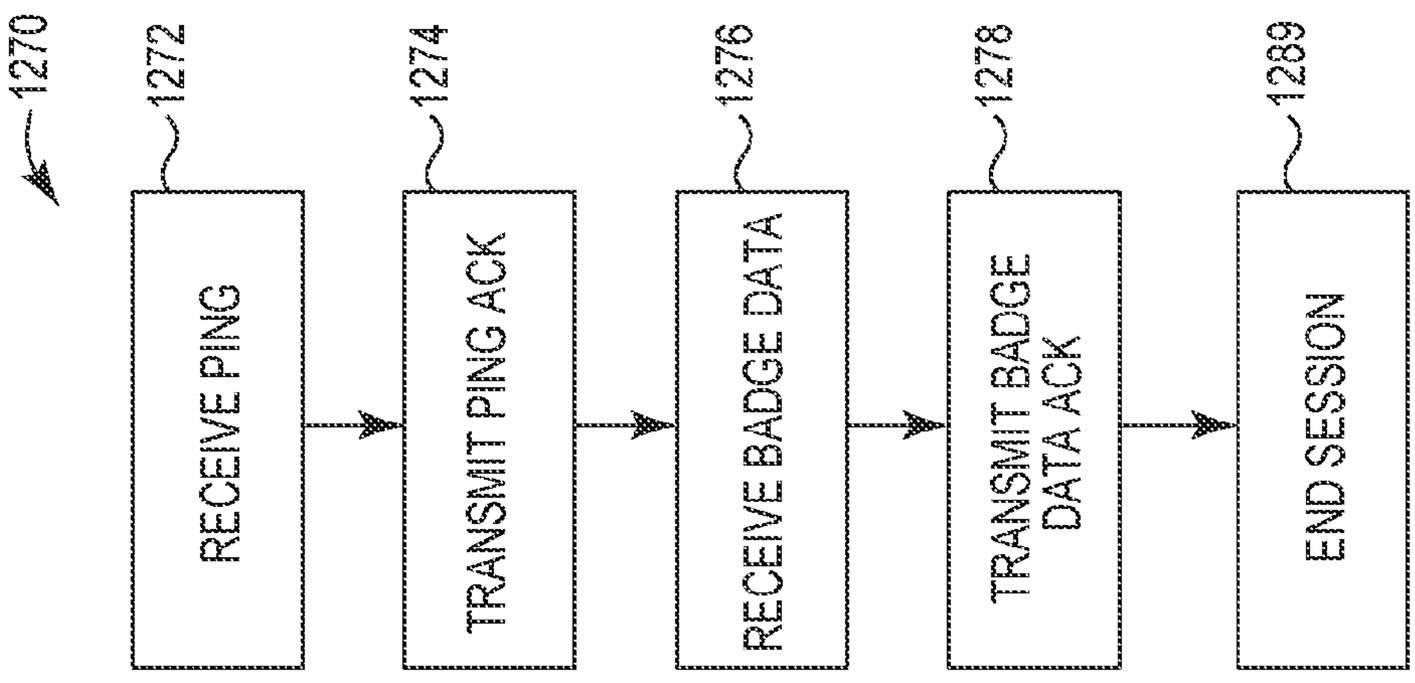
1270
1272
RECEIVE PING
1274
TRANSMIT PING ACK
1276
RECEIVE BADGE DATA
1278
TRANSMIT BADGE DATA ACK
1289
END SESSION

Fig. 50

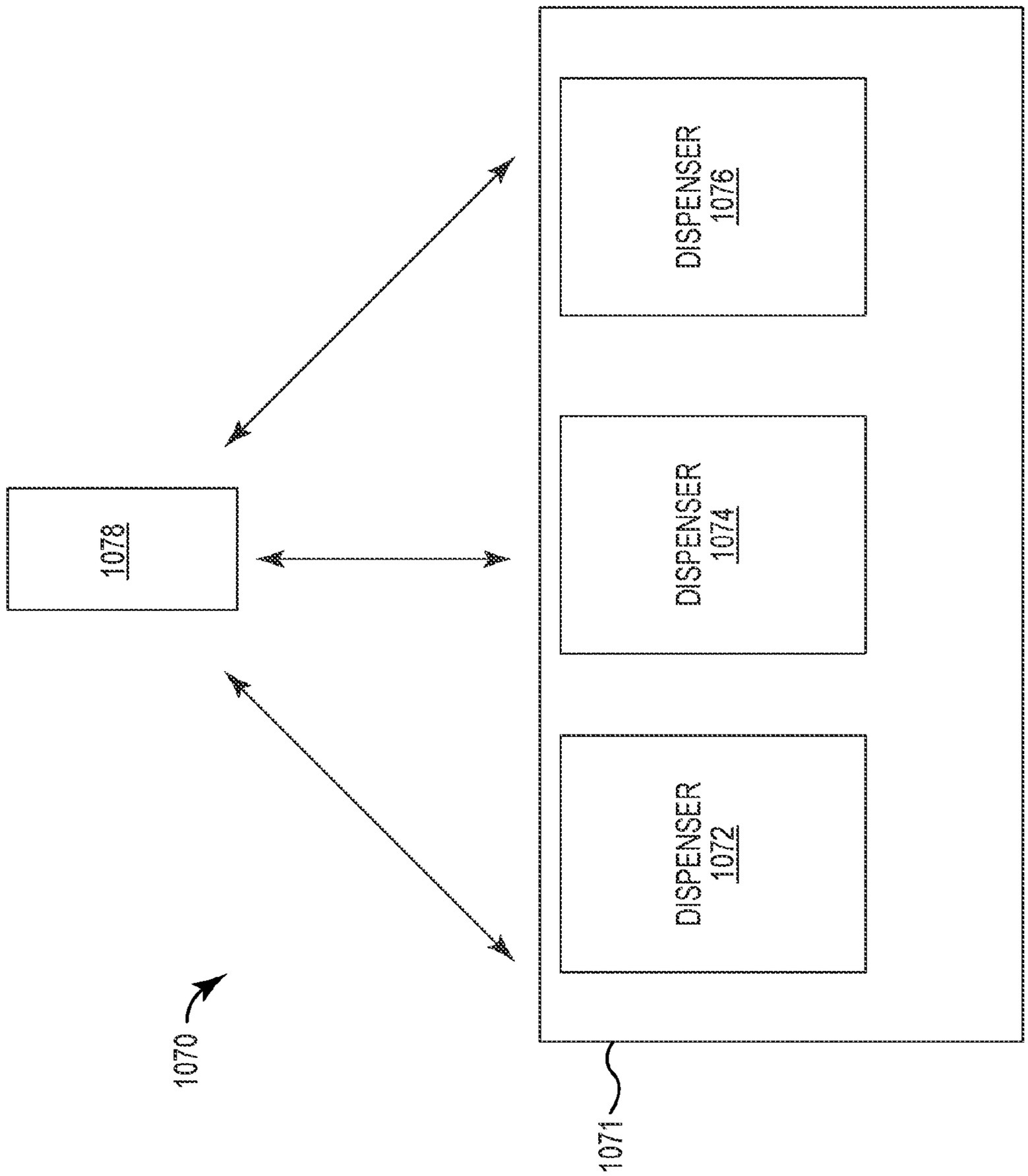
1070
1078
DISPENSER 1072
DISPENSER 1074
DISPENSER 1076
1071

Fig. 52

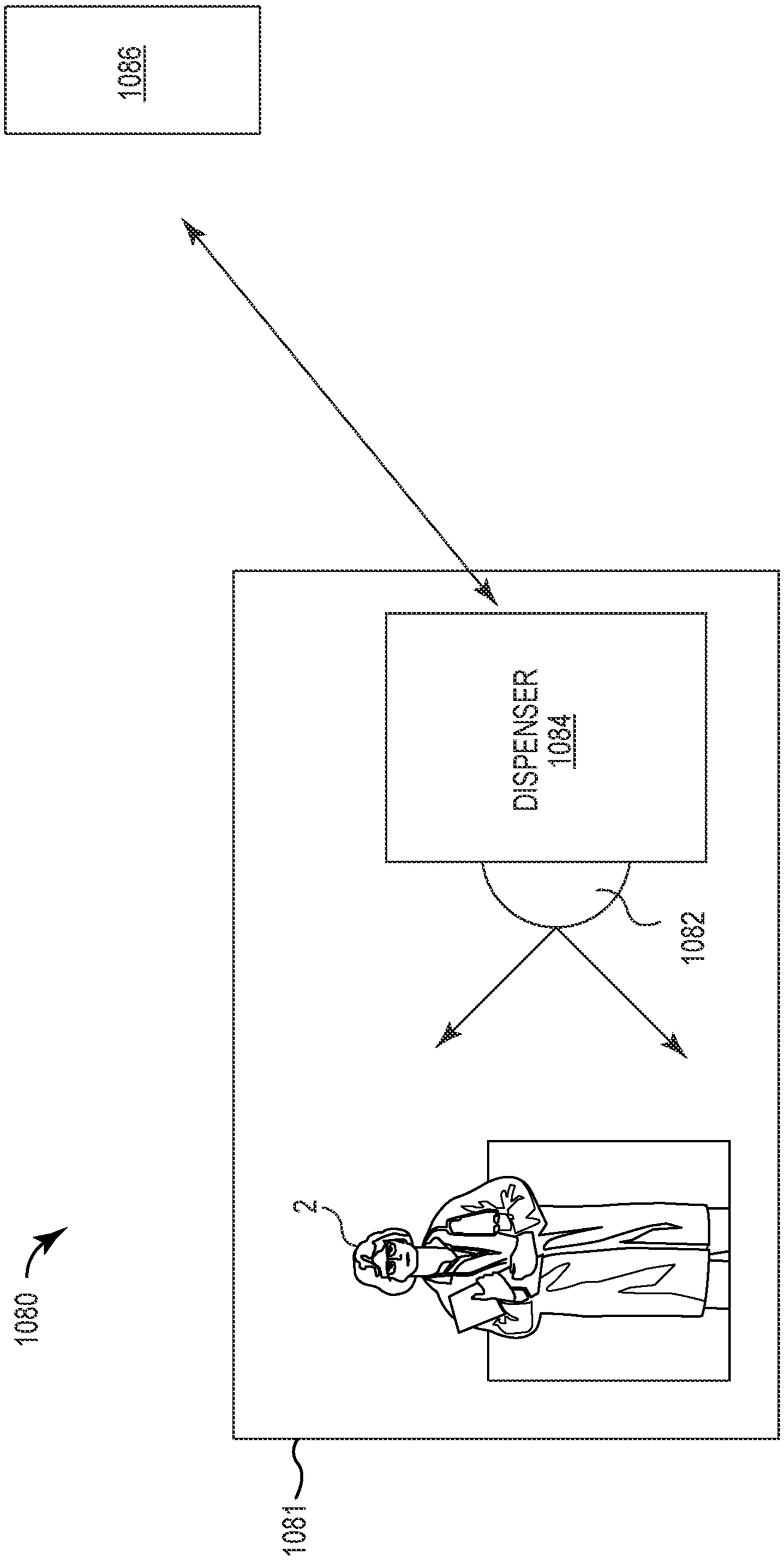

Fig. 53

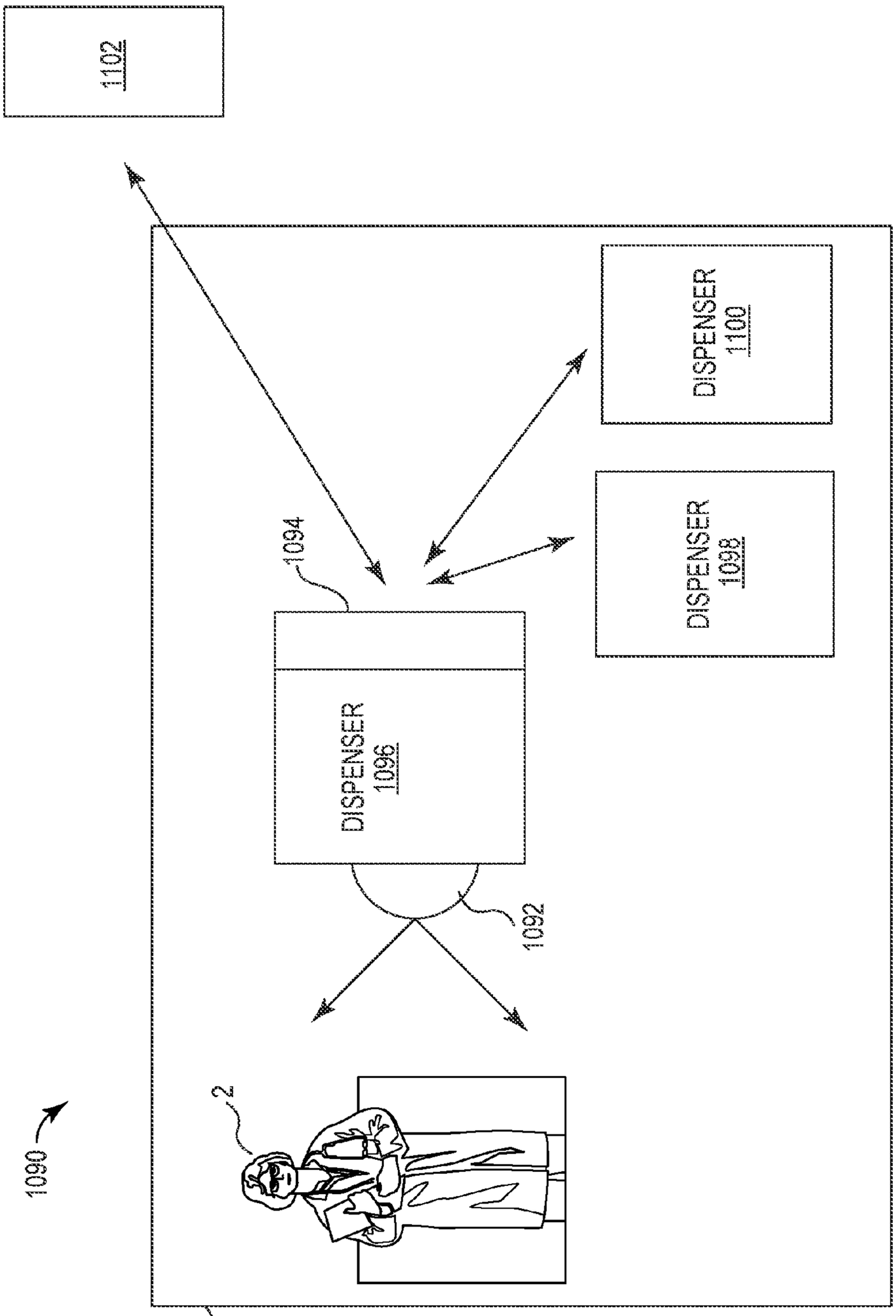
1102
DISPENSER
1100
DISPENSER
1098
1094
DISPENSER
1096
1092
1090
2
1091

Fig. 54

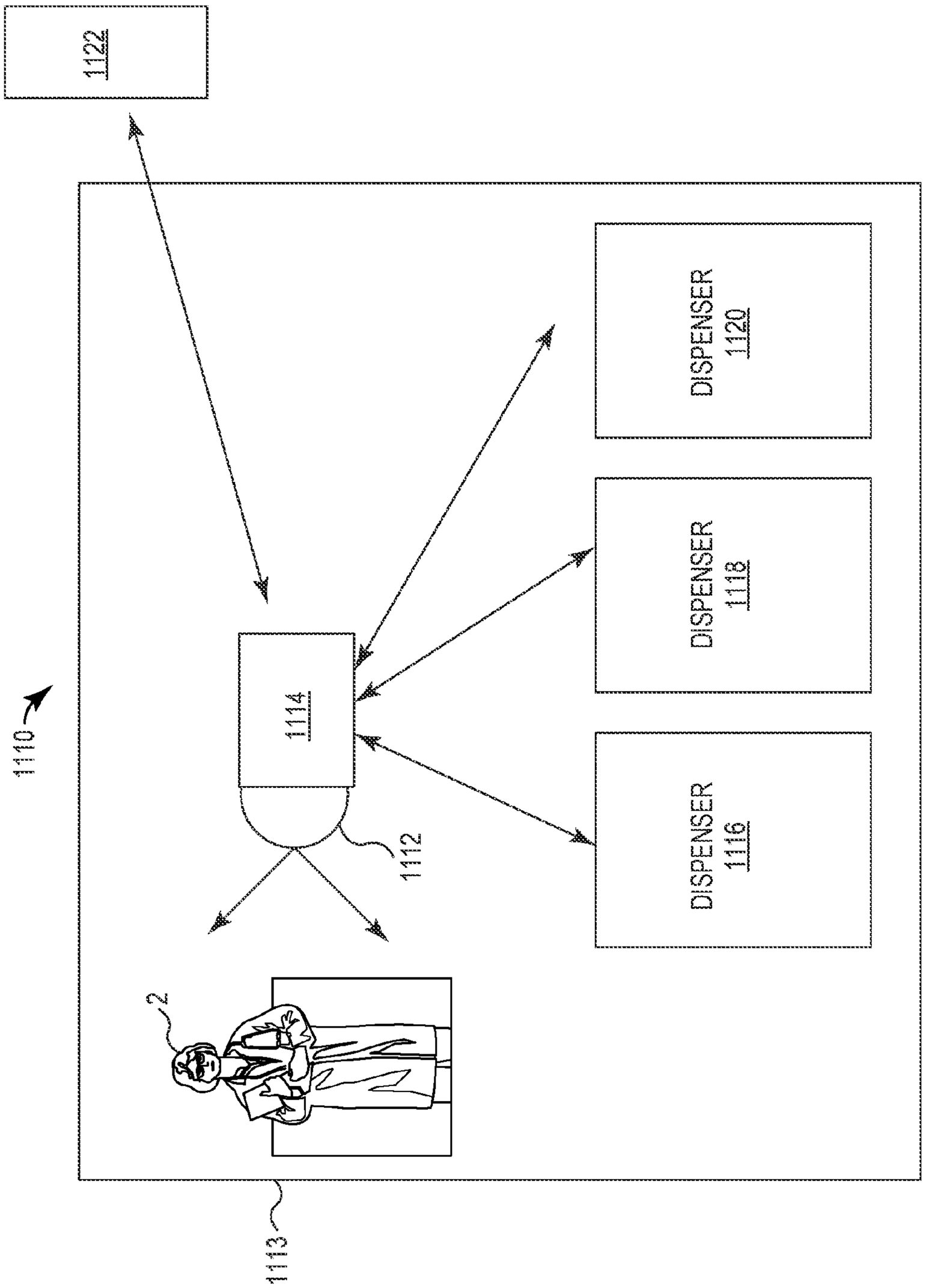
1122
1110
1114
1112
DISPENSER 1120
DISPENSER 1118
DISPENSER 1116
2
1113

Fig. 55

HAND HYGIENE COMPLIANCE MONITORING

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS REFERENCE TO RELATED APPLICATIONS

More than one reissue application has been filed for the reissue of U.S. Pat. No. 8,502,680. The reissue applications are application Ser. No. 14/819,349 (the present application) filed Aug, 5, 2015 and Ser. No. 17/383,689 filed Jul. 23, 2021, which is a divisional application of Ser. No. 14/819,349 and a reissue of the '680 patent.

This application *is a reissue application for U.S. Pat. No. 8,502,680, which issued from U.S. application Ser. No. 12/787,064, filed May 25, 2010, which* claims the benefit of U.S. Provisional Application No. 61/186,676, filed Jun. 12, 2009, and U.S. Provisional Application No. 61/243,720, filed Sep. 18, 2009, [both] *all* of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The disclosure relates to cleaning and sanitizing practices at a hospital or other healthcare facility.

BACKGROUND

Despite improvements in hand hygiene, stricter compliance requirements, and efforts to optimize isolation practices, hospitals and other healthcare facilities are losing the war on nosocomial or Hospital Acquired Infections (HAIs). A hospital acquired infection is an infection acquired in a hospital or other healthcare facility by a patient admitted for some reason other than that specific infection. Hospital acquired infections may include infections appearing 48 hours or more after hospital admission or within 30 days after discharge. They may also include infections due to transmission from colonized healthcare workers, or occupational exposure to infection among staff of the facility. Although the majority of hospital acquired infections are preventable, sadly their incidence has only increased.

Hospital acquired infections have become more rampant as antibiotic resistance spreads. Many factors contribute to the increased incidence of hospital acquired infections among hospital patients. For example, hospitals house large numbers of people who are sick and therefore have weakened immune systems. Medical staff move from patient to patient and see many patients a day, providing a way for pathogens to spread. Research indicates that hand hygiene practices are followed only 40% of the time by healthcare workers, even after exhaustive process improvements and training efforts. Many medical procedures, such as surgery, injections and other invasive procedures bypass the body's natural protective barriers, providing entry points for pathogens. The wide-spread use of antibiotics has contributed to the emergence of resistant strains of microorganisms in healthcare facilities and well as in the community.

Compliance with hand hygiene guidelines is considered the most effective action health care workers can take to reduce pathogen transmission in health care settings. Despite this, hand hygiene compliance remains low, and improvement efforts tend to lack sustainability.

SUMMARY

In general, the disclosure relates to systems and associated processes that monitor hand hygiene compliance. For example, the hand hygiene compliance system may monitor, analyze and report on hand hygiene compliance at a hospital or other healthcare facility.

In one example, the disclosure is direct to a system comprising one or more uniquely identified hand hygiene product dispensers, each associated with an area of concern (AOC) within a facility, that detects a dispense event and transmits a corresponding dispense event signal and dispenser identification information and one or more uniquely identified compliance badges, each of that receives the dispense event signal and the dispenser identification information and stores the dispenser identification information in a dispense event record that is associated with the detected dispense event.

In another example, the disclosure is directed to a system comprising at least one hand hygiene product dispenser, positioned within an area of concern (AOC) in a facility in which hand hygiene events are to be monitored, that senses a dispense event initiated by a wearer of a compliance badge and transmits dispenser data concerning the dispense event; and a plurality of compliance badges, each having uniquely associated badge identification information and each of which is worn by a different one of a plurality of wearers, the compliance badge comprising a receiver that receives the dispenser data and a controller that analyzes the dispenser data to monitor hand hygiene events initiated by the wearer.

In another example, the disclosure is directed to a system comprising at least one hand hygiene product dispenser, positioned within an area of concern (AOC) in a facility in which hand hygiene events are to be monitored, that senses a dispense event and transmits a dispense event signal indicative that a dispense event occurred and that transmits dispenser identification information and a compliance badge that receives the dispense event signal and the dispenser identification information associated with dispense events initiated by a wearer of the compliance badge, and stores dispense event records associated with each dispense event initiated by the wearer. The system may also include a plurality of compliance badges, each worn by a different one of a plurality of wearers. The system may also include one or more data gathering stations associated with the facility, each of which receives one or more of the dispense event records from at least one of the plurality of compliance badges; and a computing device that receives the dispense event records directly or indirectly from the one or more data gathering stations and analyzes the dispense event records to monitor hand hygiene events in the facility.

The details of one or more examples are set forth in the accompanying drawings and the description below. Other features and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating an example hand hygiene compliance system.

FIG. **2** is a block diagram illustrating an example communications environment within which the hand hygiene compliance system of the present disclosure may be used.

FIG. **3** is a schematic diagram illustrating and example installation of hand hygiene system components in multiple rooms and common areas of a hospital.

FIG. **4** is a schematic diagram illustrating the room components when a person is detected entering a room or other defined space.

FIG. **5** is a schematic diagram illustrating the room components when a dispense event is detected.

FIGS. **6**A-**6**C show example reports that may be generated by the reporting application.

FIG. **7** is a block diagram illustrating an example implementation of a motion detector module.

FIG. **8** is a block diagram illustrating an example implementation of a dispenser electronics module.

FIG. **9** is a block diagram illustrating an example implementation of a coordinator module.

FIG. **10** is a schematic diagram illustrating an example implementation of a motion detector module.

FIG. **11** is an electrical schematic diagram illustrating an example implementation of an id tag.

FIG. **12** is an electrical schematic diagram illustrating an example implementation of a dispenser module.

FIG. **13** is an electrical schematic diagram illustrating an example implementation of a coordinator module.

FIG. **14** is an electrical schematic diagram illustrating an example implementation of a local hospital computer or other designated computer having a WiFi access point.

FIG. **15** is a flowchart illustrating an example process of operation for a motion detector module.

FIG. **16** is a flowchart illustrating an example process of operation for a dispenser module.

FIG. **17** is a flowchart illustrating another example process of operation for a dispenser module.

FIG. **18** is a flowchart illustrating example processes of operation of a coordinator module.

FIG. **19** is a flowchart illustrating an example process by which a local hospital computer or other designated computer determines whether a compliant or non-compliant hand hygiene event has taken place.

FIG. **20** is a flowchart illustrating a process by which local hospital computer or other designated computer monitors for compliant or non-compliant hand hygiene events for dispensers located outside of a patient room or other defined space.

FIGS. **21**A-**21**F are electrical schematic diagrams illustrating example implementations for the components of an alternative hand hygiene compliance system.

FIG. **22**A is a block diagram illustrating an example of the alternative hand hygiene compliance system with multiple independent subnets

FIG. **22**B is a block diagram illustrating an example of another+alternative hand hygiene compliance system.

FIGS. **23**A and **23**B are a diagram illustrating an example hand hygiene compliance system **501** in which a plurality of hand hygiene compliance badges, each uniquely associated with a different one of a plurality of HCWs, monitor hand hygiene compliance in a healthcare or other facility.

FIG. **24** is a block diagram of an example motion detector.

FIG. **25** is a block diagram of an example dispenser.

FIG. **26** is a block diagram of an example compliance badge.

FIG. **27** is a more detailed block diagram of an example implementation for a compliance badge.

FIG. **28** is a block diagram of an example implementation for the ultrasonic zone emitter.

FIGS. **29-33** are diagrams illustrating example operation of the hand hygiene compliance system when a HCW enters and is present within a patient room AOC.

FIG. **34** illustrates an example operation of the hand hygiene compliance system after HCW exits AOC.

FIGS. **35** and **36** illustrate example operation of hand hygiene compliance system and automatic download of badge data by data gathering station.

FIG. **37** is a block diagram illustrating an example communications environment within which the example hand hygiene compliance system may be used.

FIG. **38** is a flowchart illustrating another example process of operation for a motion detector module.

FIG. **39** is a flowchart illustrating an example wake-up process for a compliance badge.

FIG. **40** is a flowchart illustrating an example process of operation for a dispenser module.

FIG. **41** is a flowchart illustrating another example process for a compliance badge.

FIG. **42** is a flowchart illustrating another example process for a compliance badge.

FIG. **43** is a flowchart illustrating an example badge data download process.

FIG. **44**A is a diagram illustrating another example hand hygiene compliance system.

FIG. **44**B is a diagram illustrating another example hand hygiene compliance system.

FIG. **45** is a block diagram of an example compliance badge.

FIG. **46** is a flowchart illustrating an example process by which a dispenser communicates with a compliance badge

FIG. **47** illustrates and example process by which a compliance badge may communicate with a dispenser.

FIG. **48** is block diagram of an example dispenser.

FIG. **49** is a flowchart illustrating an example process by which a compliance badge may communicate with a data gathering station.

FIG. **50** is a flowchart illustrating an example process by which a data gathering station may communicate with a compliance badge.

FIG. **51** is a flowchart illustrating an example process by which multiple dispense events satisfying a debounce condition may be counted as a single dispense event.

FIG. **52** is a block diagram illustrating another example hand hygiene compliance system.

FIG. **53** is a block diagram illustrating another example hand hygiene compliance system.

FIG. **54** is a block diagram illustrating an another example hand hygiene compliance system.

FIG. **55** is a block diagram illustrating another example hand hygiene compliance system.

DETAILED DESCRIPTION

In general, the disclosure relates to a system and associated processes that monitor hand hygiene compliance. For example, the hand hygiene compliance system may monitor, analyze and report on hand hygiene compliance at a hospital or other healthcare facility. FIG. **1** is a block diagram illustrating an example hand hygiene compliance system **10**. FIG. **1** shows the components associated with one room or other defined space within a hospital. These room components include a motion detector module **14**, one or more hand hygiene product dispensers **16** (shown here as hand hygiene product dispensers **16**A and **16**B, although more or fewer dispensers could be associated with each defined space), and a coordinator module **18**. Also shown is a

healthcare worker (HCW) **2** and an associated ID tag **4**. Coordinator **18** commumunicates with a local hospital server **28** or other computer and with remote users **54** via one or more network(s) **24**.

In general, hand hygiene compliance system **10** detects entry of persons into a patient room (or other defined area), identifying those persons and collecting data concerning their hand hygiene behavior. To that end, motion sensor **14** is physically installed near the door or entry to the defined space to detect entry of a person into that room or space (hereinafter referred to for simplicity as "room" or "patient room"). Motion sensor **14** includes an ID tag reader (not shown in FIG. **1**) that is activated when entry of a person into the room is detected. ID tag **4** includes electronic circuitry (such as an RFID chip and antenna) that stores and communicates HCW identification information when interrogated by the reader. The entry information and the HCW identification information are transmitted to coordinator module **18**. Alternatively, if the person entering the room is not an HCW and therefore does not have an associated id tag, the entry information and information identifying the person as a non-HCW are transmitted to coordinator module **18**.

Upon receipt of the entry and identification information, coordinator module **18** may send a "wake-up" signal to dispensers **16**A and **16**B (and other dispensers in the room, if any). This wake-up signal may cause dispensers **16**A and **16**B to enter an "invitation mode", in which the dispenser activates one or more visual or audible indicators whose purpose is to remind the person entering the room of a hand hygiene opportunity. In some examples dispensers receives such wake-up signal directly from coordinator module **18**. In other example the local hospital computer **28** support a hand compliance data base and sends such wake-up signal to dispensers.

Each dispenser **16** includes an activation sensor that detects when a hand hygiene product is dispensed. This is referred to as a "dispense event." For example, an activation sensor may detect when a dispenser button or bar is pushed or pulled to dispense hand hygiene product, may detect when an infrared or other touchless dispenser detects presence of a user, may detect the actual dispensing of the hand hygiene product, or may detect some other activation mechanism for dispensing hand hygiene product. Each time the activation sensor determines that dispenser **16** has dispensed hand hygiene product, the dispenser records a dispense event and looks for a HCW id tag signal containing HCW identification information from a target id tag **4** within range of the dispenser reader (or with non-HCW identification information if no ID tag data is detected).

The dispenser may use one or more of several techniques to obtain the HCW identification information from a target id tag **4**, and/or to ensure that the correct HCW identification information associated with the entry event is isolated in the event that two or more tags respond. The HCW identification information associated with the dispense event, and any other relevant dispenser data regarding the dispense event, such as dispenser id, product name, time, date, etc., is transmitted to coordinator module **18**.

Coordinator module **18** collects the hand hygiene data from motion sensor **14** and each of dispensers **16** in the associated room. In some examples, coordinator module **18** is AC powered and constantly turned ON and ready to receive information from the associated motion detector module **14** and dispensers **16**. In this example, coordinator modules **18** for each room in the hospital may communicate with a local hospital computer **28** or other designated computer using a wireless protocol, such as a WiFi **26** or other wireless protocol. For example, coordinator module **18** may communicate the hand hygiene data to a local hospital computer **28** or other designated computer, such as one or more a designated hospital computers, a local or remote server computer, database, etc. via a wireless protocol, such as a WiFi **26** or other wired or wireless network. In other examples, coordinator module **18** may communicate directly with a server computer **30** or other computing device via any means of electronic communication.

Local computer **28** or other designated computer attempts to reconcile each entry event with a corresponding dispense event; that is, computer **28** determines whether each person that entered the room completed an associated dispense event. An entry event and a dispense event correspond when the same person initiated both the entry and the dispense event. This occurs when the same HCW identification information is associated with both the entry event and the dispense event. This may also occur when the entry event and the dispense event are associated with non-HCW identification information.

If a dispense event corresponding to an entry event is detected "compliant hand hygiene event" is recorded. If an entry event is detected and no corresponding dispense event is detected, computer **28** records a "non-compliant hand hygiene event." For example, computer **28** may determine whether a dispense event corresponding to an entry event is detected within a target time frame. The target time frame may be determined based on a reasonable amount of time for the identified person to get to one of the dispensers in the room, but not be so long as to result in a likelihood that the person associated with the entry event comes into contact with the patient without completing a dispense event. Target time frames may be in the range of 5 to 30 seconds, for example, but other time frames may be used and the disclosure is not limited in this respect.

A server computer **30** may communicate with the local computer **28** via network(s) **24** to receive the data related to hand hygiene compliance that is gathered and stored on local computer **28** at each hospital. Server computer **30** may also send commands, instructions, software updates, etc. to the hand hygiene compliance systems at each hospital via network(s) **24**. Server computer **30** may receive data or otherwise communicate with the hand hygiene compliance systems at each of the hospitals **22** on a periodic basis, in real-time, upon request of server computer **30**, or at any other

Server computer **30** includes analysis and reporting applications that analyze the hand hygiene data and generate reports regarding hand hygiene compliance. For example, server computer **30** may analyze the hand hygiene data to monitor hand hygiene compliance by individual HCW, type of HCW (e.g., nurses, doctors, environmental services (EVS), etc.), individual departments, type of department, individual hospital, type of hospital, across multiple hospitals, or by various other selected parameters. Server computer may generate a variety of reports to provide users local to each hospital **22**A-**22**N or remote users **54** with both qualitative and quantitative data regarding hand hygiene compliance at their hospital, to compare data over time to determine whether improvement has occurred, and/or to benchmark hand hygiene compliance at multiple hospitals or other healthcare facilities.

In addition to sending entry event data and dispense event data to coordinator module **18**, motion detector module **14** and dispenser module **16** may also periodically transmit status data to the coordinator module **18**. For example,

motion detector module **14** may transmit motion detector module status data, such as motion detector id, time, group name, battery voltage, constant and variable settings (detection range, etc.) at 0.5 second, 1 second, 2 seconds, 5 seconds or other appropriate time interval. Similarly, motion detector module **14** and/or dispenser module(s) **16** may transmit dispenser module status data, such as dispenser id, time, group name, battery voltage, constant and variable settings (detection range, hand hygiene product, number of dispenses, out-of-product status, refill status, etc.) at 0.5 second, 1 second, 2 seconds, 5 seconds or other appropriate time interval.

In addition, id tags **4** may be active, passive or semi-active tags. For example, id tags **4** may periodically generate a tag signal containing, for example, the HCW identification information, battery voltage, etc., at intervals such as 0.5 seconds, 1 second, 2 seconds, 5 seconds or other appropriate time interval. As another example, id tags **4** may continuously transmit a tag signal containing the HCW identification information. As another example, id tags **4** may be passive tags which generate a tag signal containing the HCW identification information when induced by an interrogation signal.

FIG. **2** is a block diagram illustrating an example communications environment within which the hand hygiene compliance system **10** of the present disclosure may be used. One or more hospitals or other healthcare facilities **22**A-**22**N are coupled via network(s) **24** to server computer **30**. Network(s) **24** may include, for example, one or more of a dial-up connection, a local area network (LAN), a wide area network (WAN), the internet, a cell phone network, satellite communication, or other means of electronic communication. The communication may be wired or wireless. Server computer **30** is coupled to a local server computer at each hospital **22**A-**22**N via network(s) **24** to receive data related to hand hygiene compliance that is gathered and stored on local storage media at each hospital. Server computer **30** may also send commands, instructions, software updates, etc. to each hospital via network(s) **24**. Server computer **30** may receive data or otherwise communicate with the hospitals on a periodic basis, in real-time, upon request of server computer **30**, or at any other appropriate time.

The data received from hospitals **22**A-**22**N, as well as other data associated with the operation of the hand hygiene compliance system, may be stored on a database **40**. Database **40** may store, for example, hospital data **41**A-**41**N associated with each of the hospitals **22**A-**22**N, respectively; dispenser data **42**A-**42**N associated with each of the hospitals **22**A-**22**N, respectively; motion detector data **43**A-**43**N associated with each of the hospitals **22**A-**22**N, respectively; health care worker data **44**A-**44**N associated with each of the hospitals **22**A-**22**N, respectively; coordinator data **45**A-**45**N associated with each of the hospitals **22**A-**22**N, respectively; and reports **46**A-**46**N associated with each of the hospitals **22**A-**22**N, respectively.

Hospital data **41**A-**41**N may include data that uniquely identifies or is associated with the respective hospital or other healthcare facility **22**A-**22**N. As such, hospital data **41**A-**41**N may include, for example, hospital identification information, employee information, management information, accounting information, business information, pricing information, information concerning those persons or entities authorized to access the reports generated by the hand hygiene compliance system, date and time stamps, caregiver identification, visitor identification and additional information relating to other aspects of the corporation or operation and other information specific to each individual hospital **22**A-**22**N.

Dispenser data **42**A-**42**N may include, for example, any information associated with operation of the hand hygiene product dispensers in the respective hospital **22**A-**22**N. For example, dispenser data **42**A-**42**N may include, without limitation, one or more of the following data types: dispenser id; dispenser type; dispensed product name; dispensed product type (e.g., sanitizer, soap, alcohol, etc.); dispensed product form (solid, liquid, powder, pelleted, etc.); dispensed product amounts (by volume, weight, or other measure); dispensing times, dates, and sequences; detected healthcare worker ids linked to specific dispensing events; empty dispenser indications; and other information originating at the dispenser site, whether detected by a dispenser or by an associated device.

Motion detector data **43**A-**43**N may include, for example, information concerning the entry and exit of tagged persons from a hospital room or other defined area in the respective hospital **22**A-**22**N. For example, motion detector data **43**A-**43**N may include, without limitation, motion detector id; motion detector type; physical location (e.g., hospital room number, or other defined area within the hospital, such as a standalone hand washing station, procedure room, lab, common area, operating room, etc.; date of installation; maintenance records; detected person events, whether id tagged or untagged; detected healthcare worker ids; date and time stamps; and other data associated with the motion detector modules of the respective hospital **22**A-**22**N. Healthcare worker (HCW) data **44**A-**44**N may include, for example, information concerning employees of the respective hospital **22**A-**22**N. For example, HCW data **44**A-**44**N may include, without limitation, HCW name, employee id number and/or other identification information; position (physician, nurse, physician assistant, physical therapist, EVS, etc.); work schedule; and other HCW related information for the healthcare workers in the respective hospital **22**A-**22**N.

Coordinator data **45**A-**45**N may include, for example, all of the information collected by the coordinator modules in the respective hospital **22**A-**22**N. For example, coordinator data **46**A-**46**N may include, without limitation, coordinator ids; a lists of hand hygiene dispensers associated with each coordinator; lists of motion detector modules associated with each coordinator; a list of room(s) or other defined area(s) within the hospital associated with each coordinator; links to the data collected by the dispensers and motion detector modules associated with each coordinator; and other coordinator information for each coordinator in the respective hospital **22**A-**22**N.

Server computer **30** includes an analysis application **32** that analyzes the data received from each of hospitals **22**A-**22**N and stores the results for each hospital **22**A-**22**N in the database **40**. Analysis application **32** may analyze the hospital data **41**A-**41**N, dispenser data **42**A-**42**N, motion detector data **43**A-**43**N, HCW data **44**A-**44**N, and/or coordinator data **45**A-**45**N either alone or in various combinations with each other to monitor hand hygiene compliance by individual HCW, type of HCW (e.g., nurses, doctors, EVS, etc.), individual departments, type of department, individual hospital, type of hospital, across multiple hospitals, or by various other selected parameters.

A reporting application **34** generates a variety of reports that present the analyzed data for use by the person(s) responsible for overseeing hand hygiene compliance at each hospital **22**A-**22**N. Reporting application **34** may generate a variety of reports to provide users local to each hospital

22A-22N or remote users **54** with both qualitative and quantitative data regarding hand hygiene compliance at their hospital, and/or to compare data over time to determine whether improvement has occurred. Reporting application **34** may also users to benchmark hand hygiene compliance at multiple hospitals or other healthcare facilities.

Reports **46**A-**46**N associated with each hospital **22**A-**22**N, respectively, may also be stored in database **40**. Examples of the reports that may be generated by reporting application **34** are described with respect to FIGS. **6**A-**6**C. Reports **49**A-**49**N may be accessed by users local to each hospital **22**A-**22**N or by remote users **54** over one or more network(s) **24**. One or more of the reports **49**A-**49**N may be downloaded and stored on a local hospital computer, such as hospital server computer **23** shown in FIG. **1**, user computer **54**, other authorized computing device, printed out in hard copy or further communicated to others as desired.

Local hospital computer **28** (FIG. **1**) or database may also store the above-described hand hygiene data (e.g., hospital data, dispenser data, motion detector data, HCW data, and/or coordinator data) associated with that hospital. Hospital computer **28**, database, or other local computer(s), may also include local analysis and reporting applications such as those described above with respect to analysis and reporting applications **32** and **34**. In that case, reports associated with that particular hospital may be generated and viewed locally, if desired. In another example, all analysis and reporting functions are carried out remotely at server computer **30**, and reports may be viewed, downloaded or otherwise obtained remotely. In other examples, some hospitals **22** may include local storage and/or analysis and reporting functions while other hospitals **22** rely on remote storage and/or analysis and reporting. Thus, although the general case of data being stored at the local hospital computer **28** and analysis/reporting being carried out by the server computer **30** is described herein, it shall be understood that these storage, analysis and reporting functions may also be carried out locally or at some other location, and that the disclosure is not limited in this respect.

FIG. **3** is a schematic diagram illustrating and example installation of hand hygiene system components in multiple rooms and common areas of a hospital **22**. In this example, hospital **22** includes patient rooms **60**A-**60**D and common area **23**. Each patient room **60** includes one or more dispensers; in this example, each patient room includes three dispensers labeled D**1**A-D**3**A, D**1**B-D**3**B, D**1**C-D**3**C, and D**1**D-D**3**D for each patient room **60**A-**60**D, respectively. In this particular example, dispensers D**1** and D**2** may be room associated alcohol sanitizer dispensers, dispensers D**3** may be room associated soap dispenser, dispenser D**4** may be a common area alcohol sanitizer dispenser, and dispenser D**5** may be a common area soap dispenser. Dispensers D**4** and D**5** should be assigned to one of the room coordinator modules **18**, for example to the coordinator module **18**D. In some cases for common area dispensers a separate coordinator module **18** should be designated. It shall be understood that each room or defined space could have more or fewer dispensers, or different combinations of these or other types of dispensers, and that the disclosure is not limited in this respect.

Each patient room **60**A-**60**D also includes a motion detector module **14**A-**14**D and coordinator module **18**A-**18**D, respectively. Common area **23** includes automated hand washing sink **61**, nurses station **63** and dispensers D**4** and D**5**. One or more HCWs, such as HCW **4**, each having an associated electronically readable id tag **4** is present within hospital **22**. Also present within hospital **22** are one or more non-HCW persons **3** (e.g., patients, visitors, etc.), who do not have associated id tags.

Although certain examples are shown and described herein, it shall be understood that the number of motion detectors, interrogators and coordinator modules deployed in any particular hand hygiene system may vary depending upon the number and location of rooms and other defined spaces within the hospital, the number and location of dispensers, the communication ranges of the devices, their power requirements, etc. It shall be understood, therefore, that the number of motion detector modules, interrogators and coordinator modules may vary depending upon the hospital architecture and the particular system implementation and that the disclosure is not limited in this respect.

FIG. **4** is a schematic diagram illustrating the room components when a person is detected entering a room or other defined space. When an id tagged HCW **2** enters a room having the components of the hand hygiene compliance system installed, motion detector module **14**, which in some examples is installed near the door or entry to the room or other defined space, senses entry of the person **2** into the room. This is termed an "entry event." When an entry event is detected, an interrogator within motion detector module **14** looks for a HCW id tag signal and obtains the HCW identification information from any HCW id tags within range.

In one example, electronically readable id tags **4** are implemented using radio frequency identification (RFID) transponders or tags. The typical RFID tag includes an integrated circuit chip that stores HCW identification information and an antenna that generates a HCW id tag signal that includes the HCW identification information. RFID tags may be active, passive or semi-passive and may operate at any appropriate frequency. RFID tags may also be read-only, read/write or a combination. In other examples, electronically readable id tags **4** may be implemented using other mechanisms for electronically storing and conveying product information, such as bar codes, conductive inks, printed circuits, etc. Thus, although the phrase "electronically readable label" is used throughout this specification, it shall be understood that any electronically readable medium that may be used to store and convey information that is known or will be known to those of skill in the art may be used and that the disclosure is not limited in this respect.

Motion detector module **14** captures product information from the electronically readable HCW id tag **4** and passes the data to the associated coordinator module **18**. In the RFID example, motion detector module **14** may include a radio frequency (RF) transmitter and receiver, controlled by a microprocessor or digital signal processor. The RFID module includes an antenna that receives HW id tag signals from HCW id tags within range. The HCW id tag signal includes the HCW identification information from HCW id tag **4** and may also include motion detector id information, time and date of the entry event, etc.

When a non-HCW person enters a room or other defined space, an entry event will be detected but no HCW identification information will be received. This is because non-HCW persons such as patients, visitors, delivery personnel, or other persons, do not have electronically readable id tags. Thus, when a person enters a room and no HCW identification information is received, the detected entry event is associated with a non-HCW identification information to the entry event. In this way, the system is able to distinguish between entry of a HCW and entry of non-health care workers. Also, the system is able to accurately monitor hand

hygiene compliance by HCWs and discriminate between hand hygiene events by HCWs and hand hygiene events by non-HCWs.

Upon receipt of the entry event, coordinator module **18** may send a "wake up" signal to each of dispensers **16** within the room or other defined space. Upon receipt of the wake up signal, dispensers **16** may activate one or more audible or visual hand hygiene opportunity indicators **15**A and **15**B, respectively, the purpose of which is to remind the HCW or non-HCW who entered the room of hand hygiene opportunities within the room.

FIG. **5** is a schematic diagram illustrating the room components when a dispense event is detected. As discussed above, each dispenser **16** includes an activation sensor that detects each time that hand hygiene product is dispensed (a "dispense event"). The dispenser (dispenser **16**A in the example of FIG. **5**) records a dispense event and detects the HCW identification information from an id tag **4** within range of the dispenser reader. If no HCW identification information is detected, the dispenser (dispenser **16**B in this example of FIG. **5**) assumes that the dispense event was caused by a non-HCW **3** and associates the dispense event with a non-HCW identifier. This dispense event data, HCW identification information or non-HCW identifier, and any other relevant dispenser data regarding the dispense event, such as dispenser id, product name, time, date, etc., is transmitted to coordinator module **18**.

FIGS. **6**A-**6**C show example reports that may be generated by reporting application **34**. The reports may be requested and presented in a variety of ways, including text reports, graphs, tables, etc. Reporting application **34** may permit the user to request reports that convey the data in a variety of different ways. For example, reporting application **34** may permit a user to select a particular format (text, graphs, tables, combinations thereof, etc.); select by data type (dispenser data, hospital data, motion detector data, HCW data, coordinator data, etc.); select by date; select by individual HCW type of HCW, department, hospital or multiple hospitals; select by percent compliance; select for example, by highest, lowest or average compliance; or to create and generate reports based on nearly any data collected and stored by hand hygiene compliance system.

These reports may include, for example, detailed analysis and reporting on key metrics, including hand hygiene compliance by individual HCW, type of HCW (nurses, doctors, EVS, etc.), department, type of department, individual hospital, across multiple hospitals, etc. The reports may benchmark current hand hygiene practices across the entire database, across hospitals or other healthcare facilities. The reports may include trending of various key metrics over time, identify particular problem areas (e.g., individual HCW or types of HCW having unsatisfactory hand hygiene compliance) provide actionable improvement plans and assess current practices relative to best hand hygiene practices. It shall be understood that the reports shown in FIGS. **6**A-**8**C are exemplary only, and that other reports may also be generated, and the disclosure is not limited in this respect.

FIG. **6**A, for example, illustrates an example compliance report **102**. Report **102** details hand hygiene compliance by individual (nurses A-D in this example). Report **102** shows the overall percentage compliance, wash/shift compliance, sanitizer/shift compliance and the number of room entries for each nurse A-D. Report **102** also shows the average percent compliance among these four individual nurses. Report **102** could also show the aver percent compliance among all nurses in a particular department or in a particular hospital, etc.

FIG. **6**B, for example, illustrates another example compliance report **104**. Report **104** details hand hygiene compliance by shift and by function. For example, report **104** shows the percent compliance for each of three shifts (shift **1**, shift **2** and shift **3**) for three types of HCWs (nurses, physicians and EVS). Report **104** also shows the aver percent compliance for each type of HCW.

FIG. **6**C, for example, illustrates an example maintenance report **106**. Report **106** details the status of several dispensers (identified as W**231**, W**255**, W**375** and E**515** in this example). For example, report **106** shows the product status (that is, the relative amount of product remaining in the dispenser). In this example, the status is shown as "OK" for dispenser W**231**, meaning that dispenser does not need to be refilled at this time. The status is shown as "Low" for dispensers W**255**, W**375** and E**515**, meaning that those dispensers need to be refilled in the near future. Report **105** also shows the product type for each dispenser and the battery status for each dispenser. A battery status of "Low" means that the batteries should be replaced and a battery status of "OK" means that the batteries do currently not need to be replaced.

Other reports that may be generated may include, for example, summary reports for an entire hospital or other healthcare facility; the total number of dispense events per dispenser over a defined period of time; the total compliance percent for all HCWs by patient room or other defined area, by department, by hospital, or across multiple hospitals; baseline compliance thresholds by individual HCW, type of HCW, by department, by hospital, or multiple hospitals; reports comparing highest, lowest and/or average percentage compliance by any of these breakdowns; reports comparing highest, lowest and/or average number of dispense events per dispenser or per HCW; trending data showing past, present and projected future hand hygiene compliance;

The reports may indicated whether the number of dispense events per dispenser, per room, per individual HCW, per HCW type, per department, per hospital etc. is within acceptable limits and whether it met specified targets for dispense events for each of these parameters.

The reports may highlight particular problems areas where hand hygiene compliance thresholds are not being met. For example, the reports may identify certain individual HCWs, types of HCWs, departments or hospitals having hand hygiene compliance below a specified threshold. This information can help to identify where additional training or corrective action may be necessary.

The reports may also provide a summary of recommended next steps that the hospital may take to improve their hand hygiene compliance results in the future. For example, suggested next steps may be given for continuous improvement and education directed toward individual HCWs or types of HCWs, operational processes, hand hygiene outcome efficiency, etc.

FIG. **7** is a block diagram illustrating an example implementation of a motion detector module **14**. In this example, motion detector module **14** includes a battery **202**, a power supply **204**, a motion sensor **206**, a signal conditioning module **208**, a microcontroller **210**, an RF module **212**, a serial interface **216** and indicators **214**. Motion detector module **14** may be a standalone unit placed close to the entrance of a patient room or other defined space. Motion detecting capabilities are provided by motion sensor **206**. Motion sensor **206** may have the capability to distinguish incoming persons entering the room and outgoing persons leaving the room. One such motion sensor is the pyroelectric detector PIR **325**, available from Glolab Corp, Wappingers

Falls, N.Y. However, it shall be understood that other motion sensors could be used and that the disclosure is not limited in this respect. For example, motion sensor **206** could also be implemented using ultrasonic or other type of motion sensing technology.

RF module **212** provides for wireless communication between motion detector module **14** and coordinator module **18**. For example, RF module **212** may be implemented using wireless module eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex. However, it shall be understood that other wired or wireless communication modules and/or protocols could be used and that the disclosure is not limited in this respect.

Indicators **214** may be audible indicator such as a speaker or visible indicators such as LEDs, displays, etc. Indicators **214** may indicate the status of battery **202** or active/inactive status of RF module **212**, or other status of motion detector module **14**.

Microcontroller **210** includes software modules (described below) that control detection of entry events and communication between motion detector module **14** and coordinator module **18**.

FIG. **8** is a block diagram illustrating an example implementation of a dispenser electronics module **16**. In this example, dispenser module **16** includes a battery **230**, a power supply **232**, an activation sensor **234**, a microcontroller **236**, an RF module **238**, a serial interface **242** and indicators **240**. Activation sensor **234** detects dispense events. For example activation sensor may be implemented using a photo interrupter, a flex sensor, acceleration sensor, IR interrupter, IR reflectance sensor, or other mechanism for detecting mechanical movement of a dispenser button or bar when activated by a user, detecting movement of a dispensing mechanism that actually causes the hand hygiene product to be dispensed, optically detecting such mechanical movement(s) or optically detecting movement of dispensed product, etc.

RF module **238** provides for wireless communication between dispenser module **16** and coordinator module **18**. For example, RF module **238** may be implemented using the same wireless module described above with respect to motion detector module **14**, that is, the eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex. However, it shall be understood that other wired or wireless communication modules and/or protocols could be used and that the disclosure is not limited in this respect.

Dispenser indicators **240** may include audible or visual indicators activated during invitation mode, and/or may also include status indicators such as battery status, remaining product status (e.g., whether the dispenser needs to be refilled with hand hygiene product), or other relevant indication of dispenser status.

Microcontroller **236** includes software modules (described below) that control detection of dispense events and communication between dispenser module **16** and coordinator module **18**. For example, microcontroller receives an activation signal from activation sensor **234**, generates a record of a dispense event and corresponding time stamp and HCW or non-HCW identification information.

FIG. **9** is a block diagram illustrating an example implementation of a coordinator module **18**. In this example, coordinator module **18** includes a power supply **250**, an RF module **252**, a microcontroller **254**, a second RF module **256**, a serial interface **260** and indicators **258**. Power supply **250** of coordinator module **18** may be obtained from an AC wall power outlet.

RF module **256** provides for wireless communication between coordinator module **18** and the associated motion detector module **14** and dispenser modules **16**. For example, RF module **256** may be implemented using the same wireless module described above with respect to motion detector module **14** and dispenser module **16**, that is, the eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex. However, it shall be understood that other wired or wireless communication modules and/or protocols could be used and that the disclosure is not limited in this respect.

In this example, RF module **252** provides for wireless communication between coordinator module **18** and local hospital computer **28** or other designated computer or database. For example, RF module **252** may be implemented using WiFi module RFD 21715 available from RF Digital, Irvine, Calif However, it shall be understood that other wired or wireless communication modules and/or protocols could be used and that the disclosure is not limited in this respect.

Microcontroller **254** includes software modules (described below) that control detection of compliant and non-compliant events and communication between coordinator module **18** and motion detector module **14**, dispenser modules **16**, local hospital computer **28** and/or other remote communication. For example, microcontroller receives entry events and dispense events, determines whether compliant or non-compliant hand hygiene event occurred, and communicates data concerning entry events, dispense events, compliant hand hygiene events, non-compliant hand hygiene events, coordinator status, motion detector status and/or dispenser status to local hospital computer **28** or other designated computer, server or database.

FIG. **10** is a schematic diagram illustrating an example implementation of a motion detector module **14**. Motion detector **14** includes a wireless module 302 (eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex.), visible indicator(s) **304**, audible indicator(s) **306**, batteries **308**, motion sensor **206** (pyroelectric detector PIR **325**, available from Glolab Corp, Wappingers Falls, N.Y.), and fresnel lens (available from Glolab Corp., Wappingers Falls, N.Y., for example).

FIG. **11** is an electrical schematic diagram illustrating an example implementation of an id tag **4**. In this example, id tag **4** includes RF module **320** (eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex.). ID tag **4** also includes visible indicator **322** and/or audible indicator **324**. In this example, when an entry event is detected, coordinator **18** may send a "wake up" signal to id tag **4**, causing id tag **4** to enter a "reminder mode" in which visible or audible signals serve to remind the person associated with the entry event of a hand hygiene opportunity. However, it shall be understood that ID tag **4** need not include indicators **322**/**324**, nor need it include a reminder mode, that the reminder mode/indicators may be implemented or not depending upon the requirements of the particular hospital, and that the disclosure is not limited in this respect.

FIG. **12** is an electrical schematic diagram illustrating an example implementation of a dispenser module **16**. In this example, dispenser module **16** includes RF module **332** (eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex.), a flex sensor **330**, visible indicator(s) **334**, audible

indicator(s) **336**, and batteries **338**. Flex sensor **330** may be implemented using a flexible sensor such as those available from Flexpoint Sensor Systems, Inc. Draper, Utah (www-.flexpoint.com).

FIG. **13** is an electrical schematic diagram illustrating an example implementation of a coordinator module **18**. In this example, coordinator module **18** includes a WiFi module **340** (WiFi module RFD 21715 available from RF Digital, Irvine, Calif.), RF module **342** (eZ430RF2500T using the SimpliciTI wireless communication protocol, available from Texas Instruments, Inc., Dallas, Tex.), visible indicator(s) **344**, audible indicator(s) **346**, batteries **348**, diode **350** and AC to DC Power supply **352** (such as BPI 200-05-00 available from BIAS Power, Buffalo Grove, Ill.).

FIG. **14** is an electrical schematic diagram illustrating an example implementation of a WiFi access point for local hospital computer **28** or other designated computer. In this example, a WiFi access point **260** (WiFi Access point model WRT 610N (available from Linksys, Irvine, Calif.) provides for wireless communication between local hospital computer **362** or other designated computer and all of the coordinators **18** in the hand hygiene compliance system. Power is provided via an AC to DC power supply **366**.

FIG. **15** is a flowchart illustrating an example process of operation for motion detector module **14**. Motion detector module **14** detects an entry event (**404**). Motion detector module **14** then attempts to communicate with a HCW id tag **4** within a predefined range (**406**). For example, the range of motion detector module **14** may be from 0-3 meters. In general the range of motion detector module **14** may be determined so that only the HCW id tag **4** that caused the entry event is detected, rather than other HCW id tags not associated with the entry event, such as those that may already be present in the room.

In one example, when waiting for an entry event to occur, motion detector module **14** may look for HCW id tag signals at periodic intervals such as 0.5 second, 1 second, 2 seconds, 5 seconds or other appropriate time interval. Once motion detector module **14** detects an entry event, it may enter a continuous mode as it attempts to communicate with any HCW id tags **4** within range. Operation of motion detector module **14** in this way may serve to reduce power consumption and preserve battery life. It shall be understood, however, that motion detector module **14** need not operate this way, and that the disclosure is not limited in this respect. For example, motion detector module **14** could operate continuously at all times, periodically at all times, or some other combination of continuous and periodic operation.

If motion detector module **14** detects a HCW id tag signal (**408**), it associates the entry event with the detected HCW identification information (**410**) and sends the entry event data (including the HCW id, time, voltage, signal strength, and any other related information) to coordinator module **18** (**414**). If motion detector module **14** does not detect a HCW id tag signal within a predetermined period of time (**408**), motion detector module **14** associates the entry event with a non-HCW identification information (**412**) and sends the entry event data to the coordinator module (**414**).

FIG. **16** is a flowchart illustrating an example process **420** of operation for dispenser module **16**. In the example process shown in FIG. **16**, dispenser module **16** spends most of its time in a low power "sleep mode." Operation of dispenser module **16** in this way may serve to reduce power consumption and preserve battery life. It shall be understood, however, that motion detector module **14** need not operate this way, and that the disclosure is not limited in this respect. For example, dispenser module **16** need not include a sleep mode, but may be continuously active if power consumption and/or battery life is less of a concern.

Several events may cause dispenser module **16** to "wake up." For example, if a dispenser **16** receives a command to enter invitation mode (**404**), dispenser module **16** will enter invitation mode (**405**), during which audible or visible indicators on the dispenser **16** serve to remind a person entering the room of a hand hygiene opportunity. As another example, if a dispense event occurs (**406**) while the dispenser module **16** is in sleep mode (**406**), dispenser module **16** will wake up. If the dispense event is detected (**406**) while dispenser module **16** is in invitation mode (**405**), dispenser module will exit invitation mode (**408**).

Once detector module **16** detects a dispense event, dispenser module **16** looks for any HCW tag signals within range (**409**) of the dispenser. For example, detector module **16** may have an initial range of 0-1 meter or some other appropriate distance that helps to ensure that only the HCW id tag **4** associated with the HCW who initiated the dispense event is detected and not another nearby HCW id tag.

If no HCW id tag signal is detected within a predefined period of time (**410**) (such as 0.5 seconds, 1 second, 2 seconds, 5 seconds or other appropriate time interval, for example) dispenser module **16** associates the dispense event with non-HCW identification information.

If a HCW id tag signal is detected within a predefined period of time (**410**), dispenser will check whether more than one HCW id tag signals have been detected at the same time (**411**). If only one HCW id tag signal has been detected, dispenser module **16** associates the dispense event with the detected HCW identification information (**413**). Dispenser module **16** then sends the dispense event data to coordinator module **18** (**414**).

If multiple HCW id tag signals are detected (**411**), dispenser module **16** may reduce the detection radius in an attempt to isolate the HCW id tag that is closest to the dispenser (**416**). For example, dispenser module **16** may modify the output power of the interrogation signal to effectively reduce the detection radius of the dispenser. If multiple HCW id tags are still detected, dispenser module **16** may continue to reduce the detection radius until only one HCW id tag is detected. For example, dispenser module **16** may modify the detection radius from approximately 1.5 meter to approximately 1 meter, and then to 0.5 meters, etc. until a single HCW id tag is isolated. Dispenser module **16** may then associate the dispense event with the isolated HCW id tag (**413**) and sends the dispense event data to coordinator module **18** (**414**).

In addition, dispenser module **16** may be in invitation mode when an exit invitation mode command is received (**420**). This would occur, for example, when an entry event is detected but no corresponding dispense event is detected with a target time window (e.g., a non-compliant event). Dispenser module **16** would then exit invitation mode (**422**) and re-enter sleep mode.

FIG. **17** is a flowchart illustrating another example process **424** of operation for dispenser module **16**. Process **424** shown in FIG. **17** is identical to the process **420** shown in FIG. **16** except for the manner in which dispenser module **16** attempts to isolate a single HCW id tag from among multiple detected tags. In this example, dispenser module **16** analyzes the signal strength information associated with each of the multiple detected tags to determine which is closest to the dispenser **16** (**426**). Typically, the HCW id tag with the highest signal strength would be isolated as the HCW id tag that should be associated with the dispense event.

FIG. **18** is a flowchart illustrating example processes **440** of operation of coordinator module **18**. In this example, a function of coordinator module **18** is to communicate information received from the motion detector **14** and dispenser(s) **16** in the associated room or other defined space to local hospital computer **28** or other designated computer. For example, entry event data from motion detector module **14** (**442**) and transmits the entry event data to the local hospital computer **28** or other designated computer (**444**). Coordinator module **18** receives dispense event data from the associated dispenser(s) (**446**) and transmits the dispense event data to the local hospital computer **28** or other designated computer (**448**).

Another function of coordinator **18** is to communicate information, such as operational commands, etc., from local hospital computer **28** or other designated computer to the motion detector **14** and dispenser(s) **16** in the associated room or other defined space. For example, enter invitation mode commands (**450**) and exit invitation mode commands (**454**) are received by coordinator module **18** and sent to the dispensers **16** in the associated room (**452**, **456**). Similarly, return to periodic mode commands (**458**) are received by coordinator module **18** and sent to the associated motion detector module **14** (**460**).

FIG. **19** is a flowchart illustrating an example process (**462**) by which local hospital computer **28** or other designated computer processes the hand hygiene data received from coordinator module **18** to determine whether a compliant or non-compliant hand hygiene event has taken place. Computer **28** receives entry event data from coordinator module **18** (**446**). Computer **28** identifies which dispensers **16** are in the room associated with the coordinator module **18** (**468**). Computer **28** sends an enter invitation mode command to the identified dispensers **16** via coordinator **18** (**470**). Computer **28** may also send a return to periodic mode command to the associated motion detector **14** via coordinator **18** (**472**).

Computer **28** determines whether a dispense event corresponding to the entry event (that is, a dispense event having the same HCW identification information as the entry event) occurs within a target time window (**474**). The target time window is determined so that the person associated with the entry event has time to get to one of the dispensers in the room but not so long as to result in an increased likelihood that the person comes into close proximity to the patient without completing a hand hygiene event. For example, the target time window may be between 5 and 30 seconds, or some other appropriate time window.

If a corresponding dispense event is detected (**474**), computer **28** sends an exit invitation mode command to all of the identified dispensers in the room via coordinator **18** (**476**). Computer **28** records a compliant hand hygiene event (**478**) (for example, "HCW id #X entered room #Y at time t_{enter} and washed hands in less than t seconds ($t_{dispense}$-t_{enter}) at dispenser #Z"). If at some later time a HCW who was already present in the room initiates another corresponding dispense event (**480**), computer **28** will record another hand hygiene event (**482**) (for example, "($t_{dispense\#2}$-t_{enter}) seconds/minutes after entering room #Y, HCW id #X completed a second (third, fourth, etc.) hand hygiene event at dispenser #Z").

If no corresponding dispense event is detected within the target time window (**474**) computer **28** may send an exit invitation mode command to the dispensers **16** in the room (**484**). Computer **28** records a non-compliant hand hygiene event (**486**) (for example, "HCW id #X entered room #Y at time t_{enter} and failed to complete a compliant hand hygiene event within t_{target} seconds").

If at some later time a HCW who was already present in the room but had failed to complete a compliant hand hygiene event initiates a dispense event (**488**), computer **28** will record a hand hygiene event (**490**) (for example, "($t_{dispense\#2}$-t_{enter}) seconds/minutes after entering room #Y, HCW id #X completed a second (third, fourth, etc.) hand hygiene event at dispenser #Z").

For entry events associated with non-HCW identification information (e.g., a person without a HCW id tag), computer **28** may follow a similar process as process **462** shown in FIG. **19**. However, for untagged individuals (visitors, patients, etc.) computer **28** may simply record whether or not the untagged individual washed their hands within a defined period of time. For example, a compliant hand hygiene event for an untagged individual (**478**) may include, for example, "An untagged individual entered room #Y at time t_{enter} and completed a hand hygiene event at dispenser #Z in (t_{enter}-$t_{dispense}$) seconds." A non-compliant hand hygiene event for an untagged individual (**486**) may include, for example, "An untagged individual entered room #Y and time t_{enter} and did not complete a hand hygiene event within t_{target} seconds."

FIG. **20** is a flowchart illustrating a process **430** by which local hospital computer or other designated computer monitors for compliant or non-compliant hand hygiene events for dispensers located outside of a patient room or other defined space. In some hospitals, or areas or rooms within a hospital, hand hygiene dispensers may be located immediately outside a patient room. In those cases, dispense events occurring at those dispensers corresponding to entry events that occur within a defined target time window may be recorded as compliant hand hygiene events.

For example, local hospital computer or other designated computer receives dispense event data (**432**). Computer **28** determines whether a corresponding entry event occurs within a target time window (**433**). If so, computer **28** records a compliant hand hygiene event (**434**) (for example, HCW id #X completed a hand hygiene event at dispenser #Z at time $t_{dispense}$ and entered room #Y within time t_{target}"). If no corresponding entry event is received (**433**) (e.g., time t_{target} has passed without the person entering the room), computer **28** follows the procedure described above with respect to FIG. **19**. For example, computer **28** receives the entry event data (**464**), identify the dispensers in the room (**468**), send an enter invitation mode command to the dispensers in the room (**470**) (thus inviting the HCW to complete a compliant hand hygiene event) and monitor for a compliant or non-compliant hand hygiene event (**472**-**490**) as described above.

As described herein, various aspects of the hand hygiene compliance system may be computer implemented, and as such may be incorporated into computer software or hardware. For example, a computer system may collect and analyze data generated during implementation of the hand hygiene compliance system. This information may be stored and analyzed and reports generated to provide feedback to a facility manager or corporation. Furthermore, the analysis may be performed across multiple accounts, such as multiple accounts within a single corporation or organizational region, to compare, for example, one hospital in a corporation with other hospitals within the same corporation or to compare like modules of multiple hospitals.

The techniques described herein may be implemented in hardware, software, firmware or any combination thereof. If

implemented in software, the techniques may be realized at least in part by a computer-readable medium comprising instructions that, when executed by computer of a hand hygiene compliance system cause the computer to perform one or more of the techniques of this disclosure. The computer-readable data storage medium may form part of a computer program product, which may include packaging materials. The computer-readable medium may comprise random access memory (RAM) such as synchronous dynamic random access memory (SDRAM), read-only memory (ROM), non-volatile random access memory (NVRAM), electrically erasable programmable read-only memory (EEPROM), FLASH memory, magnetic or optical data storage media, a magnetic disk or a magnetic tape, a optical disk or magnetooptic disk, CD, CD-ROM, DVD, a holographic medium, or the like. The instructions may be implemented as one or more software modules, which may be executed by themselves or in combination with other software.

The computer-readable instructions may be executed in the computer of the system by one or more processors, general purpose microprocessors, ASICs, FPGAs or other equivalent integrated or discrete logic circuitry.

The instructions and the media are not necessarily associated with any particular computer or other apparatus, but may be carried out by various general-purpose or specialized machines. The instructions may be distributed among two or more media and may be executed by two or more machines. The machines may be coupled to one another directly, or may be coupled through a network, such as a local access network (LAN), or a global network such as the Internet. Accordingly, the term "processor," as used herein may refer to any structure suitable for implementation of the techniques described herein.

Various aspects of the hand hygiene compliance system may also be embodied as one or more devices that include logic circuitry to carry out the functions or methods as described herein. The logic circuitry may include a processor that may be programmable for a general purpose or may be dedicated, such as microcontroller, a microprocessor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a field programmable gate array (FPGA), and the like.

One or more of the techniques described herein may be partially or wholly executed in software. For example, a computer-readable medium may store or otherwise comprise computer-readable instructions, i.e., program code that can be executed by a processor to carry out one of more of the techniques described above.

The hand hygiene compliance system may also incorporate healthcare worker training and continuing education, such as teaching new or ongoing skills and changing paradigms and behaviors within hospitals. These may include, for example, hand hygiene training, compliance/procedural training, training oversight/monitoring/interventions, comprehensive training to impact outcomes, medical school and association curriculum, certification training, etc. This may include both upfront and periodic refresher training, training materials and a training process to help ensure that HCWs are following hand hygiene best practices.

Another example implementation of a hand hygiene compliance system, shown in FIG. **22** A, comprises multiple subnet zones **500** each of which provides independent hand hygiene compliance monitoring in limited areas. The system of FIG. **22**A may provide a power efficient system with an extended coverage without integrating into a hospital's wireless system. Health Care Workers (HCW) **2** have ID tags **7** which normally operate within a relatively short communication range (a low power setting resulting in a maximum range of about 3-10 meters, for example). The HCW id tag **7** stores all entry event data and dispense event data related to that HCW id tag. Throughout the day, as the HCW tags **7** move about the hospital, they will at times enter a data gathering area **28** within the hospital that serves as a tag data download site. An electrical schematic diagram of an example data gathering station **550** is shown in FIG. **21**E. It includes a local computer **12** having a wireless or wired connection to the hospital network and a wireless communication unit **1** able to communicate wirelessly with HCW id tags **7**. Any HCW id tag signal in the data gathering area will be detected. The data gathering station **550** may then switch the id tag into a relatively longer communication range and obtain the HCW identification information, entry event data and dispense event data associated with each HCW id tag present in the data gathering area **28**.

For example, a subnet **500** can be assigned to each patient room (shown in FIG. **22**A) and may include, for example, IR motion detector **14** (shown in FIG. **21**A) at the entry, dispensers **16**A and **16**B (shown in FIG. **21**C), wireless coordinator **18** (shown in FIG. **21**D), and an IR proximity wireless check point **502** (shown in FIG. **21** F). In this example, IR proximity wireless check point **502** and data gathering station are implemented using System on a chip CC430F5137 (Available from Texas instrument Inc., Dallas, Tex.).

Wireless communication of motion detector **14**, dispensers **16**A and **16**B, coordinator **18** and checkpoint **502** with a tag (FIG. **21**B) has a low power setting limited to one subnet **500**, or patient room in this example. IR proximity wireless check point **502** (FIG. **21** F) has similar schematics as IR motion detector (FIG. **21**A). It includes a Fresnel lens array **6** and an opaque shield **7** with transparent zones forming detection areas for a Pyroelectric detector **5**. IR proximity wireless check point **502** is placed near areas where monitoring of hand hygiene compliance is desired, such as patient-centered protection zones. Each check point **502** may therefore be associated with an operational area limited to one patient bed **502-1** or other patient-centered zone. Opaque shield **7** blocks a central part of the detection zone. For example, the opaque shield **7** blocks detection in the area of the detection zone in which the patient bed is present, thus the patient bed is essentially invisible for the Pyroelectric detector **5** but any movements in the perimeter around the bed **502-1** can be detected. This ensures that movements of the patient do not trigger motion detection. Coordinator module (FIG. **21**D) turns IR proximity wireless check point **502** in continuous mode of operation for limited time (e.g., 5-30 seconds) when an entry event occurs. When IR proximity wireless check point **502** detects the tag in proximity it can communicate with tag. The tag analyzes the time delay between last hand washing event and can remind HCW **2** that hand washing is required. In this example, tag **7** keeps stores information about all hand hygiene compliance events or non-compliance events in which this tag is involved. For example, id tag **7** records hand hygiene information (dispenser data, entry data, entry/exit into or out of check point zone) when a HCW **2** is near points a), b), c) as shown in FIG. **23**A and download information when HCW **2** is in the data gathering area **28** as shown in FIG. **23**A point d). Tag **7** may also receive from coordinator **18** information about hand compliance monitoring events which where recorded but have no connection with a person carrying a tag. Multiple tags **7** store all hand hygiene information which can

be downloaded automatically when tags are in proximity of a local subnet reader (checkpoint) **550** (FIG. **21**E).

Another example hand hygiene compliance system is shown in FIG. **22**B. The system FIG. **22**B is similar to that of FIG. **22** but does not include a coordinator module. The system of FIG. **22**B accumulates data about hand hygiene compliance only for people who have tags. In this example, each subnet zone **500** includes a motion detector **14**, dispensers **16**A and **16**B or an IR proximity wireless check point **502**. When motion or a dispense event is detected, wireless communication with the tag is turned ON for a relatively short period of time (e.g., 2-3 seconds). HCW id tags can receive hand hygiene information, analyze it and store in memory. In this example the IR proximity wireless check point **502** can synchronously reestablish communication with the id tag **7** each 1-5 seconds to confirm that specific id tag **7** still is in the protection zone.

Advantages of the hand hygiene compliance system may include documented improvements in hand hygiene compliance, patient satisfaction scores, and HAI risk reduction and associated cost savings. Advantages may also include fewer patient deaths and patient complications due to HAIs.

Although the hand hygiene compliance system has been described with respect to hospitals or other healthcare facilities, it shall be understood that this concept may also be applied to hand hygiene compliance in many different enterprises in which an integrated approach to hand hygiene in a portion of a facility or an entire facility is desired. For example, the modular hand hygiene compliance system may be adapted for use in applications such as hotel room cleaning, education facilities, long term care, restaurants, food service, food and beverage facilities, food packing, eating areas, rest rooms, food preparation areas, cooking areas, etc.

In another example hand hygiene compliance system, monitoring of hand hygiene compliance is initiated when a HCW comes into relatively close proximity to a patient. In this example, monitoring of hand hygiene compliance is organized around patient-centered critical control points (CCP), such as patient beds, examination tables, or other patient locations where monitoring of hand hygiene compliance is desired. Protection zones are set up around each CCP, thus defining a protected area around each patient. Each HCW is assigned a compliance badge that is uniquely associated with the HCW. A set of compliance rules, stored by a motion detector associated with each AOC, are communicated to each compliance badge that enters the AOC. To monitor hand hygiene compliance, each compliance badge monitors entry and exit from areas of concern (AOC), entry and exit from patient protection zones, and hand hygiene product dispense events. Using the compliance rules, each compliance badge monitors occurrence of compliant or non-compliant hand hygiene events. Each compliance badge thus monitors and stores compliance data unique to each HCW. A plurality of data gathering stations set up in various locations around the healthcare facility, such as nurse's stations, cafeterias, etc., initiate automatic download of compliance data whenever a badge is within range. The compliance data from all compliance badges in the system may be transmitted to a local hospital computer and/or remote computer **560** for data analysis and reporting.

In another example, each compliance badge need not store healthcare worker identification information. For example, each badge may include a unique badge identifier, so that all dispense events associated with each badge may be monitored and analyzed. In this example, the local or remote computer (such as local computer **555**, server computer **560** or user computer **554**) may include the ability to associate each badge with an individual HCW. However, it shall be understood that there may be circumstances in which it may be undesirable or unnecessary to specifically identify individuals and their associated hand hygiene activities, and that more generalized monitoring of hand hygiene compliance via unique badge identifiers may in some circumstances be sufficient.

FIGS. **23**A and **23**B are a diagram illustrating an example hand hygiene compliance system **501** in which a plurality of hand hygiene compliance badges, each uniquely associated with a different one of a plurality of HCWs, monitor hand hygiene compliance in a healthcare or other facility. In this example, a plurality of areas of concern (AOC) in which monitoring of hand hygiene compliance is desired are set up in various areas throughout a healthcare facility. In FIG. **23**, the AOC **520** is a patient room. The example AOC **520** includes two patient beds, **524**A and **524**B, and a sink **522**. Although a patient room is illustrated in this example, AOC **520** could also be a critical care unit, recovery room, operating room, examination room, or any other defined area within a healthcare facility in which monitoring of hand hygiene compliance may be desired. AOC **520** may also include any number of sinks, beds, or other AOC features depending upon the particular needs of each AOC or the particular set up of each AOC.

Within each AOC is at least one patient-centered critical control point (CCP). In FIG. **23**, patient beds **524**A and **524**B are defined as CCPs. Associated with AOC **520** are elements of the example hand hygiene compliance system, including one or more hand hygiene product dispensers **530**, in this case two in-room dispensers, **530**A and **530**B and one outsideroom hand hygiene product dispenser **530**C; a motion detector **540**, and critical control point (CCP) zone emitters **528**A and **528**B (referred to generally as zone emitters **528**), each associated with a CCP **524**A and **524**B, respectively. The system **501** also includes a plurality of compliance badges **504** (one of which is shown in FIG. **23**), each associated with a different one of a plurality of healthcare workers (HCW) **2** (one of which is shown in FIG. **23**).

In operation, each CCP emitter **528**A and **528**B generates a protection zone, **526**A and **526**B, respectively in this example, around the associated CCP, in this case, the two patient beds **526**A and **526**B present in AOC **520**. However, it shall be understood that critical control points and associated protection zones may be defined with respect to any area within a healthcare facility where a patient could be located and monitoring of hand hygiene compliance may be desired, such as patient beds, chemotherapy stations, treatment areas, surgical tables, examination tables, etc. In this example, zone emitters **528** generate an ultrasonic protection zone around each patient bed.

Each compliance badge **504** includes a microprocessor, an ultrasonic receiver that detects entry into a CCP protection zone **526**A or **526**B (a "protection zone entry event"), a rule implementation module (instructions for detecting occurrence of compliant or non-compliant hand hygiene events), a power conservation module, a chirp alarm, and a badge data module that stores compliant/non-compliant events and other associated data. To reduce energy consumption and increase battery life, each compliance badge **504** remains in a "power conservation mode" unless present within an AOC or within range of a data gathering station **550** (shown in FIG. **23**B).

Motion detector **540** detects movement within AOC **520**. For example, motion detector **540** detects movement within proximity to the entrance of an AOC (to detect entrance of

persons into the AOC **520**). This is termed an "entry event." Motion detector **540** may also detect movement within the AOC **520** (to detect presence of persons moving within the AOC **520**). If movement is detected, motion detector **540** broadcasts a wireless "wake-up" signal within the AOC. Each compliance badge **504** within the AOC receives the "wake-up" signal and activates the ultrasonic receiver on the badge. At this point the badge **504** is in "active mode."

Motion detector **540** also stores a set of hand hygiene compliance rules for monitoring compliant/non-compliant hand hygiene events with the associated AOC. Each type of AOC (e.g., patient room, examining room, operating room, therapy station, etc.) may be associated with a different set of compliance rules. Thus, each motion detector **540** in the system as a whole stores compliance rules specific to the AOC with which it is associated.

When a compliance badge **504** is detected entering the AOC, motion detector **540** broadcasts the compliance rules for receipt by all compliance badges within the AOC. Using the compliance rules, compliance badge **504** then monitors the associated HCWs hand hygiene compliance by monitoring entry and exit from protection zones **526**A and **526**B and any hand hygiene product dispense events that occur while badge **504** is in the AOC. Each compliance badge **504** thus monitors and stores hand hygiene compliance data unique to each HCW.

To detect dispense events, each of dispensers **530** includes an activation or event sensor that detects when hand hygiene product is dispensed (a "dispense event"). In this respect, dispensers **530** may operate in a similar manner to the dispenser described above with respect to the dispenser of FIG. **8** or **21**C, for example. Each dispenser **530** includes a wireless dispenser reader that detects HCW id data from any compliance badge **504** within range of the dispenser reader and associates the HCW id data with the detected dispense event.

The wake-up signal broadcast by motion detector **540** may also may cause dispensers **530** to enter an "invitation mode", in which the dispenser activates one or more visual or audible indicators whose purpose is to remind the person entering the room of a hand hygiene opportunity. In some examples, different dispensers throughout the AOC may display invitations at different times as the HCW **2** is detected moving about the AOC from one CCP zone to another CCP zone.

When a HCW leaves the AOC **520** and comes within range of a data gathering station **550**, data gathering station **550** initiates automatic download of the compliance data stored on compliance badge **504**. As shown in FIG. **23**B, a plurality of compliance data gathering stations **550**A-**55**N are set up at various locations around the healthcare facility, such as nurses stations, cafeterias, etc. The compliance data collected from each badge in the system may be transmitted to a local hospital computer **555** and/or remote server computer **560**. Local hospital computer **555** and/or remote server computer **560** may then analyze the data and generate one or more hand hygiene compliance reports. These reports may be viewed/printed locally at the healthcare facility and/or at the remote computer **560**. In addition, users **554** may view/print the reports remotely via a network such as the internet **558**.

FIG. **24** is a block diagram of an example motion detector **540**. Motion detector **540** includes an IR-based motion detector **622** and an RF transmitter **626**. If motion detector **622** detects an AOC entry event or movement within the AOC, the IR motion detector **622** signals the internal RF transmitter **626** to send out the wake-up broadcast to all badges within the AOC. The RF module **626** also transmits the compliance rules that define compliant/non-compliant events for the associated AOC. A memory **628** includes a wake-up module that controls transmission of the wake-up signal. Memory **628** also stores motion detector data **632**. Motion detector data **628** may include, for example, data concerning each wake-up signal (time and date stamped). Motion detector data **628** may also include, for example, battery status; motion detector id; motion detector type; physical location (e.g., hospital room number, or other defined area within the hospital, such as a standalone hand washing station, procedure room, lab, common area, operating room, therapy station, etc.); date of installation; maintenance records; detected person events, whether wearing a compliance badge (HCW) or not (non-HCW); detected healthcare worker ids; date and time stamps; and other data associated with the motion detector **540**.

FIG. **25** is a block diagram of an example dispenser **530**. Dispenser **530** includes an event/activation sensor **640**, a microcontroller **642**, an RF module **644** and indicators **646**. Event/activation sensor **640** detects dispense events, and may be implemented as described above with respect to FIG. **8**. Indicators **646** may include audible or visual indicators activated during invitation mode, and/or may also include status indicators such as battery status, remaining product status (e.g., whether the dispenser needs to be refilled with hand hygiene product), or other relevant indication of dispenser status.

Microcontroller **648** controls detection of dispense events and communication between dispenser module **16** and compliance badges **504**. For example, microcontroller receives an event signal from sensor **640**, generates a record of a dispense event and corresponding time stamp, receives HCW or non-HCW identification information from a detected compliance badge, generates corresponding dispenser data concerning the dispense event and transmits the dispenser data to the compliance badge **504**.

FIG. **26** is a block diagram of an example compliance badge **504**. Compliance badge includes an ultrasonic receiver **616** that detects the ultrasonic signal generated in a patient protection zone, an RF transceiver **613** that communicates with dispensers **530**, motion detector **540** and data gathering stations **550**, an audible (e.g., chirp) alarm **609**, visual indicators **607**. Badge **504** also includes a microcontroller **601** that controls communication with the dispensers **530**, motion detector **540** and data gathering stations **550**, detects entry into the ultrasonic protection zone, and analyzes the compliance rules to monitor hand hygiene compliance. A memory **606** stores the necessary software and data for the compliance badge **504**, including, for example, the compliance rules **608** received from the motion detector upon entry into an AOC; a rule implementation module for implementing the compliance rules to detect compliant/non-compliant hand hygiene events; a sleep/wake-up module that controls automatic power down of the ultrasonic receiver to enter power conservation mode and that also controls activation of ultrasonic receiver when a wake-up signal is received; badge data **612** associated with the compliance badge **612**; motion detector data **614** received from motion detector **540**; dispenser data **615** received from the dispensers **530**A-**530**C; and an ultrasonic signal validation module **611**.

Badge data **612** may include, for example, HCW id, healthcare facility id, AOC entry events, protection zone entry events, dispense events, compliant and non-compliant hand hygiene events, date and time stamps for each event, and any other data relevant to hand hygiene compliance.

As an alternative to motion detector **540** sending out a wake-up signal withinAOC **520** whenever motion is detected, badge **504** may include a motion sensor, such as an accelerometer, that detects movement of the associated HCW **2**. In this example, if badge **504** senses movement of HCW **2**, the ultrasonic receiver would remain activated. In this example, therefore, the ultrasonic receiver would power-down when the badge is not being used, such as, for example, when HCW **2** removes their badge, sets it down or does not use it for a period of time, such as during the times when they are on duty.

FIG. **27** is a more detailed block diagram of an example implementation for a compliance badge **504**. In general, compliance badge **504** is an ID tag with RF and ultrasonic capability. Compliance badge **504** includes a microcontroller **601**, batteries **605**, at least one visible indicator such as a Light Emitting Diode (LED) **607**, a speaker/chirp alarm **609**, an ultrasonic receiver **616** and an analog circuit with amplifier **617**. In this example, the microcontroller and memory may be implemented using system on a chip CC430F5137, available from Texas Instrument Inc., Dallas, Tex. Such a controller includes RF channels for communication with motion detector, zone emitter **528** and/or dispensers **530**. Compliance badge **504** may also include touch switch (not shown) that allows HCW **2** to turn off any audible or visual alarms on the badge if necessary.

FIG. **28** is a block diagram of an example implementation for ultrasonic zone emitter **528**. Zone emitter generates an ultrasonic patient protection zone, such as zones **526**A and **526**B, around a CCP. Zone emitter **528** includes batteries **602**, step-up power supply **621**, a low battery indicator, such as a Light Emitting Diode (LED) **603**, a speaker **604**, a controller **618**, an analog ultrasonic driver circuit **619** and an ultrasonic transducer **620**. Zone emitter **528** may include a variable shape ultrasonic emitter containing variable power settings for setting up protection zones of varying sizes, depending upon the CCP at issue. Zone emitter **529** may also provide a shaping function to the sonic coverage. In some examples, to extend battery life, zone emitter **229** may operate in a pulse mode, sending out the sonic coverage periodically, such as every 2-3 seconds. Zone emitter **529** may also be capable of sonic data transmission for a zone ID and/or low-battery alarm information may be transmitted to a compliance badge that enters into the protection zone.

Zone emitter **528** may be powered by AC power or by batteries **602**. Controller **618** in some examples can be system on a chip CC430F5137, the same as controller **601** shown on FIG. **27** for compliance badge **504**. Such a controller includes RF channels for communication with compliance badges **504** or motion detector **540**. In the event of battery powered zone emitter **528**, the wake-up signal broadcast by motion detector **540** may also be received by zone emitter **528** to activate ultrasonic transducer **620**. In this way, zone emitter **528** may operate in a power conservation mode similar to that described for badge **504**. In some examples zone emitter **528** may also include an RF transmitter, ultrasound receiver and motion detector. In such case, compliance badges **504** may also include an ultrasound transmitter for two-way communication with the zone emitter.

FIGS. **29-32** are diagrams illustrating example operation of the hand hygiene compliance system when a HCW **2** enters and is present within a patient room AOC **520**. In FIG. **29**, HCW **2** (at location **1**) washes their hands at outside dispenser **530**C. Location **1** may be in a hallway of the healthcare facility, for example. Note that while in location **1** the HCW is not present within a defined AOC, and that therefore the associated compliance badge **504** is in the power conservation mode. In power conservation mode, the ultrasonic receiver within badge **504** is off, as indicated in FIG. **23**.

When HCW **2** washes their hands at dispenser **530**C, dispenser **530**C detects the dispense event, records it, and looks for a signal containing HCW identification information from a compliance badge **504** within range of the dispenser reader (or with non-HCW identification information if no ID data is detected). The dispenser then transmits dispenser data to the compliance badge **504**, including, for example, dispenser id, product id, time and date stamp of the dispense event, battery life data, number of dispenses and number of dispense remaining until out-of-product, and/or other dispenser status information.

Dispenser **530**C will also transmit the compliance rules associated with AOC **520**. The compliance rules may include, for example, a zone interaction rule and a loitering rule. The zone interaction rule (or simply, zone rule) and the loitering rule are used by compliance badge **504** to analyze dispense events, AOC entry events and protection zone entry events to identify compliant and non-compliant hand hygiene events. The zone interaction rule defines the maximum allowable time between a dispense event and when a person is allowed to enter a patient protection zone. That is, the zone interaction rule defines the amount of time after occurrence of a dispense event within which the HCW must enter a protection zone in order for the dispense event to qualify as a compliant hand hygiene event. The loitering rule permits a HCW to leave a protection zone and return to the same protection zone within a defined period of time. The dispenser may also transmit product-specific compliance rules, if any. For example, certain hand hygiene products may have shorter or longer zone interaction times or loitering times than other hand hygiene products, for example.

In some examples, certain of dispensers **530** may be programmed not to transmit compliance rules. For example, for a dispenser **530** mounted on a common wall with a dispenser in a different AOC (for example, when two AOCs share a common wall) those dispensers may be programmed not to transmit compliance rules in the event that the compliance rules for the two AOCs are not the same. This would prevent badges in the first AOC from receiving compliance rules from dispensers located in the second AOC in the event that they are in range of the dispenser in the second AOC.

In addition to transmitting the compliance rules to badge **504** upon detection of a dispense event, dispenser **504** also resets a zone interaction timer that keeps track of whether the maximum allowable time as defined by zone interaction rule has expired. That is, detection of a dispense event results in a resetting of the zone interaction timer. Each hand hygiene event thus restarts the zone interaction timer and essentially starts a new dispense event/zone interaction cycle.

In FIG. **23**, HCW **2** has entered patient room AOC **520**. Upon detection of the entry event, motion detector **540** broadcasts a wake-up signal within the AOC. Upon receipt of the wake-up signal, badge **504** activates its ultrasonic receiver. Motion detector may also transmit a motion detector id, time and date stamp for the entry event, motion detector battery life assessment, and/or other motion detector status information. Motion detector **504** may also transmit the compliance rules associated with AOC **520**. However, detection of an entry event does not reset the zone interaction timer. In this example, only dispense events reset the zone interaction timer.

In order for a dispense event to be considered a compliant hand hygiene event, the HCW must enter a protection zone before expiration of the zone interaction timer that is started when the dispense event occurs. For example, if the zone interaction rule states that the zone interaction time is 10 seconds and Dr. Jones washes their hands (the dispense event) at dispenser **530**C at time t=0, Dr. Jones must enter either one of protection zones **526**A or **526**B before time t=10 seconds in order for the dispense event and the entry event to qualify as compliant hand hygiene events.

As shown in FIG. **30**, once inside the AOC, to be compliant, HCW **2** may either enter one of protection zones **526**A or **526**B before expiration of the zone interaction timer. Alternatively, HCW **2** may wash their hands at one of in-room dispensers **530**A or **530**B. Assuming that dispenser **530**A detects a dispense event, dispenser **530**A obtains the HCW id information from the compliance badge **504**. Dispenser **530**A would then transmit the dispenser data for the dispense event, including the HCW id, the dispenser id, product id, time and date stamp of the dispense event, battery life data, number of dispenses and number of dispense remaining until out-of-product, and any other dispenser data for receipt by compliance badge **504**.

Dispenser **530**A will also transmit the compliance rules associated with AOC **520**, and reset the zone interaction timer. Thus, each time a hand hygiene event is detected, the zone interaction timer is reset, thus permitting the HCW additional time to enter a protection zone.

In FIG. **31**, HCW **2** enters protection zone **526**A for patient bed **524**A (a "protection zone entry event" or simply "zone entry event"). Upon detection of the zone entry event (detected by badge **504** when it enters a protection zone) badge **504** checks whether the zone interaction timer is still active. If so, the detected zone entry event into protection zone **526**A is a compliant event. Because the zone entry event is a compliant event, there is no alarm. Badge **504** registers the most recent dispense (in this example, the dispense event at dispenser **530**A) and the zone entry event (in this example, the entry event into protection zone **526**A) as a compliant hand hygiene event(s). Zone id information, battery status, and/or other zone emitter status information may also be transmitted from the zone emitter **528**A to the badge **504**.

Once a compliant zone entry event is detected, the zone interaction timer is canceled; that is, as long as HCW **2** remains in protection zone **526**A, no alarm is generated as long as the zone id does not change (i.e., HCW **2** remains in the same zone) and the loitering rule (described below) is not violated.

Alternatively, if upon detection of the zone entry event the zone interaction timer has expired, badge **504** registers the dispense event and the zone entry event as non-compliant hand hygiene event(s). In addition, audible and/or visual alarms on badge **504** may be activated to alert HCW **2** that a non-compliant event occurred. Badge **504** may include a touch switch or other mechanism that enables the HCW to deactivate the alarm, or the alarms may time out after a predetermined period of time.

FIG. **32** illustrates operation of the loitering rule. In this example, HCW has already performed a compliant zone entry event into zone **528**A and is working in zone **528**A. At some later time, compliance badge **504** detects a zone exit event for HCW **2** as they leave zone **528**A. Badge **504** detects when this zone exit event occurs, and saves the zone exit event data with a date and time stamp. Badge **504** also starts the loitering timer to monitor the length of time that HCW **2** remains outside of zone **528**A. According to the loitering rule, if HCW **2** re-enters (a "zone re-entry event") the same protection zone (in this case, zone **528**A) within the prescribed loitering time, the zone exit event and zone re-entry event are determined to be compliant events. However, if HCW **2** does not re-enter the same protection zone within the prescribed loitering time (without an intervening dispense event) the zone re-entry event is determined to be non-compliant. Badge **504** will register the non-compliant zone re-entry event and activate the audible/visual alarms on compliance badge **504** to alert HCW **2** to the non-compliant event.

As another example of the loitering rule, FIG. **33** illustrates the case of HCW **2** exiting one protection zone (in this case zone **526**A) and entering a different protection zone (in this case, zone **526**B) within the prescribed loitering time. However, according to the loitering rules, entry into a second protection zone before expiration of the loitering clock for a first protection zone is defined as a non-compliant event. The non-compliant event (entry into zone **5286** without an intervening dispense event) would be stored by badge **504** as a non-compliant event. Also, even if the loitering timer for the first protection zone had expired, entry into a different protection zone without an intervening dispense event is defined as a non-compliant hand hygiene event.

The zone interaction rule(s) and the loitering rule(s) may be defined specifically for each AOC. Alternatively, compliance rules may be defined for specific types of AOCs. For example, the zone interaction rule may set the zone timer in the range of 5-20 seconds, for example. The loitering rule may define the loitering timer in the range of 3-8 seconds, for example. It shall be understood, therefore, that the zone interaction rules and/or the loitering rules may vary depending upon the AOC at issue, the hand hygiene product at issue, and the requests of the particular healthcare facility, and the disclosure is not limited in this respect.

Motion detector **540** continually monitors AOC **520** for movement to determine presence of a person or persons (other than the patient, who presumably spends most of their time in their patient bed and therefore would not trigger motion detector **540**) in the AOC. Whenever movement is detected (regardless of whether it is a HCW, patient or other person in the room), motion detector **540** broadcasts the wake-up signal. This ensures that the ultrasonic receivers on each compliance badge **504** within AOC **520** are activated for as long as they remain within AOC **520**. Thus, in FIGS. **29-33**, compliance badge **504** is indicated as being "ON" when HCW **2** is inside of AOC **520**. Motion detector **540** may broadcast the wake-up signal each time motion is detected within AOC **520**, or may broadcast the wake-up signal at periodic intervals for as long as motion is detected. For example, motion detector **540** may broadcast the wake-up signal every 5-30 seconds for as long as motion is detected. Motion detector **540** may also continue to broadcast the wake-up signal for at least some defined period of time after motion has been detected (e.g., anywhere from 1-5 minutes, for example), to ensure that the ultrasonic receivers on the badges **504** remain activated even if a HCW is still present but standing relatively still within AOC **520**.

FIG. **34** illustrates an example operation of the hand hygiene compliance system after HCW **2** exits AOC **520**. Badge **504** includes a power conservation module **613** (FIG. **26**) that manages activation and power-down of ultrasonic receiver **616**. As described above, badge **504** remains in power conservation mode, during which the ultrasonic receiver remains powered-down, if no wake-up signal is received. When badge **504** receives a wake-up signal, ultrasonic receiver is activated and a power-down timer is

started. The power-down timer defines the length of time that ultrasonic receiver will remain active after the last wake-up signal is received. Each time a wake-up signal is received, the power-down timer is reset, ensuring that the ultrasonic receiver remains activated for as long as badge **504** is within range of a wake-up signal and is thus presumed to be present within an AOC. For example, as long as HCW **2** is present within AOC **520**, badge **504** is within range of the wake-up signal sent by motion detector **540**. Each time the wake-up signal is received, badge **504** resets its power-down timer, thus ensuring that the ultrasonic receiver remains activated for as long as HCW **2** remains in AOC **520**.

When HCW **2** leaves AOC **520** and is out of range of motion detector **540**, badge **504** will no longer receive the wake-up signal from motion detector **540** and, assuming HCW **2** does not receive wake-up signals from a motion detector associated with a different AOC, the power-down timer will not be reset and will eventually expire. Badge **504** will deactivate the ultrasonic receiver when the power-down timer expires. By so doing, the battery life of badge **504** may be extended because the ultrasonic receiver need not be active if HCW **2** is not present within an AOC. The power-down timer may be defined as any period of time that is reasonable under the circumstances, for example, the power-down timer may be of sufficient length to allow HCW **2** to step out and re-enter the AOC after a short period of time, etc. The power-down timer may be anywhere between 1 and 3 minutes, for example. However, it shall be understood that the disclosure is not limited in this respect.

In FIG. **34**, HCW **2** has exited AOC **520**, the power-down timer on badge **504** has expired, and the ultrasonic receiver on badge **504** has been powered-down. Badge **504** is thus indicated as being "OFF." Badge **504** now carries a payload of data concerning hand hygiene compliance. The data carried by badge **504** includes hand hygiene compliance data uniquely linked to HCW **2**, such as AOC entry events, dispense events, zone entry events, and a record of compliant and non-compliant hand hygiene events. The data carried by badge **504** also includes redundant system status information (redundant in the sense that the same system status data may be carried by multiple compliance badges **504**) such as dispenser battery status, zone emitter battery status, out-of-product alerts, number of dispenses, etc. The data carried by badge **504** is referred to herein generally as "badge data" (indicated by reference numeral **612** in FIG. **26**, for example) and may include, for example, the hand hygiene data uniquely linked to HCW **2** as well redundant system status data.

The badge data may also include a data gauge that indicates generally the amount of badge data currently being stored by badge **504**. Phrased another way, the data gauge may indicate whether or not sufficient data is stored on badge **504** to initiate download of the badge data when the compliance badge **504** comes within range of a data gathering station **550**. Depending upon the requirements of the particular healthcare or other facility, badge data may not need to be downloaded whenever new badge data is available. For example, it may be sufficient to download badge data from each compliance badge every hour, every day or every week. The data gauge may thus be used to indicate whether a sufficient payload of data is present on badge **504** to initiate automatic download of the data. The data gauge may be programmed to reflect to the approximate length of time it may typically take to acquire a certain amount of data. In addition, regardless of the status of the data gauge, data may be automatically downloaded by data gathering stations **550** if data has not been received from a badge **504** for a predefined period of time.

Data gathering stations **550** are located at various places throughout the healthcare facility, such as nurse's stations, cafeterias, etc. In the example of FIG. **34**, data gathering station **550** is located at a nurse's station **572**. As mentioned above, data gathering station **550** initiates automatic download of badge data whenever a badge **504** is within range. In this example, data gathering station **550** includes multiple ranges or zones: a first download zone **552** (the download initiation zone) and a second download zone **554** (the maximum download zone).

FIGS. **35** and **36** illustrate example operation of hand hygiene compliance system and automatic download of badge data by data gathering station **550**. Data gathering station **550** does not initiate automatic download of badge data unless badge **504** is detected within download initiation zone **552**. Thus, in FIG. **35**, although badge **504** is present within maximum download zone **554**, badge **504** ignores download requests until it enters download initiation zone **552**. When badge **504** is detected within zone **552** (FIG. **36**), data gathering station **550** initiates automatic download of badge data. For example, data gathering station **550** may include an RF transceiver that generates an RF interrogation signal and badge data download protocol to obtain badge data from badge **504**. Download of badge data continues as long as badge **504** is detected within the maximum download zone **554**. Thus, badge data transfer may continue over a broader range than is initially required to begin automatic download.

Once all of the badge data is transferred, badge **504** may enter a "data accumulation" mode and will ignore automatic badge data download requests from any of data gathering stations **550** until the data gauge indicates that the minimum data level has been obtained, or until a maximum time period without badge data download has elapsed.

In the event that HCW **2** leaves the maximum download zone before all available badge data is transferred, there are several possible courses of action. For example, badge **504** and/or data gathering station **550** may keep track of where the data transfer left off and transfer the remaining badge data the next time a badge data download is initiated. The data gauge may be adjusted to reflect the fact that some of the badge data was transferred, or it maybe left where it was to ensure that the remaining badge data is downloaded the next time badge **504** receives a badge data download request. Alternatively, badge **504**/data gathering station **550** may abandon the attempted badge data download and resend all of the badge data the next time badge **504** comes within range of a data gathering station.

FIG. **37** is a block diagram illustrating an example communications environment within which the example hand hygiene compliance system **501** may be used. One or more hospitals or other healthcare facilities **22**A-**22**N are coupled via network(s) **558** to server computer **560**. Network(s) **558** may include, for example, one or more of a dial-up connection, a local area network (LAN), a wide area network (WAN), the internet, a cell phone network, satellite communication, or other means of electronic communication. The communication may be wired or wireless. Server computer **560** is coupled to a local server computer at each hospital **22**A-**22**N via network(s) **558** to receive data related to hand hygiene compliance that is gathered and stored on local storage media at each hospital. Server computer **560** may also send commands, instructions, software updates, etc. to each hospital via network(s) **558**. Server computer **560** may receive data or otherwise communicate with the

hospitals on a periodic basis, in real-time, upon request of server computer **30**, or at any other appropriate time.

The data received from hospitals **22**A-**22**N, as well as other data associated with the operation of the hand hygiene compliance system, may be stored on a database **740**. Database **740** may store, for example, hospital data **741**A-**741**N associated with each of the hospitals **22**A-**22**N, respectively; dispenser data **742**A-**742**N associated with each of the hospitals **22**A-**22**N, respectively; motion detector data **743**A-**743**N associated with each of the hospitals **22**A-**22**N, respectively; health care worker data **744**A-**744**N associated with each of the hospitals **22**A-**22**N, respectively; compliance data **745**A-**745**N associated with each of the hospitals **22**A-**22**N, respectively; and reports **746**A-**746**N associated with each of the hospitals **22**A-**22**N, respectively.

Hospital data **741**A-**741**N may include data that uniquely identifies or is associated with the respective hospital or other healthcare facility **22**A-**22**N. As such, hospital data **741**A-**741**N may include, for example, hospital identification information, employee information, management information, accounting information, business information, pricing information, area of concern (AOC) information, critical control point (CCP) information, data gathering station information, information concerning those persons or entities authorized to access the reports generated by the hand hygiene compliance system, date and time stamps, caregiver identification, visitor identification and additional information relating to other aspects of the corporation or operation and other information specific to each individual hospital **22**A-**22**N.

Dispenser data **42**A-**42**N may include, for example, any information associated with operation of the hand hygiene product dispensers in the respective hospital **22**A-**22**N. For example, dispenser data **42**A-**42**N may include, without limitation, one or more of the following data types: dispenser id; dispenser type; dispensed product name; dispensed product type (e.g., sanitizer, soap, alcohol, etc.); dispensed product form (solid, liquid, powder, pelleted, etc.); dispensed product amounts (by volume, weight, or other measure); dispensing times, dates, and sequences; detected healthcare worker ids linked to specific dispensing events; empty dispenser indications; dispenser AOC location; compliance rules; and other information associated with or originating at the dispenser site, whether detected by a dispenser or by an associated device.

Motion detector data **743**A-**743**N may include, for example, information concerning the entry and exit of compliance badged persons from a hospital room or other defined AOC in the respective hospital **22**A-**22**N. For example, motion detector data **743**A-**743**N may include, without limitation, motion detector id; motion detector type; physical location (e.g., hospital room number or other defined AOC within the healthcare facility); date of installation; maintenance records; detected person events, whether compliance badged or not; detected healthcare worker ids; date and time stamps; and other data associated with the motion detector modules of the respective hospital **22**A-**22**N. Healthcare worker (HCW) data **744**A-**744**N may include, for example, information concerning employees of the respective hospital **22**A-**22**N. For example, HCW data **744**A-**744**N may include, without limitation, HCW name, employee id number and/or other identification information; position (physician, nurse, physician assistant, physical therapist, EVS, etc.); work schedule; and other HCW related information for the healthcare workers in the respective hospital **22**A-**22**N.

Compliance data **745**A-**745**N may include, for example, all of the compliance information collected by the compliance badges associated with each of the respective hospitals **22**A-**22**N. For example, compliance data **746**A-**746**N may include, without limitation, records of compliant and non-compliant hand hygiene events, including compliant and non-compliant AOC entry and exit events, dispense events, and CCP entry and exit events, as determined by each compliance badge **504**A-**504**N for each hospital **22**A-**22**N.

Server computer **560** includes an analysis application **732** that analyzes the data received from each of hospitals **22**A-**22**N and stores the results for each hospital **22**A-**22**N in the database **740**. Analysis application **732** may analyze the hospital data **741**A-**741**N, dispenser data **742**A-**742**N, motion detector data **743**A-**743**N, HCW data **744**A-**744**N, and/or compliance data **745**A-**745**N either alone or in various combinations with each other to monitor hand hygiene compliance by individual HCW, type of HCW (e.g., nurses, doctors, EVS, etc.), individual departments, type of department, unit, ward, individual hospital, type of hospital, across multiple hospitals, or by various other selected parameters.

A reporting application **734** generates a variety of reports that present the analyzed data for use by the person(s) responsible for overseeing hand hygiene compliance at each hospital **22**A-**22**N. Reporting application **734** may generate a variety of reports to provide users local to each hospital **22**A-**22**N or remote users **554** with both qualitative and quantitative data regarding hand hygiene compliance at their hospital, and/or to compare data over time to determine whether improvement has occurred. Reporting application **734** may also users to benchmark hand hygiene compliance at multiple hospitals or other healthcare facilities.

Reports **746**A-**746**N associated with each hospital **22**A-**22**N, respectively, may also be stored in database **740**. Examples of the reports that may be generated by reporting application **734** are described with respect to FIGS. **6**A-**6**C. Reports **749**A-**749**N may be accessed by users local to each hospital **22**A-**22**N or by remote users **554** over one or more network(s) **558**. One or more of the reports **749**A-**749**N may be downloaded and stored on a local hospital computer, such as hospital server computer **555** shown in FIG. **23**B, user computer associated with remote users **554**, other authorized computing device, printed out in hard copy or further communicated to others as desired.

Local hospital computer **555** (FIG. **23**B) or database may also store the above-described hand hygiene data (e.g., hospital data, dispenser data, motion detector data, HCW data, and/or compliance data) associated with that hospital. Hospital computer **555**, database, or other local computer(s), may also include local analysis and reporting applications such as those described above with respect to analysis and reporting applications **732** and **734**. In that case, reports associated with that particular hospital may be generated and viewed locally, if desired. In another example, all analysis and reporting functions are carried out remotely at server computer **560**, and reports may be viewed, downloaded or otherwise obtained remotely. In other examples, some hospitals **22** may include local storage and/or analysis and reporting functions while other hospitals **22** rely on remote storage and/or analysis and reporting. Thus, it shall be understood that these storage, analysis and reporting functions may also be carried out locally or at some other location, and that the disclosure is not limited in this respect.

In another example, rather than setting up CCP protection zones around patient beds or other physical location within a healthcare or other facility, the critical control points could be defined as the patients themselves. In this example, each

patient may be assigned a CCP zone tag that establishes a personalized protection zone around the patient. The personal protection zone is able to move around as the patient moves throughout various areas within the healthcare facility. Patients and/or hospital assets may be tracked or located using the combination of compliance badges/tags and an arrangement ofAOCs set up around a hospital or other healthcare facility.

FIG. **38** is a flowchart illustrating another example process of operation for a motion detector module **540** (**802**). Upon detection of an entry event (**804**) motion detector **540** broadcasts the compliance rules specific to the associated AOC **520** (**806**). These compliance rules are then received and stored by any compliance badges within the AOC **520**. Motion detector also broadcasts a wake-up signal (**808**). Receipt of the wakeup signal causes a compliance badge to activate its ultrasonic receiver and thus go from power conservation mode (in which the ultrasonic receiver is turned off to save power) to active mode (in which the ultrasonic receiver is turned on) in which compliance badge may detect entry and exit from protection zones established within the AOC, such as protection zones **526**A and **526**B.

Upon detection of an entry event, motion detector starts a wake-up timer (**810**). The wake-up timer determines the time frame within which motion must be detected in order for motion detector **540** to continue broadcasting wake-up signals. For example, if no motion is detected within AOC **520** for a predetermined period of time as governed by the wakeup timer, motion detector will stop broadcasting wake-up signals. This is because it may be assumed in this example that, if no motion is detected before the wake-up timer expires, no HCWs are present in the AOC, and that there are therefore no compliance badges **504** present within the AOC that must be kept active for monitoring of hand hygiene compliance. Motion detector **540** continues to monitor the AOC for motion (**812**). If motion is detected (**812**), and/or periodically for as long as the wake-up timer is not expired (**814**), motion detector continues to broadcast the wake-up signal to ensure that all compliance badges within AOC **520** remain in active mode for as long as they remain in AOC **520** (**808**). If motion is not detected (**812**) and the wake-up timer is expired (**814**) motion detector stops broadcasting the wakeup signal (**816**).

FIG. **39** is a flowchart illustrating an example wake-up process (**820**) for a compliance badge **504**. When a compliance badge **504** receives a wake-up signal broadcasted from a motion detector **540** (**822**), compliance badge **504** activates its ultrasonic receiver (**824**). At this time a power-down timer controlled by power conservation module **613** of compliance badge **504** is started (**826**). Each time a wake-up signal is received (**828**) the power-down timer is restarted (**826**). When no wake-up signal has been received (**828**) and the powerdown timer has expired (**830**), compliance badge **504** powers down the ultrasonic receiver (**832**).

FIG. **40** is a flowchart illustrating an example process (**840**) of operation for a dispenser module, such as dispensers **530**A-**530**C. When a dispenser detects a dispense event (**842**), the dispenser gets the HCW id information from the compliance badge **504** associated with the HCW who initiated that dispense event (**844**). One way dispenser module may do this is as described above with respect to dispenser module **16** as shown in FIGS. **16** and **17**. The dispenser may then transmit the dispenser data (**846**) (e.g., data concerning the dispense event and associated HCW id data and date and time stamps, as well as battery status, total number of dispenses, number of dispenses remaining, out-of-product or low product status, and/or other dispenser status information, etc.). Dispenser **530** also transmits the compliance rules specific to the associated AOC **520** (**848**). This is may occur alternatively or in addition to the transmission of the compliance rules by motion detector **540**.

FIG. **41** is a flowchart illustrating another example process (**850**) for a compliance badge. When a dispense event is detected (**852**) compliance badge **504** starts the zone interaction timer (**854**). When compliance badge **504** detects a zone entry event (**856**), compliance badge **504** determines whether the zone interaction timer has expired (**858**). If not, the zone entry event is recorded as a compliant hand hygiene event (**860**). Alternatively, if the zone interaction timer has expired (**858**), compliance badge **504** records the zone entry event as a non-compliant hand hygiene event (**862**) and may activate the badge alarm(s) to alert the HCW to the occurrence of a non-compliant event.

FIG. **42** is a flowchart illustrating another example process (**870**) for a compliance badge. This process begins with the assumption that there has been detection of a previous compliant zone entry event, and the HCW is present within the protection zone. When compliance badge **504** detects a zone exit event (**872**), the loitering timer is started (**874**). If badge **504** detects another zone entry event (**876**), badge **504** checks whether the second zone entry event corresponds to the same protection zone as the initially compliant zone entry event (**878**). If so, badge **504** determines whether the loitering timer has expired (**880**). If the loitering timer has not expired, the second zone entry event is recorded as a compliant hand hygiene event (**882**).

Alternatively, if badge **504** detects a second zone entry event (**876**), and the second zone entry event does not corresponds to the same protection zone as the initially compliant zone entry event (**878**), badge **504** records the second zone entry event is recorded as a non-compliant hand hygiene event (**884**). Any badge alarms may also be activated at this point to alert the HCW to the occurrence of a non-compliant hand hygiene event. This is because, for purposes of hand hygiene compliance, a HCW should not be allowed to work in a first protection zone and enter into a second, different protection zone (and potentially carrying with him or her any contaminants from the first protection zone) without an intervening dispense event.

It should be noted that if at any time during any of the processes shown in FIG. **42** a dispense event is detected, compliance badge returns to execute the process shown in FIG. **41**. In this way, each time a dispense event is performed, the associated HCW is permitted to enter any protection zone in the AOC, so long as it is done within the amount of time permitted by the zone interaction timer.

FIG. **43** is a flowchart illustrating an example badge data download process (**900**) executed by a compliance badge. When compliance badge **504** receives a data download request (**902**), compliance badge **504** checks whether its data gauge is full (**904**). If not, the badge may ignore the data download request (**906**). Badge **504** will continue to ignore all data download requests until the data gauge is full (**904**). If the data gauge is full, compliance badge **504** initiates a badge data download communication protocol with the data gathering station that sent the data download request (**908**). When the badge data download is complete (**901**), badge **504** resets its data gauge (**912**). Data gathering station periodically broadcasts data download requests throughout the maximum data gathering zone (e.g., maximum data gathering zone **554**). Badge **504** continues to transmit badge data (**916**) as long it is within the maximum data gathering zone and is receiving download requests (**914**).

If at any point during the badge data download the badge **504** exits the maximum data gathering zone, badge **504** will no longer receive data download requests (**914**). This means that the badge is out of range of the data gathering station and cannot complete the badge data download (i.e., the badge data download was incomplete). At this point the badge **504** may wholly abandon the badge data download and re-attempt to transfer all of the badge data the next time it receives a badge data download request (**918**). Badge **504** may leave the data gauge at the full position to ensure that the badge data download is initiated the next time badge **504** receives a badge data download request. Alternatively, badge **504** may mark where the badge data transfer left off and continue the badge data download at some future time (**918**). In the event that an incomplete badge data download occurs and the remaining badge data is to be downloaded later, badge **504** may adjust the data gauge to indicate that a portion of the badge data has been downloaded, or may leave the data gauge at the full position to ensure that the badge data download continues the next time a data download request is received.

Although example zone emitters **528** are described herein as generating ultrasonic protection zones, and that compliance badges **504** include ultrasonic receivers for detecting entry and exit from the ultrasonic protection zones, it shall be understood that other implementations for generating protection zones and for detecting entry and exit from those zones could also be used without departing from the scope of the present disclosure. For example, zone emitters **528** could generate protection zones using radio frequency (RF), infrared (IR), microwave or any other appropriate frequency or frequency spectrum, or that the zone emitters could use motion detectors or other means of detecting presence within a protected zone, and the zone emitters and compliance badges would then include the hardware and software components associated with the chosen implementation. Likewise, although compliance badges **504**, motion detectors **540** and dispensers **530** are described herein as communicating via RF signals, it shall be understood that other forms of wireless communication, including ultrasonic, infrared, microwave, etc., could be used without departing from the scope of the present disclosure.

Although certain examples are shown and described herein, it shall be understood that depiction of different features as modules or units is intended to highlight different functional aspects and does not necessarily imply that such modules or units must be realized by separate hardware or software components. Rather, functionality associated with one or more modules or units may be performed by separate hardware or software components, or integrated within common or separate hardware or software components. Further, it shall be understood that while various components of example hand hygiene systems are shown and described this disclosure, hand hygiene systems with additional or different components are contemplated within the scope of the disclosure. In various examples, one or more components of a hand hygiene system described in this disclosure may be omitted from a hand hygiene system, as will be appreciated by those of ordinary skill in the art.

FIG. **44**A is a diagram illustrating another example hand hygiene compliance system **1000**A in which a plurality of uniquely identifiable hand hygiene compliance badges, such as compliance badge **1004** worn by a wearer, such as HCW **2**, and one or more dispensers, such as dispensers **1006**A-**1006**C, monitor hand hygiene events in a healthcare or other facility in which monitoring of hand hygiene activities is desired. In these examples, each compliance badge may, but need not, store healthcare worker identification information. For example, each badge may include a unique badge identifier, so that all dispense events associated with each badge may be monitored and analyzed. In this example, a local or remote computer (such as local computer **555**, server computer **560**, or user computer **554**) may include the ability to associate each badge with an individual HCW. However, it shall be understood that there may be circumstances in which it may be undesirable or unnecessary to specifically identify individuals and their associated hand hygiene activities, and that more generalized monitoring of hand hygiene compliance via unique badge identifiers may in some circumstances be sufficient.

Hand hygiene compliance system **1000**A shares some of the components of hand hygiene compliance system **501** (FIGS. **23**A and **23**B) in that a plurality areas of concern (AOC) in which monitoring of hand hygiene compliance is desired are set up in various areas throughout a healthcare facility. At least one of a plurality of hand hygiene compliance badges, such as compliance badge **1004**, is used to store and transmit hand hygiene compliance data to a data gathering station, in this case data gathering station **1020**. Unlike the example of hand hygiene compliance system **501**, however, hand hygiene compliance system **1000**A does not include patient-centered critical control points (CCPs) or corresponding critical control point zone emitters **528**. Hand hygiene compliance system **1000**A may therefore provide some similar advantages to hand hygiene compliance system **501** while requiring fewer components and offering easier installation. The data gathering station **1020** may transmit the hand hygiene information to one or more local and/or remote computers as described above with respect to FIG. **1** or FIG. **23**B, for example.

Hand hygiene system **1000**A includes hand hygiene product dispensers **1006**, in this case three dispensers **1006**A, **1006**B, and **1006**C. In different examples, hand hygiene system **1000**A may include fewer dispensers (e.g., one or two) or more dispensers, depending on and the physical layout and functional requirements of AOC **1002**. Regardless, each dispenser **1006** includes an activation or event sensor that detects when a hand hygiene product is dispensed. This is referred to as a "dispense event." In this respect, each dispenser **1006** may operate in a similar manner to the dispensers described with respect to FIG. **8**, **21**C, or **23**, for example. Further, each dispenser **1006** may include a wireless dispenser reader that detects presence of a compliance badge within range of the dispenser reader.

Dispensers **1006** may also communicate with the at least one compliance badge **1004**. For example, when a dispense event is detected and presence of a compliance badge is detected, the dispenser may transmit a dispense event signal. The dispense event signal is indicative that a dispense event occurred, and may include dispenser identification information. The dispense event signal may also include, in some examples, status information associated with the dispenser, such as battery status, product type, fault conditions, total number of dispenses, total number of badged and/or unbadged dispenses, etc. For purposes of the present description, a "badged dispense" means a dispense of product to a person who has a compliance badge, that is, the dispenser detected a compliance badge within range at the time the dispense event took place. An "unbadged dispense" means a dispense of product to a person who does not have a badge; that is, the dispenser did not detect a badge at the time the dispense event took place.

FIG. **44**B is a diagram illustrating another example hand hygiene compliance system **1000**B. Hand hygiene system

1000B is similar to hand hygiene system 1000A of FIG. 44A, except that system 1000B also includes a motion detector 1010. The hardware components and operation of motion detector 1010 may correspond to motion detector 540 described with respect to FIGS. 23 and 24, for example. In operation, motion detector 1010 detects movement within AOC 1002. For example, motion detector 1010 may detect movement within proximity to the entrance of an AOC 1002 (to detect entrance of persons into AOC 1002). This is termed an "entry event." Motion detector 1010 may also detect movement within AOC 1002 (to detect presence of persons moving within AOC 1002). If movement is detected, motion detector 1010 may perform one or more functions. For example, motion detector 1010 may send a "wake-up" signal to dispensers 1006. This wake-up signal may cause dispensers 1006 to enter an invitation mode, in which at least one dispenser 1006 activates one or more visual or audible indicators whose purpose is to remind the person entering the room of a hand hygiene opportunity. Motion detector 1010 may alternatively or in addition perform any additional functions attributed to motion detectors according to this disclosure.

In addition, motion detector 1010 may also communicate with the at least one compliance badge 1004. For example, when a movement is detected within the AOC, motion detector 1010 may transmit motion detector data for receipt by one or more of any compliance badges present in the AOC. Motion detector data may include, for example, battery status; motion detector id; motion detector type; physical location (e.g., hospital room number, or other defined area within the hospital, such as a standalone hand washing station, procedure room, lab, common area, operating room, therapy station, etc.); date of installation; maintenance records; detected person events, whether a person is wearing a compliance badge (HCW) or not (non-HCW); detected healthcare worker ids; date and time stamps (e.g., of an entry event); and other data associated with motion detector 1010.

FIG. 45 is a block diagram of an example compliance badge 1004. As discussed above, compliance badge 1004 receives, stores, and transmits various data to facilitate operation of hand hygiene system (such as system 1000A, 1000B, or any of the other hand hygiene compliance systems described herein). Compliance badge 1004 includes a microcontroller 1032, an RF transceiver 1034, and LF receiver 1038, and a memory 1036. RF transceiver 1034 communicates with dispensers 1006, a motion detector 1010 (if present), and data gathering stations 1020. In this example, an LF receiver receives LF (low frequency) wake-up signals broadcast by a dispenser upon detection of a dispense event and/or, in some examples, by a motion detector upon detection of an entry event. Microcontroller 1032 controls communication via RF transceiver 1034 and may also analyze various data including, for example, dispenser data and/or motion detector data, to monitor hand hygiene compliance or to log data concerning dispense events initiated by the HCW associated with the compliance badge. Memory 1036 stores software and data useful for the operation of badge 1030 such as, for example, dispense event records 1037, badge status data 1039, dispenser mailbox data 1035, and/or any other data generated or received by the badge 1004. Dispense event records 1037 may include, for example, a plurality of data records, each corresponding to a different dispense event initiated by the wearer of badge 1030. For example, each dispense event record stored in dispense event records 1037 may include a time and date of the dispense event, dispenser identification information, and/or any other appropriate dispense event data. Badge status data 1039 may include, for example, badge identification information, battery status, fault conditions, the time of last data download, data gauge level, and/or any other appropriate badge status information. Dispenser mailbox data 1035 may include, for example, a plurality of mailbox data records, each corresponding to the mailbox data associated with a different dispenser. Each mailbox data record may include, for example, dispenser status information such as battery status, the total number of dispense events, the number of badged dispense events, fault conditions, etc. for a different one of the dispensers in the hand hygiene system. In this way, the dispenser status information, badge status data, and/or dispense event records are physically carried to the data gathering station(s) as the wearer(s) of the compliance badge(s) move about the facility, where they are downloaded into the system for analysis and review.

Compliance badge 1004 may be implemented in a similar manner to some of the example compliance badges described herein. However, because example hand hygiene systems 1000A and 1000B do not include critical control point zone emitters described with respect to hand hygiene system 501, compliance badge 1004 need not include associated zone emitter hardware and software, e.g., ultrasonic receiver 616, ultrasonic receiver power conservation rules, and the like. Nevertheless, in some examples, a compliance badge that does include zone emitter functionality may be used in hand hygiene system 1000A and 1000B in addition to, or in lieu of, compliance badge 1004. That is, compliance badge 504 may be used in an environment where the full functionality of compliance badge is not enabled or perhaps is not used in every AOC.

With further reference to FIGS. 44A and 44B, hand hygiene systems 1000A and 1000B include one or more data gathering stations, such as data gathering station 1020. Data gathering station 1020 functions to retrieve data from compliance badge 1004 and, in some examples, transmit data to compliance badge 1004. The components and operation of data gathering station 1020 may be similar to the components and operation of data gathering station 550 described, for example, in FIGS. 23 and 34-37. For example, when HCW 2 leaves the AOC 1002 and comes within range of a data gathering station 1020, data gathering station 1020 compliance badge 1004 transmits its corresponding badge data for receipt by data gathering station 1020. In general, a healthcare or other facility may include a plurality of data gathering stations 1020 set up at various locations around the healthcare facility. Regardless, data gathering station 1020 may begin downloading badge data when compliance badge 1004 is within range of data gathering station 1020. In some examples, data gathering station 1020 includes a single download zone that is defined by where data gathering station 1020 begins downloading data. In other examples, data gathering station 1020 includes a plurality of different download zones. In the examples of FIGS. 44A and 44B, data gathering station 1020 includes a first download zone 1020 (e.g., a download initiation zone) and a second download zone 1024 (e.g., a maximum download zone).

Independent of the number or specific configuration of data gathering stations 1020, data gathering station 1020 may function to retrieve badge data from a plurality of compliance badges 1004. Badge data may then be used and/or distributed in a broader communication environment including, for example, a local hospital computer or other computer, a remote server computer, or to remote users, e.g., as described with respect to FIG. 1 and FIG. 37. Distribution to the communication environment may facilitate viewing,

analysis and/or report generation based on badge data, thereby allowing hand hygiene compliance to be monitored or otherwise evaluated. In this manner, hand hygiene compliance systems **1000**A and **1000**B can function to monitor and evaluate hand hygiene compliance.

In at least some of the example hand hygiene compliance systems shown and/or described herein, conservation of power in one or more of the various system components may be addressed, if desired. For example, the battery life of the compliance badges and/or other components of the system (that is, those that may be battery powered) may impact the effectiveness of the system. Reasons for this may include the possibility that healthcare workers may be ill-inclined to use badges that require frequent battery replacement, or to replace them with a frequency sufficient to ensure continuous or near continuous operability of the badge. When badges or other system components are not operational, the opportunity to collect data relevant to hand hygiene compliance associated with those components is lost. In addition, if healthcare workers or other employees of a facility in which hand hygiene is to be monitored find the use of the compliance badge to be cumbersome due to shorter than desired battery life, this may lead to a tendency not to use the compliance badge or not to change the batteries as needed, further reducing opportunities to collect hand hygiene compliance data.

As discussed with respect to FIG. **16**, for example, a dispenser module may spend at least some of its time in a low power "sleep mode." Operation of a dispenser in this way may serve to reduce power consumption and preserve battery life. A command to enter invitation mode, detection of an entry event, movement in proximity to the dispenser, or detection of a dispense event are various factors that may be used to "wake up" the dispenser.

An example communication protocol between a dispenser and a compliance badge for an example system such as that shown in FIG. **44**A that attempts to minimize power usage in a compliance badge will now be described with respect to FIGS. **46** and **47**.

FIGS. **46** and **47** are flowcharts illustrating example processes (**1200**, **1250**) executed by a dispenser and a compliance badge, respectively, during a communication session. For purposes of description, the process of FIG. **46** will be described with reference to a compliance badge operating in a system such as system **1000**A in FIG. **44**A. The disclosure is not limited in this respect, however, and other compliance badges and hand hygiene compliance systems as described herein may employ the process of FIG. **46**.

In this example, the compliance badge (such as compliance badge **1030** shown in FIG. **45**) includes an RF transceiver (such as RF transceiver **1036** as shown in FIG. **45**) for communication with one or more dispensers and/or other system components (if present) and an LF receiver (such as LF receiver **1038** as shown in FIG. **45**). The one or more dispensers (such as dispenser **1040** shown in FIG. **48**) include an RF transceiver (such as RF transceiver **1044** as shown in FIG. **48**) for communication with the compliance badges and an LF transmitter (such as LF transmitter **1048** as shown in FIG. **48**). In this example, each dispenser may store dispenser identification information (such as dispenser id **1047** in FIG. **48**) and mailbox data (such as mailbox data **1049** in FIG. **48**). Dispenser id **1047** includes dispenser identification that uniquely identifies the dispenser. Mailbox data **1049** includes status data associated with the dispenser such as battery status, product status, product type, the total number of dispenses, the total number of badged dispenses, fault conditions, etc.

FIG. **46** shows the process (**1200**) by which a dispenser may communicate with a compliance badge. The dispenser detects the dispense event (**1202**). For example, dispense event sensor **1045** shown in FIG. **48** may detect activation of the dispenser by a user via a button or push bar, dispensation of chemical product, touch-free detection of a user's hands, etc. The dispenser increments the total number of dispense events (**1204**). The dispenser broadcasts a LF (low frequency) wake-up signal (**1206**). For example, when dispense event sensor **1046** detects a dispense event, microcontroller **1042** may instruct LF transmitter **1048** to broadcast a LF wake-up signal. In general, the term "LF" refers to radio frequencies in the range of 30 kHz-300 kHz. The LF transmitter **1048** may transmit a 134 kHz wake-up signal, for example. The LF wake-up signal is a relatively lower power, lower range signal as compared to those transmitted and received by the RF transceiver in either the compliance badge or the dispenser. The LF wake-up signal may include dispenser identification information. The LF wake-up signal may also specify an RF (900 MHz, for example) channel over which dispenser-badge communication will occur. Alternatively, the dispenser identification information may be sent via the RF channel specified in the LF wake-up signal.

Due to its proximity at the time of the dispense event, the compliance badge associated with the healthcare worker that initiated the dispense event is highly likely to receive the LF wake-up signal, although other badges present in the AOC may also receive the LF wake-up signal. When a compliance badge receives the LF wake-up signal, the compliance badge's microcontroller (e.g., microcontroller **1036** of FIG. **45**) activates the RF transceiver (e.g., RF transceiver **1034**) on the compliance badge so that the badge may communicate with the dispenser. In this example, the compliance badge may transmit and RF acknowledge signal (ACK) acknowledging that it received the LF wake-up signal and is ready to communicate with the dispenser.

After transmitting the LF wake-up signal (**1206**) the dispenser may determine whether the acknowledgement (ACK) is received from a compliance badge (**1208**). If no acknowledge of the LF wake-up signal is received (**1208**), then the dispense event was likely initiated by an unbadged person. The dispenser updates the mailbox data (**1218**) and returns to sleep mode (**1219**) to await detection of anther dispense event.

If an acknowledge of the LF wake-up signal is received (**1208**), then the dispense event was likely initiated by a person wearing a compliance badge. The dispenser may increment a badged dispense event counter (**1210**). This counter may be used to keep track of the number of badged dispenses experienced by the dispenser. The dispenser may also transmit the dispenser identification information (**1212**) uniquely identifying the dispenser. The badge associates the dispenser identification information with the dispense event, along with a time and date stamp, and stores this data in a dispense event record (such as dispense event records **1037** as shown in FIG. **45**), as discussed below.

The dispenser determines whether mailbox data is to be sent (**1214**). Whether or not mailbox data is to be sent may depend, for example, on whether the dispenser has a predetermined amount of mailbox data stored. Mailbox data may also be sent according to a schedule, such as after every predetermined number of dispense events (e.g., after every 10 dispenses, after every 25 dispenses, or other appropriate

number of dispenses, etc.), on a periodic schedule (e.g., every 3 hours, once per day, or other appropriate time period, etc).

If the dispenser is to transmit mailbox data (**1214**), the dispenser transmits the mailbox data (**1215**). In this example, a predetermined number of mailbox data records are sent. If a mailbox data acknowledgement from a compliance badge is not received (**1216**) the dispenser may assume that the transmission of the mailbox data failed and may retransmit the unreceived mailbox data at a later time (**1217**). If a mailbox data acknowledgement from a compliance badge is received (**1216**), the dispenser checks to see if there are additional mailbox data records to be sent (**1214**). For example, a predetermined number of mailbox data records may be sent, an ACK received, more records sent, etc., until all of the mailbox data is sent or until the badge is out of range. Once the dispenser does not receive a mailbox data acknowledgement (**1216**) (e.g., because the badge has gone out of range or because of an error) or the dispenser has sent all of its mailbox data (**1214**), the dispenser updates its mailbox data (**1212**) and returns to sleep mode (**1213**).

In this example, by not transmitting mailbox data at each dispense event, battery life on the compliance badge may be increased. However, it shall be understood that all mailbox data may be transmitted at each dispense event rather than saving mailbox data until some future time, and it shall be understood that the disclosure is not limited in these or other respects.

The badge may use a protocol to determine how any received mailbox data is to be stored. If the badge does not have enough room to store a new mailbox record, for example, it may drop its oldest record. As another example, if the badge already has a mailbox record for the dispenser, it may replace the older record with the new record. In addition, the dispenser may use the RSSI (receive signal strength indicator) information from the badge to determine which badge to communicate with in the event two or more badges are within range of the dispenser when a dispense event occurs.

FIG. **47** illustrates and example process (**1220**) by which a compliance badge may communicate with a dispenser. The LF receiver on the compliance badge listens for the LF wake-up signal (**1222**). When the LF wake-up signal is received (**1224**), the badge activates its RF transceiver (**1226**) and transmits an LF signal acknowledge (**1230**) via the RF channel indicated by the dispenser in the LF wake-up signal. If no mailbox data is to be sent (**1232**), the compliance badge may return to sleep mode (**1236**). In this example, the RF transceiver (both transmitting and receiving) are powered off when the badge is in sleep mode. In other examples, the RF transmitter may be powered up at periodic intervals (e.g., every few hundred milliseconds) to "ping" for a data gathering station as discussed herein below.

If mailbox data is to be sent (**1232**), the compliance badge receives the mailbox data (**1234**) transmitted by the dispenser. In this example, the mailbox data is received via the RF communication channel indicated in the LF wake-up signal. After the mailbox data is received, the dispenser transmits the mailbox data acknowledge (**1236**). The process (**1232-1236**) may repeat until the dispenser is finished sending mailbox data or the badge goes out of range of the dispenser. The compliance badge may then return to sleep mode (**1236**).

Processes similar to those described with respect to FIGS. **46**, **47** and **55** may also be used with example system **1000**B as shown in FIG. **44**B. In that example, the LF wake-up signal could be transmitted by the motion detector **1010** upon detection of an entry event. The LF wake-up signal may cause the compliance badge **1004** to activate its RF transceiver so that it may communicate with a dispenser at which the HCW initiates a dispense event. If no dispense event occurs within a predetermined period of time, the compliance badge may return to the sleep mode. Initiation of a dispense event by HCW **2** would trigger the processes described in FIGS. **46** and **47**, causing the compliance badge to wake-up and communicate with the dispenser as described in FIGS. **46** and **47**, for example.

Although the processes of FIGS. **46** and **47** have been described with respect to the systems of FIGS. **44**A and **44**B, it shall be understood that these or similar techniques could be implemented in any of the example hand hygiene compliance systems described herein. For example, an LF wake-up signal could be broadcast by a dispenser upon detection of an entry event to cause a compliance badge to activate its RF transceiver (or receiver) may be implemented in any of the systems described herein. Also, an LF wake-up signal could be broadcast by a motion detector upon detection of an entry event in those systems described herein or in other systems that include a motion detector that detects entry events into an AOC. Similarly, the process by which dispense event data and mailbox data is sent may also be implemented in any of the other hand hygiene systems described herein, or in other hand hygiene compliance systems.

As another example, in the system shown in FIGS. **44**A and/or **44**B, the dispenser/badge communication need not include a wake-up function. Also, the wake-up need not be implemented using LF, nor does the dispenser/badge communication need to be RF. It shall be understood that the specific implementation described is for purposes of example only, and that the disclosure is not limited in this respect.

In addition, although not shown with respect to FIG. **47**, compliance badge may analyze some of all of the dispense event records to determine one or more compliance metrics associated with one or more dispense events. For example, the compliance badge may determine a total number of dispense events initiated by the associated HCW over a given period of time; may compare the total number of dispense events to a target; or determine other compliance metrics. Alternatively or in addition, some or all of the dispense event records, badge status data, and/or dispenser mailbox data may be analyzed at a computing device that receives the badge data at any point after it has been downloaded to a data gathering station.

FIG. **49** is a flowchart illustrating an example process (**1250**) by which a compliance badge may communicate with a data gathering station. Process (**1250**) may be implemented in any of the hand hygiene compliance systems described herein. In this example, a badge, from sleep mode (**1252**) may at periodic intervals determine whether it is time to send a "ping" for a data gathering station (**1253**). If not, the badge remains in sleep mode (**1252**) until it is time to send a ping. If it is time to ping, the badge may activate its RF transceiver (**1254**) and transmit a ping (**1256**). If a data gathering station is within range and transmits a ping acknowledge (ping ACK), and the ping ACK is received by the badge (**1257**), the badge may transmit some or all of its badge data (such as badge data **1035** in FIG. **45**). If no ping acknowledge is received by the badge (**1257**), the badge continues to transmit pings at the predetermined periodic intervals (**1252-1256**) until ping ACK is received.

The determination as to whether it is time to ping (**1253**) may be determined in several ways. For example, whether or not a badge is "pinging" may depend on the amount of data the badge has stored. If a badge only has a few records stored it may not ping for a data gathering station, and may instead wait until it has a predetermined amount of badge data to transfer. This may help to save battery life on the compliance badge. In some examples a badge may ping on a periodic basis, such as every few seconds or some other appropriate time interval. In other examples, a combination of these methods may be used.

Once the compliance badge transmits the badge data (**1258**) it waits to receive a badge data acknowledge from the data gathering station (**1259**). If no badge data acknowledge is received within a predetermined period of time (e.g., several hundred microseconds), the badge may try sending the badge data again at a later time (**1260**). The badge may then return to sleep mode (**1264**). If a badge data acknowledge is received (**1259**), the badge may erase the transmitted badge data from its memory (**1262**). This provides memory space for the badge to receive and store additional data in the future. The badge may then return to sleep mode (**1264**). In the event that the badge does not transmit all of its badge data at once, the process (**1258-1259**) may repeat until all data is sent or until a badge data acknowledge is not received (for example, if the badge goes out of range).

FIG. **50** is a flowchart illustrating an example process (**1270**) by which a data gathering station may communicate with a compliance badge. Process (**1270**) may be implemented in any of the hand hygiene compliance systems described herein. When a data gathering station receives a ping (**1272**), the data gathering station transmits a ping acknowledge (**1274**) and establishes communication with the associated compliance badge. The data gathering station receives the badge data from the compliance badge that transmitted the ping (**1276**). After the badge data is received, the data gathering station transmits a badge data acknowledge (**1278**). If more badge data is to be sent, the process (**1276-1278**) may repeat until all of the transmitted badge data has been received or until the badge goes out of range. The data gathering station may then terminate the session (**1279**).

In a busy healthcare facility, it is likely that more than one compliance badge may attempt to transmit badge data to a particular data gathering station at any given time. In that case, the system may implement techniques to ensure that each compliance badge is given a chance to transfer badge data before their associate memory becomes full. For example, if more than one badge is attempting to or is transmitting badge data at one time, the data gathering station may permit each badge to send only a predetermined amount of data (e.g., a predetermined number of records or bytes), and may cycle between badges, receiving the predetermined amount of data from each, for as long as each badge remains in range. Alternatively, the data gathering station may determine a priority based on the amount of data stored on each badge, the length of time since each badge has downloaded badge data, some combination thereof, or by some other method of establishing priority.

As another alternative, the data gathering station may place each badge requesting to download in a "holding pattern" while communicating with the first badge. While in the "holding pattern," each badge may ping faster than the usual ping rate until the badge data is downloaded or the badge goes out of range.

Communication between the badge and a data gathering station may end as the badge passes out of range. At some point, once the badge is out of range, one of the acknowledgements will not be received and both the badge and the data gathering station may return to their initial operating states.

Once the badge data (such as badge data **1035**) has been downloaded to the data gathering station, the badge data may be transmitted to a local or remote computing device for analysis or review. Dispense event data associated with a particular compliance badge can be compared to anticipated or expected dispense event data. For example, a computing device may analyze the badge data from one or more compliance badge to determine one or more compliance metrics associated with one or more dispense events. For example, a computing device may determine a total number of dispense events initiated by the wearer of a particular badge over a given period of time; may compare the number of dispense events to a target; or determine other compliance metrics. If the system server or other computing device includes the HCW identification information associated with each compliance badge, the hand hygiene data may in some examples be associated with a particular individual. Alternatively or in addition, the hand hygiene data may be associated with the individual's job function (e.g., nurse, physician, administrator, cleaning staff, etc.). Further, hand hygiene data associated with a particular hospital or grouping of hospitals or other facilities can be compared to hand hygiene data associated with different hospitals or groups as part of a communications environment.

FIG. **51** is a flowchart illustrating an example process (**1280**) by which multiple dispense events satisfying a debounce condition may be counted as a single dispense event. At times a user of a hand hygiene product dispenser will "pump" a dispenser multiple times in quick succession. Although the dispenser will detect each individual "pump" of the dispenser, multiple "pumps" in quick succession may usually be attributed to a single user and a single dispense event. a dispenser may "debounce" a sequence of dispenses satisfying a debounce condition. The debounce may be accomplished by the dispenser, in which case the dispenser would increment it's dispense event counter by a single count rather than the actual number of detected dispense events if the debounce condition is satisfied. Alternatively, the debounce may be accomplished at a local or remote computer after the data has been downloaded from the badge. In this example, the dispenser would detect and count each and every detected dispense event, and a local or remote computer would analyze the dispense event records for debounce conditions. As another example, the dispenser may debounce unbadged dispenses while badged dispenses may be debounced at a local and/or remote computer. It shall be understood, therefore, that there are several alternative examples of how, when and where debouncing of dispense events may occur, and that the disclosure is not limited in this respect.

Process (**1280**) of FIG. **51** begins when multiple dispense events are detected (**1282**). If one or more debounce conditions are satisfied (**1282**) the multiple detected dispense events satisfying the debounce condition may be counted as a single dispense event (**1286**). If the debounce condition(s) are not satisfied, the multiple dispense events are counted as separate dispense events.

To determine whether the debounce condition(s) are satisfied, a processor may compare the time between successive dispenses to a debounce threshold. If successive dispenses occur within the time frame established by the debounce threshold, the debounce condition is satisfied and the successive dispenses are counted as a single dispense. The

debounce condition may include, for example, a debounce threshold of between 1-3 seconds between successive dispenses. The debounce condition may also indicate, for example, that all dispenses occurring within a 5 second time frame should be counted as a single dispense. Other debounce conditions and debounce threshold are also contemplated, and the disclosure is not limited in this respect.

It should again be noted that although in certain examples features and combinations of features are depicted as modules or units working together, in different examples, the modules or units do not need to be realized by separate hardware or software components. Further, although combinations of features are depicted in various examples, all the features depicted in a specific example do not necessarily need to be implemented together to produce a hand hygiene system according to the disclosure.

For example, FIG. **52** is a block diagram illustrating a comparatively simple hand hygiene compliance system **1070** that could be used at a hospital, healthcare facility, food service facility, institutional facility, or other facility where hand hygiene monitoring is desired. Hand hygiene compliance system **1070** includes at least one hand hygiene product dispenser which, in the illustrated example includes three dispensers **1072**, **1074**, and **1076**. The dispensers may be associated with an AOC, such as AOC **1071**. Each of the hand hygiene product dispensers **1072**, **1074**, and **1076** may communicate dispenser data to one or more computing devices, such as computing device **1078**.

Hand hygiene product dispensers **1072**, **1074**, and **1076** may be similar to various hand hygiene product dispensers described above including, for example, dispenser **16** (FIGS. **1** and **8**), the dispenser shown in FIG. **21**C, dispenser **530** (FIG. **25**), dispenser **1040** (FIG. **54**), and/or any other dispenser shown or described herein. In this respect, each of hand hygiene product dispensers **1072**, **1074**, and **1076** includes an activation or event sensor to detect a dispense event. Upon detecting a dispense event, the dispenser may transmit at least some dispense event data, which may include any status information concerning the dispenser, to the one or more designated computing devices **1078**, e.g., for analysis and storage. Alternatively, the dispenser may transmit dispense event data at periodic intervals or only when a certain amount of data is present on the dispenser. Alternatively, the dispenser may store the dispense event and/or status data for later retrieval by a service technician via a handheld device, laptop computer, cell phone, PDA, or other device that interfaces directly or indirectly with the dispenser, for example.

Each of hand hygiene product dispensers **1072**, **1074**, and **1076** may communicate with a computing device **1078** via wired or wireless communication, such as a wireless network, radio frequency transmission, wireless telephone network, or other wired or wireless means of communication. In other examples, hand hygiene product dispensers **1072**, **1074**, and **1076** may communicate with designated computing device **1078** using a USB cable, or using removable media, such as magnetic or optical disks, or memory cards or sticks. In any example, dispense event data may be transmitted to one or more computing devices, such as computing device **1078**.

Computing device **1078** may analyze and/or present various hand hygiene data obtained by the dispensers. In this manner, hand hygiene compliance system **1070** may track and monitor hand hygiene product dispenser utilization. Computing device **1078** may determine various compliance metrics for each dispenser or dispensers, such as a total number of dispense events per unit time. The computer **1078** may also analyze and generate reports concerning the dispenser data in various groupings, such as by dispenser, by AOC, by facility, by groups of facilities, or by any other grouping or groupings that may be of interest.

While hand hygiene product dispensers **1072**, **1074**, and **1076** in the example of FIG. **53**A are limited to detecting dispense events, one or more of hand hygiene product dispensers **1072**, **1074**, and **1076** may include additional functionality, such as a motion detector to detect movement proximate to the hand hygiene product dispenser. A motion detector may provide additional hand hygiene compliance data to determine, for example, how frequently users execute dispense events as compared to how frequently users come within the movement detection proximity of the hand hygiene product dispenser.

FIG. **53** is a block diagram illustrating an example hand hygiene compliance system **1080**, which includes a hand hygiene product dispenser **1084** and a motion detector **1082**. In this example, motion detector **1082** is integrated with hand hygiene product dispenser **1084** and configured to movement within range of the motion detector **1082**. Hand hygiene product dispenser **1084** communicates with designated computing device **1086** as described above with respect to FIG. **52**.

In general, hand hygiene compliance system **1080**, and in particular motion detector **1082**, detects movement within the detection range of motion detector **1082**. Motion detector **1082** detects movement within the AOC, and may transmit detected motion event data (for example the event time, battery voltage, signal strength, and any other related information) to a designated computing device **1086**. Upon detecting a dispense event, hand hygiene product dispenser **1084** may transmit dispense event data and/or detected motion event data, to designated computing device **1086** as discussed above with respect to FIG. **53**A.

In addition, to promote hand hygiene compliance, hand hygiene product dispenser **1084** may include visible and/or audible indicator(s) as described with respect to FIG. **12**. In these examples, hand hygiene product dispenser **1084** can enter an invitation mode when motion detector **1082** detects movement, e.g., as described with respect to FIG. **19**. Designated computing device **1086** and hand hygiene product dispenser **1084**, working alone or in cooperation, may initiate a product dispenser invitation mode upon detecting a motion event data. The product dispenser can subsequently exit the invitation mode upon detecting a dispense event or upon the expiration of a target time window. By including invitation mode functionality, hand hygiene system **1080** may increase the likelihood that a person in close proximity to hand hygiene product dispenser **1084** executes a hand hygiene event.

Although the example hygiene compliance system of FIG. **53** only illustrates a single hand hygiene product dispenser **1084** and motion detector **1082**, it shall be understood that any of the hand hygiene compliance systems described herein may include multiple hand hygiene product dispensers and/or multiple motion detectors.

FIG. **54** is a block diagram illustrating another example hand hygiene compliance system **1090**. Hand hygiene compliance system **1090** includes one or more AOCs, such as AOC **1081**, each including a main dispenser **1096** and one or more secondary hand hygiene product dispensers, such as dispensers **1098** and **1100**. Main dispenser **1096** includes a communication unit **1094** that communicates dispenser data from the AOC for receipt by one or more computing devices, such as computing device **1102**. Main dispenser may also include an optional motion detector **1092** as described above

with respect to FIG. **53**B. In this example, optional motion detector **1092** and communication unit **1094** are integrated with main dispenser **1096**. Secondary dispensers **1098** and **1100** communicate their respective dispenser data to the main dispenser **1096**. Main dispenser **1096** in turn communicates with one or more computing devices, such as computing device **1102** via wired or wireless communication.

FIG. **55** is a block diagram illustrating another example hand hygiene compliance system **1110**. One or more AOCs, such as AOC **1113**, include a coordinator **1114**, and at least one hand hygiene product dispenser, in this case dispensers **1116**, **1118**, and **1120**. An optional motion detector **1112** and coordinator **1114** may be integrated into a single unit (as shown in FIG. **55**) that in this example is separate from the hand hygiene product dispensers **1116**, **1118**, and **1120**. Alternatively, the optional motion detector and the coordinator need not be integrated, and may instead be implemented separately (such as shown in FIG. **1**, for example). Dispensers **1116**, **11118**, and **1120** (and motion detector **1112**, if implemented) communicate their respective dispenser data to coordinator **1114**. Coordinator **1114** in turn communicates the dispenser data associated with AOC **1113** to one or more computing devices, such as computing device **1122**.

Various examples have been described. These and other examples are within the scope of the following claims.

The invention claimed is:

1. A system comprising:

one or more uniquely identified hand hygiene product dispensers, each associated with an area of concern (AOC) within a facility*; and*

one or more uniquely identified compliance badges;

wherein each of the one or more uniquely identified hand hygiene product dispensers is configured to: **[**, that**]** detect**[**s**]** a dispense event*;*

detect whether one of the one or more uniquely identified compliance badges is within range of the dispenser;

in response to detecting that one of the one or more uniquely identified compliance badges is within range of the dispenser, associate the detected dispense event with the detected one of the one or more uniquely identified compliance badges that is within range of the dispenser and increment a total number of badged dispense events detected by the dispenser;

in response to detecting that none of the one or more uniquely identified compliance badges are within range of the dispenser, increment a total number of unbadged dispense events detected by the dispenser; and

transmit**[**s**]** a corresponding dispense event signal and dispenser identification information *to the detected one of the one or more uniquely identified compliance badges within range of the dispenser, wherein each dispense event signal further includes dispenser status information including a total number of dispense events detected by the dispenser, the total number of badged dispense events detected by the dispenser, and the total number of unbadged dispense events detected by the dispenser*; and

wherein each of the one or more uniquely identified compliance badges**[**, each of that**]** *is configured to:*

receive**[**s**]** the dispense event signal and the dispenser identification information*;* and

store**[**s**]** the dispenser identification information *and the dispenser status information* in a dispense event record that is associated with the detected dispense event.

2. The system of claim **1** wherein **[**the dispenser**]** *each of the one or more uniquely identified hand hygiene product dispensers is further configured to* increment**[**s**]** a dispense event counter upon detection of a dispense event.

3. The system of claim **1** wherein **[**the**]** *each of the one or more uniquely identified* compliance badge*s is further configured to* store**[**s**]** a time and date stamp indicative of a time at which the dispense event occurred in the associated dispense event record.

4. The system of claim **3** wherein **[**the dispenser**]** *each of the one or more uniquely identified hand hygiene product dispensers* further includes a low frequency transmitter that transmits a low frequency wake-up signal upon detection of a dispense event.

5. The system of claim **4** wherein the **[**at least one**]** compliance badge comprises a low frequency receiver **[**that**]** *configured to* receive**[**s**]** the low frequency wake-up signal and, upon receipt, activate**[**s**]** a radio frequency transceiver.

6. The system of claim **1** further comprising one or more data gathering stations associated with the facility, each of which *is configured to* receive**[**s**]** one or more of the dispense event records *from* the one or more compliance badges.

7. The system of claim **6** further comprising a computing device **[**that**]** *configured to* receive**[**s**]** the dispense event records directly or indirectly from the one or more data gathering stations and analyze**[**s**]** the dispense event records to monitor hand hygiene events in the facility.

8. The system of claim **7** wherein the computing device *is further configured to* generate**[**s**]** reports concerning the hand hygiene events in the facility.

9. The system of claim **1** wherein the dispenser *is further configured to* count**[**s**]** two or more successive dispense events as a single dispense event when the two or more successive dispense events satisfy a debounce condition.

10. The system of claim **1** wherein a local or a remote computer *is configured to* count**[**s**]** two or more successive dispense events as a single dispense event when the two or more successive dispense events satisfy a debounce condition.

11. The system of claim **1** **[**wherein the dispenser further transmits dispenser status information,**]** wherein the dispenser status information *further* includes one or more of a battery status, a fault condition**[**s**]**, a time of last status data, *and* a data gauge level**[**, a total number of dispense events, and a total number of badged dispense events**]**.

12. A system comprising:

at least one hand hygiene product. dispenser, positioned within an area of concern (AOC) in a facility in which hand hygiene events are to be monitored**[**,**]** *;*

a plurality of compliance badges each having uniquely associated badge identification information;

wherein the at least one hand hygiene product dispenser is configured to: **[**that**]**

[senses**]** *detect* a dispense event **[**initiated by a wearer of a compliance badge**]**;

detect whether one of the plurality of compliance badges is within range of the dispenser;

in response to detecting one of the plurality of compliance badges within range of the dispenser, associate the dispense event with the detected one of the plurality of compliance badges within range of the dispenser and increment. a total number of badged dispense events;

in response to detecting none of the plyurality of compliance badges within range of the dispenser, increment a total number of unbadged dispensein respon events; and

transmit[s] dispenser data concerning the dispense event *to the detected one of the plurality of compliance badges within range of the dispenser the dispenser data including dispenser identification information and dispenser status information including a total number of disperse events detected by the dispenser, the total number of badged dispense events and the total number of unbadged dispense events;* [and]

[a] *wherein the detected one of the* plurality of compliance badges [, each having uniquely associated badge identification information and each of which is worn by a different one of a plurality of wearers, wherein each compliance badge] *is configured to* receive[s] the dispenser data [associated with dispense events initiated by the wearer of the compliance badge,] and store[s] *the dispenser data in a corresponding* dispense event record[s associated with each dispense event initiated by the wearer].

13. The system of claim **12** wherein [each] *the at least one hand hygiene product* dispenser *is further configured to* increment[s] a dispense event counter upon detection of a dispense event.

14. The system of claim **12** wherein the *detected one of the plurality of* compliance badge*s is further configured to* store[s] a time and date stamp indicative of a time at which the dispense event occurred.

15. The system of claim **12** further comprising one or more data gathering stations associated with the facility, *wherein* each of [which] *the one or more data gathering stations is configured to* receive[s] one or more of the dispense event records *from* the one or more compliance badges.

16. The system of claim **15** further comprising a computing device [that] *configured to* receive[s] the dispense event records directly or indirectly from the one or more data gathering stations and analyze[s] the dispense event records to monitor hand hygiene events in the facility.

17. The system of claim **16** wherein the computing device *is further configured to* generate[s] reports concerning the hand hygiene events in the facility.

18. A system comprising:

at least one hand hygiene product dispenser, positioned within an area of concern (AOC) in a facility in which hand hygiene events are to be monitored, [that] *the at least one hand hygiene product dispenser configured to:*

sense[s] a dispense event;

detect a compliance badge within range of the dispenser;

in response to detecting the compliance badge within range of the dispenser, associate the dispense event with the detected compliance badge, increment a total number of badged dispense events and transmit[s] a dispense event signal indicative that a dispense event occurred [and that transmits] *to the detected one of the plurality of compliance badges within range of the dispenser, wherein the dispense event signal includes* dispenser identification information *and dispenser status information including a total number of dispense events sensed by the dispenser, the total number of badged dispense events sensed by the dispenser and a total number of unbadged dispense events sensed by the dispenser, wherein the total number of unbadged dispense events includes dispense events sensed by the dispenser for which no compliance badge was detected within range of the dispenser;* and

[a] *wherein the detected* compliance badge [that] *is configured to* receive[s] the dispense event signal [and the dispenser identification information associated with dispense events initiated by a wearer of the compliance badge,] and store[s] *a* dispense event record[s associated with each dispense event initiated by the wearer] *including the dispenser identification information and the dispenser status information.*

19. The system of claim **18** further comprising a plurality of compliance badges, each [worn by] *associated with* a different one of a plurality of wearers.

20. The system of claim **19** further comprising:

one or more data gathering stations associated with the facility, each of which *is configured to* receive[s] one or more of the dispense event records from at least one of the plurality of compliance badges; and

a computing device [that] *configured to* receive[s] the dispense event records directly or indirectly from the one or more data gathering stations and analyze[s] the dispense event records to monitor hand hygiene events in the facility.

21. The system of claim 12, wherein each of the plurality of compliance badges is configured to store a plurality of dispense event records, each dispense event record corresponding to a different dispense event, each dispense event record including a time and date of the dispense event and the dispenser identification information corresponding to the dispense event.

22. The system of claim 12, wherein each dispense event record includes a time and date of the dispense event and the dispenser identification information.

23. The system of claim 12 wherein each dispense event record includes a time and date of the dispense event, the dispenser identification information, a dispenser type, a dispensed product name, a dispensed product type, a healthcare worker id, and a dispenser empty indication.

24. The system of claim 21, wherein each compliance badge is configured to wirelessly transmit the plurality of dispense event records for receipt by a data gathering station when the badge is within range of the data gathering station.

25. The system of claim 1, wherein each of the one or more uniquely identified hand hygiene product dispensers further includes a badged dispense event counter configured to store the total number of badged dispense events detected by the dispenser.

26. The system of claim 1 wherein each of the one or more uniquely identified compliance badges is configured to store the dispenser status information in a data record corresponding to the dispenser identification information.

* * * * *