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DESCRIPTION

Technical Field

[0001] The invention relates to surgical instrument radio frequency identification, RFID, tag reading apparatus. The invention further relates to a surgical instrument tracking system. The invention further relates to a method of reading RFID tags on a plurality of surgical instruments of a surgical instrument set, each RFID tag containing identification information for the respective surgical instrument.

Background

[0002] A surgeon typically requires a number of specific sets of surgical instruments in order to perform an operation. Before the operation can be started a check of each instrument set must be made to confirm that all the necessary surgical instruments are present. This process is typically repeated once the operation has been carried out, both before and after the patient is closed up. Each of these checks is typically carried out by two members of the surgical team.

[0003] Reusable surgical instruments are required to be decontaminated and sterilised before they can be used again. Surgical instrument sets are typically provided within trays, and during the decontamination and sterilisation process the surgical instruments in each set typically remain together. The instruments in each set are checked off against an instrument list at least twice during the decontamination and sterilisation process; once on the dirty side of the process, before the process is started and once on the clean side of the process, after the process has been completed. Historically the decontamination and sterilisation process has been carried out by the central sterile services departments, CSSD, of the hospitals in which the instruments are used but economic pressures are driving some hospitals to outsource their CSSD functions to offsite, third party providers. Hospitals are increasingly being required to track each surgical instrument over a period of years in order to manage contamination risk, especially Creutzfeldt-Jakob disease, CJD. The correct identification of each surgical instrument, and its originating hospital, during the decontamination and sterilisation process is therefore becoming increasingly important.

[0004] Rather than relying on visual identification by highly trained staff of each of hundreds of different types of surgical instrument, various labelling systems are available which are directly applied to each surgical instrument. These include etched bar codes, stick-on labels and RFID tags. The bar codes and labels suffer from deterioration due to the harsh conditions to which they are exposed during the decontamination and sterilisation process, and include edges which can provide locations for prions, such as CJD prions, to attach themselves to. RFID tags may offer a solution to these problems but current RFID tag readers for surgical instruments can only read the RFID tags on a few surgical instruments at a time and require the

instruments to be separated from their set during reading. For example, EP2218421 describes an identification antenna for RFID tags attached to surgical instruments which are placed on the antenna.

[0005] US 2006/043177 describes a radio frequency identification (RFID) reader device for interrogating a smart surgical instrument tray with a number of surgical instruments that are tagged with RFID read/write tags that identify each surgical instrument in terms of manufacturer, part number, name, usage, maintenance history. The surgical instrument tray arrives at a distribution centre, via a conveyer belt on which the RFID reader is mounted. As the surgical instrument tray is presented into a wireless radio frequency field of the RFID reader device, an interrogation signal is emitted that activates the RFID tags that are placed on the surgical instruments, and enables a response by the RFID tags via a transceiver/antenna combination. The transceivers and the antenna collect data from the RFID tagged surgical instruments and pass the data to a data output device, such as a desk top PC.

[0006] US2011/112384 describes a medical system which comprises a central control unit for displaying a diagnostic measured value using a display element and an invasive unit, having an invasive consumable. The invasive consumable is set up to invasively intervene in a tissue of a patient. The invasive unit has a contactlessly readable electronic identifier for storing at least one piece of information. The central control unit is set up to electronically read the information in the electronic identifier.

[0007] WO2013/104743 describes a storage/transport container for medical instruments comprising a container for receiving medical instruments and a device for detecting and transferring data of medical instruments. The device comprises a control unit, a reading unit and an identification element arranged on a medical instrument. The control unit is connected to the reading unit and exchanges data with the reading unit and processes, stores and/or forwards the data to a second identification element on the container. The reading unit exchanges data with the identification element and forwards the data to the control unit. The device has a sensor unit which detects the medical instrument by measuring a variable and exchanges signals with the control unit, which initiate the exchange of data between the reading unit and the identification element, and the reading unit transfers the exchanged data to the control unit.

[0008] DE 10 2012 107 274 discloses a device for simultaneously identifying a plurality of surgical instruments including an RFID tag reader, a camera, a barcode reader and a weighing device. Vibrating means are provided to apply vibration to the instruments in order to move the instruments to allow instruments undetected by the camera or the barcode reader to be read during a second reading operation.

Summary

[0009] The invention is defined in the appended independent claims. Preferred embodiments

are disclosed in the dependent claims. It is an object to provide an improved surgical instrument radio frequency identification, RFID, tag reading apparatus. It is a further object to provide an improved surgical instrument tracking system. It is a further object to provide an improved method of reading RFID tags on a plurality of surgical instruments of a surgical instrument set, each RFID tag containing identification information for the respective surgical instrument.

[0010] A first aspect of the disclosure provides surgical instrument radio frequency identification, RFID, tag reading apparatus comprising an interrogation zone, an RFID tag reader, a radio frequency, RF, antenna, guidance apparatus and a controller. The interrogation zone is arranged to receive a surgical instrument set comprising a plurality of surgical instruments. Each surgical instrument comprises a respective RFID tag containing identification information for the surgical instrument. The RF antenna is coupled to the RFID tag reader and arranged to transmit an RF signal. The RF signal has a signal field at least part of which extends within the interrogation zone. The RF antenna is arranged to receive RF return signals from at least some of the RFID tags, each RF return signal containing the identification information of the respective RFID tag. The guidance apparatus is arranged to cause a predetermined relative movement between the RFID tags on the surgical instruments and the RF signal. The controller is arranged to perform step a. of receiving the surgical instrument identification information from the RFID tag reader for each RFID tag from which an RF return signal is received. The controller is arranged to perform step b. of comparing the received surgical instrument identification information with a surgical instrument list of the surgical instrument set. And the controller is arranged to perform step c. of determining whether surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list, and if not, generate an incomplete list alert. The guidance apparatus is arranged to perform rotation and the controller is further arranged to, in response to an incomplete list alert perform step d. of transmitting a control signal to the guidance apparatus comprising instructions arranged to cause a predetermined rotational relative movement between the RFID tags on the surgical instruments and the RF signal. The predetermined rotational relative movement is different to said predetermined relative movement. The controller is further arranged then to repeat steps a. to c., wherein the repeated step b. performs a cumulative comparison of the received surgical instrument identification information with the surgical instrument list.

[0011] The surgical instrument RFID tag reading apparatus may enable the RFID tags on the surgical instruments in a set to be read whilst retaining the surgical instruments together. The apparatus may enable the surgical instruments in a set to be checked against an instrument list for the set without any manual handling of the instruments. The surgical instrument RFID tag reading apparatus may enable the RFID tags on the surgical instruments in a set to be read in a single process. Because the controller compares surgical instrument identification information received from the RFID tags on the surgical instruments with the instrument list the apparatus may not generate a false positive identification of the presence of a surgical instrument. The apparatus may therefore perform a more accurate check of the surgical instruments in a set than is possible when performing a manual check in which surgical

instruments are visually identified and manually checked off a manual list. The apparatus may avoid incorrect identification of a surgical instrument and may avoid the wrong instrument being checked off the instrument list.

[0012] By performing a different predetermined relative movement between the RFID tags and the RF signal the apparatus may receive RF return signals from the RFID tags on instruments for which no return RF signal was received during the initial predetermined relative movement. Performing two different predetermined relative movements between the RF signal and the RFID tags may increase the likelihood of the apparatus reading the RFID tags on all of the surgical instruments in the set. Performing a cumulative comparison when repeating step b. may ensure that only those surgical instruments for which identification information has not previously been received are considered. The apparatus is able to check instruments off the instrument list cumulatively so that it is not necessary to receive identification information for each surgical instrument in the set during one predetermined relative movement.

[0013] In an embodiment, the controller is further arranged to, after repeating step c., generate a fail alert if surgical instrument identification information has still not been cumulatively received for all of the surgical instruments on the surgical instrument list.

[0014] In an embodiment, the apparatus further comprises a fail inspection zone and the guidance apparatus is arranged to deliver the surgical instrument set into the fail inspection zone in response to a said fail alert. This may ensure that instrument sets having one or more instruments missing from the instrument list, which may be due to the instrument's RFID tag not being read or the instrument being missing, are set to one side where a manual inspection for the missing instrument or instruments can be carried out.

[0015] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set through the RF signal along a predetermined path. The predetermined relative movement between the RF signal and the surgical instrument set, into, through and out of the RF signal, is thereby performed along a predetermined path.

[0016] In an embodiment, the guidance apparatus comprises one of a guide rail and conveyor apparatus. The guide rail and the conveyor apparatus are each arranged to guide movement of the surgical instrument set through the RF signal along the predetermined path.

[0017] In an embodiment, the predetermined relative movement comprises movement along the predetermined path in a first direction and the further predetermined relative movement comprises movement along the predetermined path in a second direction, opposite to the first direction.

[0018] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set along the predetermined linear path at one of a plurality of predetermined speeds. This may enable the apparatus to use a different speed for the relative movement and for the further relative movement. This may also enable the apparatus to use a

different speed for different instrument sets, which may for example enable a lower speed to be used for instrument sets comprising a large number of surgical instruments. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0019] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set along the predetermined path at a speed which varies along said path. The speed varies according to a predetermined speed profile. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0020] In an embodiment, the speed varies according to one of a plurality of predetermined speed profiles. This may enable the speed profile to be selected according to the instrument set, which may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0021] In an embodiment, the guidance apparatus is arranged to at least one of rotate, tilt and shake the surgical instrument set. A predetermined rotational or tilting relative movement may therefore be caused between the RF signal and the surgical instrument set. Shaking the surgical instrument set may cause the position of at least some of the surgical instruments to change. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0022] In an embodiment, the guidance apparatus comprises an interrogation platform arranged to receive the surgical instrument set. The interrogation platform is movably mounted and arranged to cause at least one of rotation, tilting and shaking of the surgical instrument set.

[0023] In an embodiment, the guidance apparatus is arranged to cause the relative movement between the RFID tags on the surgical instruments and the RF signal by guiding movement of the surgical instrument set through the RF signal along a first predetermined path in a first direction. The guidance apparatus is arranged to cause the further relative movement between the RFID tags on the surgical instruments and the RF signal by one of: guiding movement of the surgical instrument set through the RF signal along the first predetermined path in a second direction, different to the first direction; guiding movement of the surgical instrument set through the RF signal along a second predetermined path different to the first predetermined path; rotating the surgical instrument set; and tilting the surgical instrument set.

[0024] In an embodiment, the guidance apparatus is arranged to shake the surgical instrument set prior to the further relative movement.

[0025] In an embodiment, the surgical instrument set comprises an instrument carrier configured to carry the surgical instruments. The interrogation zone is arranged to receive the instrument carrier carrying the surgical instruments and the guidance apparatus is arranged to receive the instrument carrier carrying the surgical instruments and is arranged to cause said

predetermined relative movement between the instrument carrier, and thus the surgical instruments, and the RF signal.

[0026] In an embodiment, the instrument carrier is one of a metal tray and a plastic tray.

[0027] In an embodiment, the instrument carrier comprises a base which reflects RF signals and an instrument platform which is at least partially transparent to RF signals. The instrument platform is mounted within the instrument carrier raised above the base. RF signals from the RF antenna may therefore be reflected from the base back towards the surgical instruments and RF return signals transmitted towards the base may be reflected back towards the RF antenna. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0028] In an embodiment, the guidance apparatus comprises weighing apparatus. The controller is further arranged to receive a weight of the surgical instrument set from the weighing apparatus. The controller is arranged to compare the weight with a reference weight associated with the surgical instrument list. The controller is arranged to determine whether the received weight is substantially equal to the reference weight, and if not, generate an incomplete list alert. Comparing the received weight with the reference weight may provide a supplementary check of whether all of the surgical instruments on the instrument list are present.

[0029] In an embodiment, the guidance apparatus comprises an antenna carrier on which the RF antenna is mounted. The antenna carrier is movably mounted and arranged to undergo at least one of a predetermined linear movement, rotation and tilting such that at least one of a predetermined linear, rotational and tilting relative movement is caused between the RF signal and the surgical instrument set. A predetermined relative movement between the RF signal and the surgical instruments may therefore be achieved without movement of the surgical instruments. This may enable the apparatus to have a compact form. The apparatus may also perform movement of the RF signal in addition to movement of the surgical instruments, which may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0030] In an embodiment, the apparatus comprises a second RF antenna coupled to an RFID tag reader. The RF antennas are arranged in a spaced relationship generally opposing each other such that the interrogation zone is located generally between the RF antennas. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0031] In an embodiment, each RF antenna is coupled to the RFID tag reader. In an embodiment, each RF antenna is coupled to a respective RFID tag reader and the controller is arranged to receive surgical instrument identification information from each RFID tag reader.

[0032] A second aspect of the disclosure provides a surgical instrument RFID tag reading

system comprising surgical instrument RFID tag reading apparatus and an instrument carrier. The instrument carrier comprises a base and an instrument platform. The base is reflective to RF signals. The instrument platform is at least partially transparent to RF signals and the instrument platform is mounted within the instrument carrier raised above the base. The RFID, tag reading apparatus comprises an interrogation zone, an RFID tag reader, a radio frequency, RF, antenna, guidance apparatus and a controller. The interrogation zone is arranged to receive a surgical instrument set comprising a plurality of surgical instruments. Each surgical instrument comprises a respective RFID tag containing identification information for the surgical instrument. The RF antenna is coupled to the RFID tag reader and arranged to transmit an RF signal. The RF signal has a signal field at least part of which extends within the interrogation zone. The RF antenna is arranged to receive RF return signals from at least some of the RFID tags, each return RF signal containing the identification information of the respective RFID tag. The guidance apparatus is arranged to cause relative movement between the RFID tags on the surgical instruments and the RF signal. The controller is arranged to perform step a. of receiving the surgical instrument identification information from the RFID tag reader for each RFID tag from which an RF return signal is received. The controller is arranged to perform step b. of comparing the received surgical instrument identification information with a surgical instrument list of the surgical instrument set. And the controller is arranged to perform step c. of determining whether surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list, and if not, generate an incomplete list alert. The guidance apparatus is arranged to perform rotation and the controller is further arranged to, in response to an incomplete list alert perform step d. of transmitting a control signal to the guidance apparatus comprising instructions arranged to cause a predetermined rotational relative movement between the RFID tags on the surgical instruments and the RF signal. The predetermined rotational relative movement is different to said predetermined relative movement. The controller is further arranged then to repeat steps a. to c., wherein the repeated step b. performs a cumulative comparison of the received surgical instrument identification information with the surgical instrument list.

[0033] The surgical instrument RFID tag reading system may enable the RFID tags on the surgical instruments in a set to be read whilst retaining the surgical instruments together. The raised instrument platform may enable RF signals from the RF antenna to be reflected from the base back towards the surgical instruments and RF return signals transmitted towards the base may be reflected back towards the RF antenna. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0034] The system may enable the surgical instruments in a set to be checked against an instrument list for the set without any manual handling of the instruments. The surgical instrument RFID tag reading system may enable the RFID tags on the surgical instruments in a set to be read in a single process. Because the controller compares surgical instrument identification information received from the RFID tags on the surgical instruments with the instrument list the apparatus may not generate a false positive identification of the presence of a surgical instrument. The system may therefore perform a more accurate check of the

surgical instruments in a set than is possible when performing a manual check in which surgical instruments are visually identified and manually checked off a manual list. The system may avoid incorrect identification of a surgical instrument and may avoid the wrong instrument being checked off the instrument list.

[0035] By performing a different predetermined relative movement between the RFID tags and the RF signal the apparatus may receive RF return signals from the RFID tags on instruments for which no return RF signal was received during the initial predetermined relative movement. Performing two different predetermined relative movements between the RF signal and the RFID tags may increase the likelihood of the apparatus reading the RFID tags on all of the surgical instruments in the set. Performing a cumulative comparison when repeating step b. may ensure that only those surgical instruments for which identification information has not previously been received are considered. The apparatus is able to check instruments off the instrument list cumulatively so that it is not necessary to receive identification information for each surgical instrument in the set during one predetermined relative movement.

[0036] In an embodiment, the controller is further arranged to, after repeating step c., generate a fail alert if surgical instrument identification information has still not been cumulatively received for all of the surgical instruments on the surgical instrument list.

[0037] In an embodiment, the apparatus further comprises a fail inspection zone and the guidance apparatus is arranged to deliver the surgical instrument set into the fail inspection zone in response to a said fail alert. This may ensure that instrument sets having one or more instruments missing from the instrument list, which may be due to the instrument's RFID tag not being read or the instrument being missing, are set to one side where a manual inspection for the missing instrument or instruments can be carried out.

[0038] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set through the RF signal along a predetermined path. The predetermined relative movement between the RF signal and the surgical instrument set, into, through and out of the RF signal, is thereby performed along a predetermined path.

[0039] In an embodiment, the guidance apparatus comprises one of a guide rail and conveyor apparatus. The guide rail and the conveyor apparatus are each arranged to guide movement of the surgical instrument set through the RF signal along the predetermined path.

[0040] In an embodiment, the predetermined relative movement comprises movement along the predetermined path in a first direction and the further predetermined relative movement comprises movement along the predetermined path in a second direction, opposite to the first direction.

[0041] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set along the predetermined linear path at one of a plurality of predetermined speeds. This may enable the apparatus to use a different speed for the relative

movement and for the further relative movement. This may also enable the apparatus to use a different speed for different instrument sets, which may for example enable a lower speed to be used for instrument sets comprising a large number of surgical instruments. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0042] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set along the predetermined path at a speed which varies along said path. The speed varies according to a predetermined speed profile. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0043] In an embodiment, the speed varies according to one of a plurality of predetermined speed profiles. This may enable the speed profile to be selected according to the instrument set, which may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0044] In an embodiment, the guidance apparatus is arranged to at least one of rotate, tilt and shake the surgical instrument set. A predetermined rotational or tilting relative movement may therefore be caused between the RF signal and the surgical instrument set. Shaking the surgical instrument set may cause the position of at least some of the surgical instruments to change. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0045] In an embodiment, the guidance apparatus comprises an interrogation platform arranged to receive the surgical instrument set. The interrogation platform is movably mounted and arranged to cause at least one of rotation, tilting and shaking of the surgical instrument set.

[0046] In an embodiment, the guidance apparatus is arranged to cause the relative movement between the RFID tags on the surgical instruments and the RF signal by guiding movement of the surgical instrument set through the RF signal along a first predetermined path in a first direction. The guidance apparatus is arranged to cause the further relative movement between the RFID tags on the surgical instruments and the RF signal by one of: guiding movement of the surgical instrument set through the RF signal along the first predetermined path in a second direction, different to the first direction; guiding movement of the surgical instrument set through the RF signal along a second predetermined path different to the first predetermined path; rotating the surgical instrument set; and tilting the surgical instrument set.

[0047] In an embodiment, the guidance apparatus is arranged to shake the surgical instrument set prior to the further relative movement.

[0048] In an embodiment, the surgical instrument set comprises an instrument carrier configured to carry the surgical instruments. The interrogation zone is arranged to receive the instrument carrier carrying the surgical instruments and the guidance apparatus is arranged to

receive the instrument carrier carrying the surgical instruments and is arranged to cause said predetermined relative movement between the instrument carrier, and thus the surgical instruments, and the RF signal.

[0049] In an embodiment, the instrument carrier is one of a metal tray and a plastic tray.

[0050] In an embodiment, the instrument carrier comprises a base which reflects RF signals and an instrument platform which is at least partially transparent to RF signals. The instrument platform is mounted within the instrument carrier raised above the base. RF signals from the RF antenna may therefore be reflected from the base back towards the surgical instruments and RF return signals transmitted towards the base may be reflected back towards the RF antenna. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0051] In an embodiment, the guidance apparatus comprises weighing apparatus. The controller is further arranged to receive a weight of the surgical instrument set from the weighing apparatus. The controller is arranged to compare the weight with a reference weight associated with the surgical instrument list. The controller is arranged to determine whether the received weight is substantially equal to the reference weight, and if not, generate an incomplete list alert. Comparing the received weight with the reference weight may provide a supplementary check of whether all of the surgical instruments on the instrument list are present.

[0052] In an embodiment, the guidance apparatus comprises an antenna carrier on which the RF antenna is mounted. The antenna carrier is movably mounted and arranged to undergo at least one of a predetermined linear movement, rotation and tilting such that at least one of a predetermined linear, rotational and tilting relative movement is caused between the RF signal and the surgical instrument set. A predetermined relative movement between the RF signal and the surgical instruments may therefore be achieved without movement of the surgical instruments. This may enable the apparatus to have a compact form. The apparatus may also perform movement of the RF signal in addition to movement of the surgical instruments, which may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0053] In an embodiment, the apparatus comprises a second RF antenna coupled to an RFID tag reader. The RF antennas are arranged in a spaced relationship generally opposing each other such that the interrogation zone is located generally between the RF antennas. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0054] In an embodiment, each RF antenna is coupled to the RFID tag reader. In an embodiment, each RF antenna is coupled to a respective RFID tag reader and the controller is arranged to receive surgical instrument identification information from each RFID tag reader.

[0055] A third aspect of the disclosure provides a surgical instrument tracking system comprising a surgical instrument set and a plurality of surgical instrument RFID tag reading apparatus. The surgical instrument set comprises a plurality of surgical instruments each comprising a respective RFID tag containing identification information for the surgical instrument. Each surgical instrument RFID tag reading apparatus is arranged to receive the surgical instrument set. Each surgical instrument RFID reading apparatus comprises an interrogation zone, an RFID tag reader, a radio frequency, RF, antenna, guidance apparatus and a controller. The interrogation zone is arranged to receive the surgical instrument set. The RF antenna is coupled to the RFID tag reader and arranged to transmit an RF signal. The RF signal has a signal field at least part of which extends within the interrogation zone. The RF antenna is arranged to receive RF return signals from at least some of the RFID tags, each RF return signal containing the identification information of the respective RFID tag. The guidance apparatus is arranged to cause a predetermined relative movement between the RFID tags on the surgical instruments and the RF signal. The controller is arranged to perform step a. of receiving the surgical instrument identification information from the RFID tag reader for each RFID tag from which an RF return signal is received. The controller is arranged to perform step b. of comparing the received surgical instrument identification information with a surgical instrument list of the surgical instrument set. And the controller is arranged to perform step c. of determining whether surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list, and if not, generate an incomplete list alert. The controller is further arranged to, in response to an incomplete list alert perform step d. of transmitting a control signal to the guidance apparatus comprising instructions arranged to cause a further predetermined relative movement between the RFID tags on the surgical instruments and the RF signal. The further predetermined relative movement is different to said predetermined relative movement. The controller is further arranged then to repeat steps a. to c., wherein the repeated step b. performs a cumulative comparison of the received surgical instrument identification information with the surgical instrument list.

[0056] The surgical instrument tracking system may enable the RFID tags on the surgical instruments in a set to be read at a plurality of locations, whilst retaining the surgical instruments together. The system may enable the surgical instruments in a set to be checked at each location against an instrument list for the set without any manual handling of the instruments. The surgical instrument RFID tag reading apparatus may enable the RFID tags on the surgical instruments in a set to be read in a single process at each location. Because the controller compares surgical instrument identification information received from the RFID tags on the surgical instruments with the instrument list the system may not generate a false positive identification of the presence of a surgical instrument. The system may therefore perform more accurate checking and tracking of the surgical instruments in a set than is possible when performing manual checks in which surgical instruments are visually identified and manually checked off a manual list at each location. The surgical instrument RFID tag reading apparatus may avoid incorrect identification of a surgical instrument and may avoid the wrong instrument being checked off the instrument list.

[0057] By performing a different predetermined relative movement between the RFID tags and the RF signal the apparatus may receive RF return signals from the RFID tags on instruments for which no return RF signal was received during the initial predetermined relative movement. Performing two different predetermined relative movements between the RF signal and the RFID tags may increase the likelihood of the apparatus reading the RFID tags on all of the surgical instruments in the set. Performing a cumulative comparison when repeating step b. may ensure that only those surgical instruments for which identification information has not previously been received are considered. The apparatus is able to check instruments off the instrument list cumulatively so that it is not necessary to receive identification information for each surgical instrument in the set during one predetermined relative movement.

[0058] In an embodiment, the controller is further arranged to, after repeating step c., generate a fail alert if surgical instrument identification information has still not been cumulatively received for all of the surgical instruments on the surgical instrument list.

[0059] In an embodiment, the apparatus further comprises a fail inspection zone and the guidance apparatus is arranged to deliver the surgical instrument set into the fail inspection zone in response to a said fail alert. This may ensure that instrument sets having one or more instruments missing from the instrument list, which may be due to the instrument's RFID tag not being read or the instrument being missing, are set to one side where a manual inspection for the missing instrument or instruments can be carried out.

[0060] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set through the RF signal along a predetermined path. The predetermined relative movement between the RF signal and the surgical instrument set, into, through and out of the RF signal, is thereby performed along a predetermined path.

[0061] In an embodiment, the guidance apparatus comprises one of a guide rail and conveyor apparatus. The guide rail and the conveyor apparatus are each arranged to guide movement of the surgical instrument set through the RF signal along the predetermined path.

[0062] In an embodiment, the predetermined relative movement comprises movement along the predetermined path in a first direction and the further predetermined relative movement comprises movement along the predetermined path in a second direction, opposite to the first direction.

[0063] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set along the predetermined linear path at one of a plurality of predetermined speeds. This may enable the apparatus to use a different speed for the relative movement and for the further relative movement. This may also enable the apparatus to use a different speed for different instrument sets, which may for example enable a lower speed to be used for instrument sets comprising a large number of surgical instruments. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0064] In an embodiment, the guidance apparatus is arranged to guide movement of the surgical instrument set along the predetermined path at a speed which varies along said path. The speed varies according to a predetermined speed profile. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0065] In an embodiment, the speed varies according to one of a plurality of predetermined speed profiles. This may enable the speed profile to be selected according to the instrument set, which may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0066] In an embodiment, the guidance apparatus is arranged to at least one of rotate, tilt and shake the surgical instrument set. A predetermined rotational or tilting relative movement may therefore be caused between the RF signal and the surgical instrument set. Shaking the surgical instrument set may cause the position of at least some of the surgical instruments to change. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0067] In an embodiment, the guidance apparatus comprises an interrogation platform arranged to receive the surgical instrument set. The interrogation platform is movably mounted and arranged to cause at least one of rotation, tilting and shaking of the surgical instrument set.

[0068] In an embodiment, the guidance apparatus is arranged to cause the relative movement between the RFID tags on the surgical instruments and the RF signal by guiding movement of the surgical instrument set through the RF signal along a first predetermined path in a first direction. The guidance apparatus is arranged to cause the further relative movement between the RFID tags on the surgical instruments and the RF signal by one of: guiding movement of the surgical instrument set through the RF signal along the first predetermined path in a second direction, different to the first direction; guiding movement of the surgical instrument set through the RF signal along a second predetermined path different to the first predetermined path; rotating the surgical instrument set; and tilting the surgical instrument set.

[0069] In an embodiment, the guidance apparatus is arranged to shake the surgical instrument set prior to the further relative movement.

[0070] In an embodiment, the surgical instrument set comprises an instrument carrier configured to carry the surgical instruments. The interrogation zone is arranged to receive the instrument carrier carrying the surgical instruments and the guidance apparatus is arranged to receive the instrument carrier carrying the surgical instruments and is arranged to cause said predetermined relative movement between the instrument carrier, and thus the surgical instruments, and the RF signal.

[0071] In an embodiment, the instrument carrier is one of a metal tray and a plastic tray.

[0072] In an embodiment, the instrument carrier comprises a base which reflects RF signals and an instrument platform which is at least partially transparent to RF signals. The instrument platform is mounted within the instrument carrier raised above the base. RF signals from the RF antenna may therefore be reflected from the base back towards the surgical instruments and RF return signals transmitted towards the base may be reflected back towards the RF antenna. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0073] In an embodiment, the guidance apparatus comprises weighing apparatus. The controller is further arranged to receive a weight of the surgical instrument set from the weighing apparatus. The controller is arranged to compare the weight with a reference weight associated with the surgical instrument list. The controller is arranged to determine whether the received weight is substantially equal to the reference weight, and if not, generate an incomplete list alert. Comparing the received weight with the reference weight may provide a supplementary check of whether all of the surgical instruments on the instrument list are present.

[0074] In an embodiment, the guidance apparatus comprises an antenna carrier on which the RF antenna is mounted. The antenna carrier is movably mounted and arranged to undergo at least one of linear movement, rotation and tilting such that at least one of a predetermined linear, rotational and tilting relative movement is caused between the RF signal and the surgical instrument set. A predetermined relative movement between the RF signal and the surgical instruments may therefore be achieved without movement of the surgical instruments. This may enable the apparatus to have a compact form. The apparatus may also perform movement of the RF signal in addition to movement of the surgical instruments, which may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0075] In an embodiment, the apparatus comprises a second RF antenna coupled to an RFID tag reader. The RF antennas are arranged in a spaced relationship generally opposing each other such that the interrogation zone is located generally between the RF antennas. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0076] In an embodiment, each RF antenna is coupled to the RFID tag reader. In an embodiment, each RF antenna is coupled to a respective RFID tag reader and the controller is arranged to receive surgical instrument identification information from each RFID tag reader.

[0077] A fourth aspect of the disclosure provides a method of reading RFID tags on a plurality of surgical instruments of a surgical instrument set. Each RFID tag contains identification information for the respective surgical instrument. The method comprises step a. of transmitting an RF signal having a signal field. The method comprises step b. of locating the RFID tags within the RF signal field. The method comprises step c. of causing a predetermined relative movement between the RF signal and the RFID tags. The method comprises step d. of

receiving a RF return signal from at least some of the RFID tags. Each RF return signal contains the identification information of the respective RFID tag. The method comprises step e. of obtaining the surgical instrument identification information from each RF return signal. The method comprises step f. of comparing the received surgical instrument identification information with a surgical instrument list of the surgical instrument set. The method comprises step g. of determining whether surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list. If surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list, an incomplete list alert is generated. The method further comprises, in response to an incomplete list alert, step h. of causing a further predetermined relative movement between the RF signal and the RFID tags. The predetermined further relative movement is different to said predetermined relative movement. The method then repeats steps a. to g. By performing a different predetermined relative movement between the RFID tags and the RF signal, RF return signals may be received from the RFID tags on instruments for which no return RF signal was received during the initial relative movement.

[0078] The method may enable the RFID tags on the surgical instruments in a set to be read whilst retaining the surgical instruments together. The method may enable the surgical instruments in a set to be checked against an instrument list for the set without any manual handling of the instruments. The method may enable the RFID tags on the surgical instruments in a set to be read in a single process. Because the method compares surgical instrument identification information received from the RFID tags on the surgical instruments with the instrument list the method may not generate a false positive identification of the presence of a surgical instrument. The method may therefore perform a more accurate check of the surgical instruments in a set than is possible when performing a manual check in which surgical instruments are visually identified and manually checked off a manual list. The method may avoid incorrect identification of a surgical instrument and may avoid the wrong instrument being checked off the instrument list.

[0079] Performing two different predetermined relative movements between the RF signal and the RFID tags may increase the likelihood of reading the RFID tags on all of the surgical instruments in the set. Performing a cumulative comparison when repeating step f. may ensure that only those surgical instruments for which identification information has not previously been received are considered. The method is able to check instruments off the instrument list cumulatively so that it is not necessary to receive identification information for each surgical instrument in the set during one relative movement.

[0080] In an embodiment, the method further comprises, after repeating step g., generating a fail alert if surgical instrument identification information has still not been cumulatively received for all of the surgical instruments on the surgical instrument list.

[0081] In an embodiment, the method further comprises delivering the surgical instrument set into a fail inspection zone in response to a said fail alert. This may ensure that instrument sets having one or more instruments missing from the instrument list, which may be due to the

instrument's RFID tag not being read or the instrument being missing, are set to one side where a manual inspection for the missing instrument or instruments can be carried out.

[0082] In an embodiment, the predetermined relative movement comprises movement along a predetermined path.

[0083] In an embodiment, the predetermined relative movement comprises movement along the predetermined path at a speed which varies along said path, and wherein the speed is varied along said path according to a predetermined speed profile. This may enable a different speed profile to be used for the relative movement and for the further relative movement. This may also enable different speeds to be used for different instrument sets, which may for example enable a lower speed to be used for instrument sets comprising a large number of surgical instruments. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0084] In an embodiment, in step h. the further relative movement is one of movement in a second direction, different to the first direction, rotation by a second angle different to the first angle, tilting in a second plane different to the first plane, tilting by a second angle different to the first angle, or a different one of linear movement in a first direction, rotation by a first angle, and tilting in a first plane and by a first angle. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0085] In an embodiment, step h. additionally comprises shaking the surgical instrument set prior to the further relative movement such that the position of at least some of the surgical instruments is changed. This may increase the likelihood of receiving a return RF signal for all of the surgical instruments in the instrument set.

[0086] In an embodiment, the surgical instrument set comprises an instrument carrier configured to carry the surgical instruments. Step c. comprises causing relative movement between the RF signal and the instrument carrier, and thus the RFID tags.

[0087] In an embodiment, the relative movement between the RF signal and the RFID tags comprises movement of the surgical instruments through the RF signal.

[0088] In an embodiment, the further relative movement between the RF signal and the RFID tags comprises movement of the surgical instruments through the RF signal.

[0089] In an embodiment, the relative movement between the RF signal and the RFID tags comprises movement of the RF signal across the surgical instruments.

[0090] In an embodiment, the further relative movement between the RF signal and the RFID tags comprises movement of the RF signal across the surgical instruments.

[0091] A fifth aspect of the disclosure provides a computer program comprising instructions

which, when executed on at least one processor, cause the at least one processor to perform any of the steps of the above method of reading RFID tags on a plurality of surgical instruments of a surgical instrument set.

[0092] A sixth aspect of the disclosure provides a carrier containing the computer program, wherein the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

[0093] Embodiments of the disclosure will now be described, by way of example only, with reference to the accompanying drawings.

Brief Description of the drawings

[0094]

Figure 1 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a first embodiment;

Figure 2 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a second embodiment;

Figure 3 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a fourth embodiment;

Figure 4 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a sixth embodiment;

Figure 5 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a embodiment;

Figure 6 is a diagrammatic side view of surgical instrument RFID tag reading apparatus according to an eleventh embodiment;

Figure 7 is a diagrammatic end view of the surgical instrument RFID tag reading apparatus of Figure 6;

Figure 8 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a twelfth embodiment;

Figure 9 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a thirteenth embodiment;

Figure 10 is a diagrammatic representation of surgical instrument RFID tag reading apparatus according to a fourteenth embodiment;

Figure 11 is a diagrammatic representation of a surgical instrument tracking system according

to a fifteenth embodiment;

Figure 12 is a diagrammatic representation of a surgical instrument tracking system according to a sixteenth embodiment;

Figure 13 shows the steps of a method according to a seventeenth embodiment of reading RFID tags on a plurality of surgical instruments of a surgical instrument set;

Figure 14 shows the steps of a method according to a nineteenth embodiment of reading RFID tags on a plurality of surgical instruments of a surgical instrument set;

Figure 15 shows the steps of a method according to a twentieth embodiment of reading RFID tags on a plurality of surgical instruments of a surgical instrument set;

Figure 16 shows the steps of a method according to a twenty-first embodiment of reading RFID tags on a plurality of surgical instruments of a surgical instrument set;

Figure 17 shows the steps of a method according to a twenty-second embodiment of reading RFID tags on a plurality of surgical instruments of a surgical instrument set;

Figure 18 shows the steps of a method according to a twenty-third embodiment of reading RFID tags on a plurality of surgical instruments of a surgical instrument set;

Figure 19 is a diagrammatic representation of a surgical instrument RFID tag reading system according to a twenty-fourth embodiment; and

Figure 20 is a part cut-away view of the instrument tray of Figure 19.

Detailed description

[0095] Referring to Figure 1, a first embodiment provides surgical instrument radio frequency identification, RFID, tag reading apparatus 10. The apparatus 10 comprises an interrogation zone 12, an RFID tag reader 14, a radio frequency, RF, antenna 18, guidance apparatus 22 and a controller 24.

[0096] The interrogation zone 12 is arranged to receive a surgical instrument set 14 (shown for clarity in Figure 1 but not forming part of this embodiment). The surgical instrument set comprises a plurality of surgical instruments, each of which has a respective RFID tag provided on it. Each RFID tag contains identification information for its surgical instrument.

[0097] The RF antenna 18 is coupled to the RFID tag reader 16. The RF antenna 18 is arranged to transmit an RF signal 20 having a signal field at least part of which extends within the interrogation zone. The RF signal field is also arranged to receive RF return signals from the RFID tags on the surgical instruments. Each RF return signal will contain the identification

information of the respective RFID tag. RFID tags, RF antennas and RFID tag readers will be well known to the skilled person, so their structure, signalling and operation will not be described in further detail here.

[0098] The guidance apparatus of this embodiment takes the form of a guide rail 22 which is arranged such that the surgical instrument set 14 can move along the guide rail, in the direction indicated by the arrow, along a predetermined path. The movement of the surgical instrument set along the guide rail causes predetermined relative movement between the RFID tags on the surgical instruments and the RF signal 20.

[0099] The controller 24 is arranged to receive the surgical instrument identification information from the RFID tag reader for each of the RFID tags from which an RF return signal has been received. The controller is arranged to compare the received surgical instrument identification information with a surgical instrument list of the surgical instrument set. The surgical instrument list specifies each surgical instrument which should be present within the surgical instrument set. The controller is arranged to determine whether surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list. If surgical instrument identification information has not been received for each of the surgical instruments on the surgical instrument list, the controller generates an incomplete list alert. Missing surgical instrument identification information for a surgical instrument on the instrument list indicates that an RFID tag has not been read for that surgical instrument. This may be because the RFID tag did not see the RF signal, the RF antenna did not see the return RF signal transmitted by the RFID tag, or the surgical instrument is missing from the set. The apparatus 10 may therefore generate a false negative due to signalling error but it cannot generate a false positive, since a return RF signal will not be received if a surgical instrument RFID tag is not present.

[0100] A second embodiment provides surgical instrument radio frequency identification, RFID, tag reading apparatus 30 as shown in Figure 2. The apparatus 30 of this embodiment is similar to the apparatus 10 of Figure 1, with the following modifications. The same reference number are retained for corresponding features.

[0101] In this embodiment, the guidance apparatus takes the form of a conveyor 32, which may be a belt conveyor or a roller conveyor. The conveyor 32 is arranged to transport the surgical instrument set 14 into and through the RF signal in the direction of the arrow, along a predetermined path. It will be appreciated however that the conveyor 32 could equally be arranged to transport the surgical instrument set in the opposite direction.

[0102] A third embodiment provides surgical instrument radio frequency identification, RFID, tag reading apparatus having the same general structure as the apparatus shown in Figure 2. In this embodiment, the conveyor is arranged to guide movement of the surgical instrument set along the predetermined path at a speed which varies along the path. The speed varies according to a preselected speed profile. The speed profile may be a linearly increasing or decreasing speed or may be a nonlinear profile, for example with the speed increasing or

decreasing along one or more sections of the path and remaining constant along one or more other sections.

[0103] Figure 3 shows surgical instrument radio frequency identification, RFID, tag reading apparatus 40 according to a fourth embodiment. The apparatus of this embodiment is similar to the apparatus 10 of Figure 1, with the following modifications. The same reference number are retained for corresponding features.

[0104] In this embodiment, the guidance apparatus comprises an interrogation platform 42 which is arranged to receive the surgical instrument set 14. The guidance apparatus is movably mounted and is arranged to rotate, as indicated by the arrow, to rotate the surgical instrument set within the RF signal 20. This causes a predetermined rotational relative movement between the RF signal and the RFID tags on the surgical instruments in the surgical instrument set.

[0105] A fifth embodiment provides surgical instrument radio frequency identification, RFID, tag reading apparatus having the same general structure as the apparatus 40 shown in Figure 3. In this embodiment, the guidance apparatus additionally comprises weighing apparatus, which in this embodiment is incorporated into the interrogation platform 42. The weighing apparatus is arranged to generate an instrument set weight signal containing the weight measured by the weighing apparatus.

[0106] The controller is arranged to receive the weight of the surgical instrument set from the weighing apparatus and to compare the weight with a reference weight associated with the surgical instrument list. The controller is arranged to determine whether the received weight is substantially equal to the reference weight, indicating that all of the surgical instruments on the instrument list are present. It will be appreciated that the reference weight will in practice be a weight range, to allow for differences in the actual weight of each surgical instrument, within a known manufacturing tolerance. If the received weight is not equal to the reference weight, within the weight range, this indicates that one or more surgical instruments are missing, and the controller is arranged to generate an incomplete list alert when this occurs.

[0107] Figure 4 shows surgical instrument radio frequency identification, RFID, tag reading apparatus 50 according to a sixth embodiment. The apparatus of this embodiment is similar to the apparatus 10 of Figure 1, with the following modifications. The same reference number are retained for corresponding features.

[0108] In this embodiment, the guidance apparatus comprises an interrogation platform 52 which is arranged to receive the surgical instrument set 14. The guidance apparatus is movably mounted and is arranged to tilt, as indicated by the arrow, to tilt the surgical instrument set within the RF signal 20. This causes tilting relative movement between the RF signal and the RFID tags on the surgical instruments in the surgical instrument set.

[0109] A seventh embodiment provides surgical instrument radio frequency identification,

RFID, tag reading apparatus 60 as shown in Figure 5. The apparatus 60 of this embodiment is similar to the apparatus 30 of Figure 2 and the apparatus 40 of Figure 3, with the following modifications. The same reference number are retained for corresponding features.

[0110] In this embodiment, the guidance apparatus comprises both conveyor apparatus 62 and an interrogation platform 42. The surgical instrument set additionally comprises an instrument carrier, this example a metal instrument tray 69, in which the surgical instruments are carried. The interrogation zone is arranged to receive the instrument tray carrying the surgical instruments. The conveyors 64a, 64b are arranged to transport the instrument tray, and thus the surgical instruments into and through the RF signal. It will be appreciated that a plastic instrument tray may alternatively be used, and the instrument tray will typically of the type known as an autoclavable instrument tray.

[0111] The conveyor 62 comprises two conveyor belts 64a, 64b, provided on opposing sides of the interrogation platform. The interrogation platform 62 is movably mounted and is arranged to rotate, as indicated by the arrow, to rotate the surgical instrument set 14, 69 within the RF signal 20. It will be appreciated that the interrogation platform 52, arranged to tilt the surgical instrument set within the RF signal, may alternatively be used, as may an interrogation platform configured for both rotational and tilting movement.

[0112] Each conveyor belt 64a, 64b is arranged to transport the surgical instrument tray 69 along a predetermined path in two opposing linear directions, so that the surgical instrument set may be moved into, through and out of the RF signal 20 in either direction.

[0113] The controller 66 of this embodiment is arranged to transmit a first control signal 68 to the guidance apparatus 42, 63 comprising instructions arranged to cause an initial predetermined relative movement between the RFID tags on the surgical instruments and the RF signal. The controller 66 is additionally arranged, in response to an incomplete list alert, after the initial relative movement has been completed, to generate a second control signal 68 to the guidance apparatus 42, 63 comprising instructions arranged to cause further predetermined relative movement between the RFID tags on the surgical instruments and the RF signal. The further relative movement is different to the initial relative movement.

[0114] For example, the first control signal may comprise instructions arranged to cause the conveyor apparatus 62 to transport the surgical instrument tray 69 into the interrogation zone 12 and to deliver the surgical instrument tray onto the interrogation platform 42. If an incomplete list alert is generated, a second control signal is transmitted comprising instructions to cause the interrogation platform to rotate, thereby rotating the surgical instrument tray. It will be appreciated that when the interrogation platform 52, arranged to tilt, is used or an interrogation platform configured to both rotate and tilt, the second control signal will comprise instructions arranged to cause the interrogation platform to rotate, tilt or rotate and tilt.

[0115] An initial substantially linear predetermined relative movement between the RFID tags on the surgical instruments and the RF signal is thereby followed by a rotational and/or tilting

predetermined relative movement between the RFID tags on the surgical instruments and the RF signal. The second control signal may, for example, cause the interrogation platform to rotate by 180° or 360° , or may cause the interrogation platform to rotate by $+\theta$ and then by $-\theta$, to return the interrogation platform to its starting position. θ may be any angle up to 180° , although it is most preferably any angle up to 45° .

[0116] Alternatively, the first control signal may comprise instructions arranged to cause the conveyor apparatus to transport the surgical instrument set at a first speed, or with a first speed profile, and the second control signal may comprise instructions arranged to cause the conveyor apparatus to reverse direction and transport the surgical instrument set back through the RF signal in the opposite direction. This may be done at a second speed, or with a second speed profile, different to the first.

[0117] The following combinations of speed, reversing movement and rotation may, for example, be implemented:

No. of passes through RF Signal	Speed	Rotation	Direction
1	Fast	nil	
1	Slow	nil	
1	Profile	nil	
2	1 fast 2nd Fast	nil	
2	1 Fast 2nd Slow	nil	
2	1 Fast 2nd Profile	nil	
2	1 Slow 2nd Slow	nil	
2	1 Profile 2nd Profile	nil	
1	Fast	180°	Clockwise
1	Slow	180°	Clockwise
1	Profile	180°	Clockwise
2	1 fast 2nd Fast	180°	Clockwise
2	1 Fast 2nd Slow	180°	Clockwise
2	1 Fast 2nd Profile	180°	Clockwise
2	1 Slow 2nd Slow	180°	Clockwise
2	1 Profile 2nd Profile	180°	Clockwise
1	Fast	180°	Anticlockwise
1	Slow	180°	Anticlockwise
1	Profile	180°	Anticlockwise

No. of passes through RF Signal	Speed	Rotation	Direction
2	1 fast 2nd Fast	180°	Anticlockwise
2	1 Fast 2nd Slow	180°	Anticlockwise
2	1 Fast 2nd Profile	180°	Anticlockwise
2	1 Slow 2nd Slow	180°	Anticlockwise
2	1 Profile 2nd Profile	180°	Anticlockwise

[0118] As a result of the further predetermined relative movement, the controller again receives surgical instrument identification information. The controller is arranged to compare this surgical instrument identification information with the surgical instrument list and determine whether surgical instrument identification information has now been received for each of the surgical instruments on the surgical instrument list. The comparison is a cumulative comparison of the received surgical instrument identification information with the surgical instrument list. Performing a cumulative comparison when repeating the comparison means that only those surgical instruments for which identification information has not previously been received are considered the second time round. Because the instruments are checked off the instrument list cumulatively it is not necessary to receive identification information for each surgical instrument in the set during either relative movement alone.

[0119] If surgical instrument identification information has still not been received for each of the surgical instruments on the surgical instrument list, the controller generates a fail alert.

[0120] In an eighth embodiment, again described with reference to Figure 5, the controller is additionally arranged to generate a third control signal 68 comprising instructions to cause the conveyor apparatus 62 to move the surgical instrument tray 69 out of the RF signal, which may be done at a third speed or with a third speed profile. The apparatus 60 of this embodiment is therefore able to process a plurality of surgical instrument sets 14 in series, the surgical instrument trays 69 moving through the apparatus on the conveyor belts 64, one after another.

[0121] In a ninth embodiment, again described with reference to Figure 5, the second control signal 68 additionally comprises instructions to cause the conveyor apparatus 62 to move the surgical instrument tray 69 rapidly back and forth, thereby shaking the surgical instrument set. This causes the position of at least some of the surgical instruments to change within the tray prior to the further predetermined relative movement being performed.

[0122] In a tenth embodiment, again described with reference to Figure 5, the conveyors 64a, 64b are arranged to transport the surgical instrument set at a speed which varies along the path of the conveyors. The speed varies according to a preselected speed profile. The speed profile may be a linearly increasing or decreasing speed or may be a nonlinear profile, for

example with the speed increasing or decreasing along one or more sections of the path and remaining constant along one or more other sections.

[0123] Figures 6 and 7 show surgical instrument radio frequency identification, RFID, tag reading apparatus 70 according to an eleventh embodiment. The apparatus of this embodiment is similar to the apparatus 60 of Figure 5, with the following modifications. The same reference number are retained for corresponding features.

[0124] In this embodiment, the apparatus 70 comprises four RF antennas 18a, 18b, 18c, 18d arranged as two opposing pairs 18a, 18c and 18b, 18d above the interrogation platform 42. Each of the antennas is coupled to the RFID tag reader 16. It will be appreciated that each antenna may alternatively be coupled to a respective RFID tag reader, and the controller 66 is arranged to receive surgical instrument identification information from each RFID tag reader.

[0125] The surgical instrument set 74 comprises a plurality of surgical instruments provided within an instrument tray, as described above. The surgical instrument tray is loaded onto the interrogation platform in the direction indicated by the arrow, thereby causing substantially linear relative movement between the RFID tags on the surgical instruments and the RF signal.

[0126] Figure 8 shows surgical instrument radio frequency identification, RFID, tag reading apparatus 80 according to a twelfth embodiment. The apparatus of this embodiment is similar to the apparatus 70 of Figures 6 and 7, with the following modifications. The same reference number are retained for corresponding features.

[0127] In this embodiment, the interrogation platform 82 is movably mounted and is arranged to rotate, tilt and shake, as indicated by the arrows, to rotate and tilt the surgical instrument set 74 within the RF signal 20, and the shake the surgical instruments within the tray.

[0128] A thirteenth embodiment provides surgical instrument radio frequency identification, RFID, tag reading apparatus 90 as shown in Figure 9. The apparatus 90 of this embodiment is similar to the apparatus 10 of Figure 1, with the following modifications. The same reference number are retained for corresponding features.

[0129] In this embodiment, the guidance apparatus comprises an antenna carrier 92 on which the RF antenna 18 is mounted. The antenna carrier is movably mounted and is arranged for linear movement, rotation and tilting. The controller 94 is arranged to generate a control signal 98 comprising instructions to cause the antenna carrier 92 to undergo at least one of a predetermined linear movement, a predetermined rotation, and a predetermined tilting movement. The RF signal can therefore be moved linearly relative to the surgical instrument set, may be rotated about the instrument set or may be tilted about the instrument set 14, or any combination of these, to cause a predetermined relative movement between the RF signal and the surgical instrument RFID tags.

[0130] A fourteenth embodiment provides surgical instrument radio frequency identification,

RFID, tag reading apparatus 100 as shown in Figure 10. The apparatus 100 of this embodiment is similar to the apparatus 30 of Figure 2, with the following modifications. The same reference number are retained for corresponding features.

[0131] In this embodiment, a second RF antenna 102 is provided, generally opposite the RF antenna 18 and underneath the conveyor apparatus 32, such that the interrogation zone is located generally between the RF antennas. The second antenna is coupled to the RFID tag reader 16 and its RF signal 104 extends into the interrogation zone and partially overlaps with the RF signal 20 of the RF antenna 18.

[0132] Referring to Figure 11, a fifteenth embodiment provides a surgical instrument tracking system 200. The system 200 comprises a surgical instrument set, IS, 202 and a plurality, two in this example, of surgical instrument RFID tag reading apparatus 10, as described above with reference to Figure 1. It will be appreciated that any of the above described surgical instrument RFID tag reading apparatus 30, 40, 50, 60, 70, 80, 90, 100 described with reference to Figures 2 to 10 may alternatively be used.

[0133] The instrument set 202 comprises a plurality of surgical instruments each comprising a respective RFID tag containing identification information for the surgical instrument.

[0134] Each surgical instrument RFID tag reading apparatus is arranged to receive the surgical instrument set at a respective location.

[0135] For example, the system 200 may be used within an operating theatre of a hospital. The surgical instrument RFID tag reading apparatus 10 provided at location 1 may be used to check that the instrument set IS 202 is complete before an operation is commenced, and the apparatus at location 2 may be used to check that the instrument set IS 202 is complete once the operation is completed. The surgical instruments can therefore be tracked over the course of an operation, to ensure that all of the surgical instruments required to perform the operation are present before starting the operation and to ensure that all of the surgical instruments are accounted for after the operation.

[0136] Alternatively, the system 200 may be used within the CSSD of a hospital. The surgical instrument RFID tag reading apparatus 10 provided at location 1 may be used to inspect the instrument set IS 202 before commencing the autoclave sterilisation and decontamination, and the apparatus at location 2 may be used to check that the instrument set IS 202 is complete once sterilisation and decontamination is completed. The surgical instruments can therefore be tracked over the sterilisation and decontamination process, to ensure that all of the surgical instruments are accounted for and the instrument set is complete and ready for use.

[0137] A sixteenth embodiment provides a surgical instrument tracking system 210 as shown in Figure 12. The system 210 of this embodiment is similar to the system 200 of the previous embodiment, with the following modifications. The same reference numbers are retained for corresponding features.

[0138] In this embodiment, the system 210 comprises two surgical instrument RFID tag reading apparatus 10, as described above with reference to Figure 1, and two surgical instrument RFID tag reading apparatus 60, as described above with reference to Figure 5.

[0139] This system 210 may be used within a hospital to track a surgical instrument set during the sterilisation and decontamination process and during use to perform an operation. The first two surgical instrument RFID tag reading apparatus 60 may be provided within the CSSD, as described above, and the second two surgical instrument RFID tag reading apparatus 10 may be provided in an operating theatre, as described above.

[0140] Referring to Figure 13, a seventeenth embodiment provides a method 300 of reading RFID tags on a plurality of surgical instruments of a surgical instrument set. Each RFID tag contains identification information for the respective surgical instrument.

[0141] The method 300 comprises the following steps:

1. a. transmitting an RF signal having a signal field 302;
2. b. locating the RFID tags within the RF signal field 304;
3. c. causing a predetermined relative movement between the RF signal and the RFID tags 306;
4. d. receiving a RF return signal from at least some of the RFID tags 308, each RF signal return containing the identification information of the respective RFID tag;
5. e. obtaining the surgical instrument identification information from each RF return signal 310;
6. f. comparing the received surgical instrument identification information with a surgical instrument list of the surgical instrument set 312; and
7. g. determining whether surgical instrument identification information has been received for each of the surgical instruments on the surgical instrument list 314, and if not, generating an incomplete list alert 316.

[0142] Referring to Figure 14, an eighteenth embodiment provides a method 320 of reading RFID tags on a plurality of surgical instruments of a surgical instrument set. The method 320 of this embodiment is similar to the method 300 of the previous embodiment, with the following modifications. The same reference numbers are retained for corresponding steps.

[0143] In this embodiment, the method 320 comprises, in response to an incomplete list alert 316, the following additional steps:

- h. causing further predetermined relative movement between the RF signal and the RFID tags 322, the further predetermined relative movement being different to said predetermined relative movement; and
- i. repeating steps a. 302 to g. 314.

[0144] If after repeating step g., surgical instrument identification information has still not been cumulatively received for all of the surgical instruments on the surgical instrument list, the method proceeds to generate a fail alert 324.

[0145] The predetermined relative movement performed in step c. 306 comprises one of linear movement in a first direction, rotation by a first angle, and tilting in a first plane and by a first angle. The further predetermined relative movement performed in step h. 322 comprises one of linear movement in a second direction, different to the first direction, rotation by a second angle different to the first angle, tilting in a second plane different to the first plane, tilting by a second angle different to the first angle, or a different one of linear movement in a first direction, rotation by a first angle, and tilting in a first plane and by a first angle.

[0146] In a nineteenth embodiment, also described with reference to Figure 14, in step c. 306 the predetermined relative movement is movement along a predetermined path at a first speed and in step h. 322 the further predetermined relative movement is movement along the predetermined path at a second speed, different to the first. Each linear movement may be at a constant speed or may follow a speed profile, in which the speed of movement is varied. The further predetermined movement may alternatively be along a different predetermined path.

[0147] Referring to Figure 15, a twentieth embodiment provides a method 330 of reading RFID tags on a plurality of surgical instruments of a surgical instrument set. The method 330 of this embodiment is similar to the method 320 of the previous embodiment, with the following modifications. The same reference numbers are retained for corresponding steps.

[0148] In this embodiment, the method 330 additionally comprises shaking the surgical instrument set 332 such that the position of at least some of the surgical instruments is changed. The shaking is performed before the further relative movement 322.

[0149] Referring to Figure 16, a twenty-first embodiment provides a method 340 of reading RFID tags on a plurality of surgical instruments of a surgical instrument set. The method 340 of this embodiment is similar to the method 300 described with reference to Figure 13, with the following modifications. The same reference numbers are retained for corresponding steps.

[0150] In this embodiment, the surgical instrument set, and thus the RFID tags on the surgical instruments, is moved through the RF signal 342.

[0151] Referring to Figure 17, a twenty-second embodiment provides a method 350 of reading RFID tags on a plurality of surgical instruments of a surgical instrument set. The method 350 of this embodiment is similar to the method 300 described with reference to Figure 13, with the following modifications. The same reference numbers are retained for corresponding steps.

[0152] In this embodiment, the RF signal is moved across the surgical instruments, and thus across the RFID tags on the surgical instruments.

[0153] Referring to Figure 18, a twenty-third embodiment provides a method 360 of reading RFID tags on a plurality of surgical instruments of a surgical instrument set.

[0154] The method 360 is implemented using the apparatus 60 shown in Figure 5. The instrument set 14 of this embodiment additionally has an RFID tag on the instrument tray.

[0155] The method comprises:

placing the instrument tray containing the surgical instruments on the conveyor apparatus 362;

turning on the RFID reader and the RF antenna to transmit an RF signal and searching for identification, ID, information for the RFID tags on the surgical instruments 364;

receiving ID information for the tray 366;

retrieving the instrument list for the tray 380;

receiving surgical instrument ID information from at least some of the RFID tags on the surgical instruments 368;

comparing the received surgical instrument ID information with the surgical instrument list and determining whether ID information has been received for each of the surgical instruments on the list 370;

if ID information has been received for each of the surgical instruments on the list, displaying a 'tray positive' status 372 and exiting the tray from the apparatus 374; and

if ID information has not been received for each of the surgical instruments on the list, causing further relative movement between the RF signal and the RFID tags, by repeating the scan by at least one of: moving the conveyor apparatus in the opposite direction; moving the conveyor apparatus at a different speed; rotating the interrogation platform; tilting the interrogation platform; and shaking the interrogation platform or moving the conveyor apparatus backwards and forwards to shake the instrument tray;

comparing all the received surgical instrument ID information with the surgical instrument list and determining whether ID information has been received for each of the surgical instruments on the list 370; and

if ID information has been received for each of the surgical instruments on the list, displaying a 'tray positive' status 372 and exiting the tray from the apparatus 374; and

if ID information has still not been received for each of the surgical instruments on the list, transmitting a fail alert 378.

[0156] Referring to Figures 19 and 20, a twenty-fourth embodiment provides a surgical instrument RFID tag reading system 400 comprising a surgical instrument RFID tag reading apparatus 10 and an instrument carrier, in the form of an instrument tray 402. The instrument tray comprises a base 404 and an instrument platform 406. The instrument platform is mounted within the instrument tray raised above the base. The base is reflective to RF signals and the instrument platform is at least partially transparent to RF signals.

[0157] It will be appreciated that any of the above described surgical instrument RFID tag reading apparatus 10, 30, 50, 60, 70, 80, 90, 100 described with reference to Figures 2 to 10 may alternatively be used.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- US2006043177A [0005]
- US2011112384A [0006]
- WO2013104743A [0007]
- DE102012107274 [0008]

PATENTKRAV

1. Kirurgisk instrumentradiofrekvensidentifikations-, RFID, tag-læsningsanordning (10, 30, 40, 50, 60, 70, 80, 90) omfattende:

en forespørgselszone (12), der er indrettet til at modtage et kirurgisk instrumentsæt (14)

omfattende en flerhed af kirurgiske instrumenter, hvor hvert kirurgisk instrument omfatter et tilsvarende RFID-tag, der indeholder identifikationsinformationer for det kirurgiske instrument;

en RFID-tag-læser (16);

en radiofrekvens-, RF, antenne (18), der er koblet til RFID-tag-læseren og indrettet til at sende et RF-signal (20) med et signalfelt, hvor mindst en del deraf strækker sig inden i forespørgselszonen og er indrettet til at modtage RF-retursignaler fra mindst nogle af RFID-taggene, hvor hvert RF-retursignal indeholder identifikationsinformationerne for det tilsvarende RFID-tag;

føringsanordning (22, 32, 42, 52, 62, 64, 72, 82), der er indrettet til at forårsage en forudbestemt relativ bevægelse mellem RFID-taggene på de kirurgiske instrumenter og RF-signalet; og

en styreenhed (24), der er indrettet til at:

a. modtage de kirurgiske instrumentidentifikationsinformationer fra RFID- tag-læseren for hvert RFID-tag, hvorfra et RF-retursignal er modtaget;

b. sammenligne de modtagne kirurgiske instrumentidentifikationsinformationer med en kirurgisk instrumentliste over det kirurgiske instrumentsæt;

c. bestemme, om kirurgiske instrumentidentifikationsinformationer er modtaget for hvert af de kirurgiske instrumenter på den kirurgiske instrumentliste, og hvis ikke: generere en advarsel om ukomplet liste,

og **kendetegnet ved**, at føringsanordningen er indrettet til at forårsage en forudbestemt rotationsbevægelse mellem RF-antennen (18) og det kirurgiske instrumentsæt (14), og styreenheden endvidere er indrettet til, som reaktion på en advarsel om ukomplet liste:

d. at sende et styresignal (68) til føringsanordningen omfattende instruktioner, der er indrettet til at forårsage en forudbestemt relativ bevægelse mellem RFID-taggene på de kirurgiske instrumenter og RF-antennen (18), hvor den forudbestemte relative rotationsbevægelse adskiller sig fra den forudbestemte relative bevægelse; og

e. gentage a. til c.

2. Kirurgisk instrument-RFID-tag-læsningsanordning ifølge krav 1, hvor styreenheden er indrettet til at generere og sende et styresignal (68) til føringsanordningen omfattende instruktioner for at foranledige føringsanordningen til at føre bevægelse af det kirurgiske instrumentsæt langs en forudbestemt bane ved en hastighed, der varierer langs banen, og hvor
5 hastigheden varierer i forhold til en forudbestemt hastighedsprofil.

3. Kirurgisk instrument-RFID-tag-læsningsanordning ifølge krav 1 eller krav 2, hvor føringsanordningen (42, 52, 62, 72, 82) er bevægeligt monteret og indrettet til at udføre mindst én af rotation og vipning, således at der forårsages en forudbestemt rotations- eller
10 vipningsbevægelse mellem RF-antennen (18) og det kirurgiske instrumentsæt, og rystning, således at positionen af mindst nogle af de kirurgiske instrumenter ændres.

4. Kirurgisk instrument-RFID-tag-læsningsanordning ifølge et hvilket som helst af kravene 1 til 3, hvor føringsanordningen (42) omfatter vejeanordning og styreenheden endvidere er
15 indrettet til at:

modtage en vægt af det kirurgiske instrumentsæt fra vejeanordningen;
sammenligne vægten med en referencevægt forbundet med den kirurgiske instrumentliste; og
bestemme, om den modtagne vægt i alt væsentligt svarer til referencevægten, og hvis
20 ikke, generere en advarsel om ukomplet liste i c.

5. Kirurgisk instrument-RFID-tag-læsningsanordning ifølge et hvilket som helst af kravene 1 til 4, hvor føringsanordningen omfatter en antennebærer (92), hvorpå RF-antennen er monteret, hvilken antennebærer er bevægeligt monteret og indrettet til at foretage mindst én af en
25 forudbestemt lineær bevægelse, rotation og vipning, således at der foranlediges mindst én af en forudbestemt lineær, relativ rotations- og vipningsbevægelse mellem RF-antennen (18) og det kirurgiske instrumentsæt.

6. Kirurgisk instrument-RFID tag-læsningssystem (400) omfattende:
30 kirurgisk instrument-RFID-tag-læsningsanordning (10, 30, 40, 50, 60, 70, 80, 90) ifølge et hvilket som helst foregående krav; og
en instrumentbærer (402) omfattende: en basis (404), der reflekterer RF-signaler; og en instrumentplatform (406), der er mindst delvist transparent for RF-signaler, hvilken instrumentplatform er monteret inde i instrumentbæreren hævet over basis.

7. Kirurgisk instrumentsporingssystem (200, 210) omfattende:

et kirurgisk instrumentsæt (202), der omfatter en flerhed af kirurgiske instrumenter, der hvert omfatter et tilsvarende RFID-tag, der indeholder identifikationsinformationer for det kirurgiske instrument; og
en flerhed af kirurgisk instrument-RFID-tag-læsningsanordninger (10, 30, 40, 50, 60, 70, 80, 90) ifølge et hvilket som helst af kravene 1 til 5, hvor hver anordning indrettet til at modtage det kirurgiske instrumentsæt.

8. Fremgangsmåde (300) til læsning af RFID-tags på en flerhed af kirurgiske instrumenter fra et kirurgisk instrumentsæt, hvor hvert RFID-tag indeholder identifikationsinformationer for det tilsvarende kirurgiske instrument, hvilken fremgangsmåde omfatter følgende trin:

- a. transmission af et RF-signal med et signalfelt (302);
- b. lokalisering af RFID-taggene inde i RF-signalfeltet (304);
- c. at foranledige en forudbestemt relativ bevægelse mellem RF-signalfeltet og RFID-taggene (306);
- d. modtagelse af et RF-retursignal fra mindst nogle af RFID-taggene (308), idet hvert RF-retursignal indeholder identifikationsinformationerne for det tilsvarende RFID-tag;
- e. opnåelse af de kirurgiske instrumentidentifikationsinformationer fra hvert RF-retursignal (310);
- f. sammenligning af de modtagne kirurgiske instrumentidentifikationsinformationer med en kirurgisk instrumentliste over det kirurgiske instrumentsæt (312);
- g. bestemmelse af, om de kirurgiske instrumentidentifikationsinformationer er modtaget for hvert af de kirurgiske instrumenter på den kirurgiske instrumentliste (314), og hvis ikke: generering af en advarsel om ukomplet liste (316) og **kendetegnet ved** endvidere at omfatte, som reaktion på en advarsel om ukomplet liste, følgende trin:
- h. at foranledige en forudbestemt relativ rotationsbevægelse mellem RF-signalfeltet og det kirurgiske instrumentsæt, hvor den relative rotationsbevægelse adskiller sig fra den forudbestemte relative bevægelse; og
- i. gentagelse af trin a. til g.

9. Fremgangsmåde ifølge krav 8, hvor den forudbestemte relative bevægelse omfatter bevægelse langs en forudbestemt bane ved en hastighed, der varierer langs banen, og hvor

hastigheden varierer langs banen i forhold til en forudbestemt hastighedsprofil.

- 5 **10.** Fremgangsmåde ifølge krav 8 eller krav 9, hvor i trin c. den forudbestemte relative bevægelse omfatter én af lineær bevægelse i en første retning, rotation om en første vinkel, og vipning i et første plan og i en første vinkel.
- 10 **11.** Fremgangsmåde ifølge krav 10, hvor i trin h. den yderligere relative bevægelse er én af bevægelse i en anden retning, der adskiller sig fra den første retning, rotation om en anden vinkel, der adskiller sig fra den første vinkel, vipning i et andet plan, der adskiller sig fra det første plan, vipning i en anden vinkel, der adskiller sig fra den første vinkel, eller en anden én af lineær bevægelse i en første retning, rotation om en første vinkel og vipning i et første plan og i en første vinkel.
- 15 **12.** Fremgangsmåde ifølge et hvilket som helst af kravene 8 til 11, hvor trin h. endvidere omfatter rystning af det kirurgiske instrumentsæt før den yderligere relative bevægelse, således at positionen af mindst nogle af de kirurgiske instrumenter ændres.
- 20 **13.** Fremgangsmåde ifølge et hvilket som helst af kravene 8 til 12, hvor den relative bevægelse mellem RF-signalfeltet og RFID-taggene omfatter bevægelse af de kirurgiske instrumenter gennem RF-signalfeltet.
- 14.** Fremgangsmåde ifølge et hvilket som helst af kravene 8 til 13, hvor den relative bevægelse mellem RF-signalfeltet og RFID-taggene omfatter bevægelse af RF-signalfeltet over de kirurgiske instrumenter.

DRAWINGS

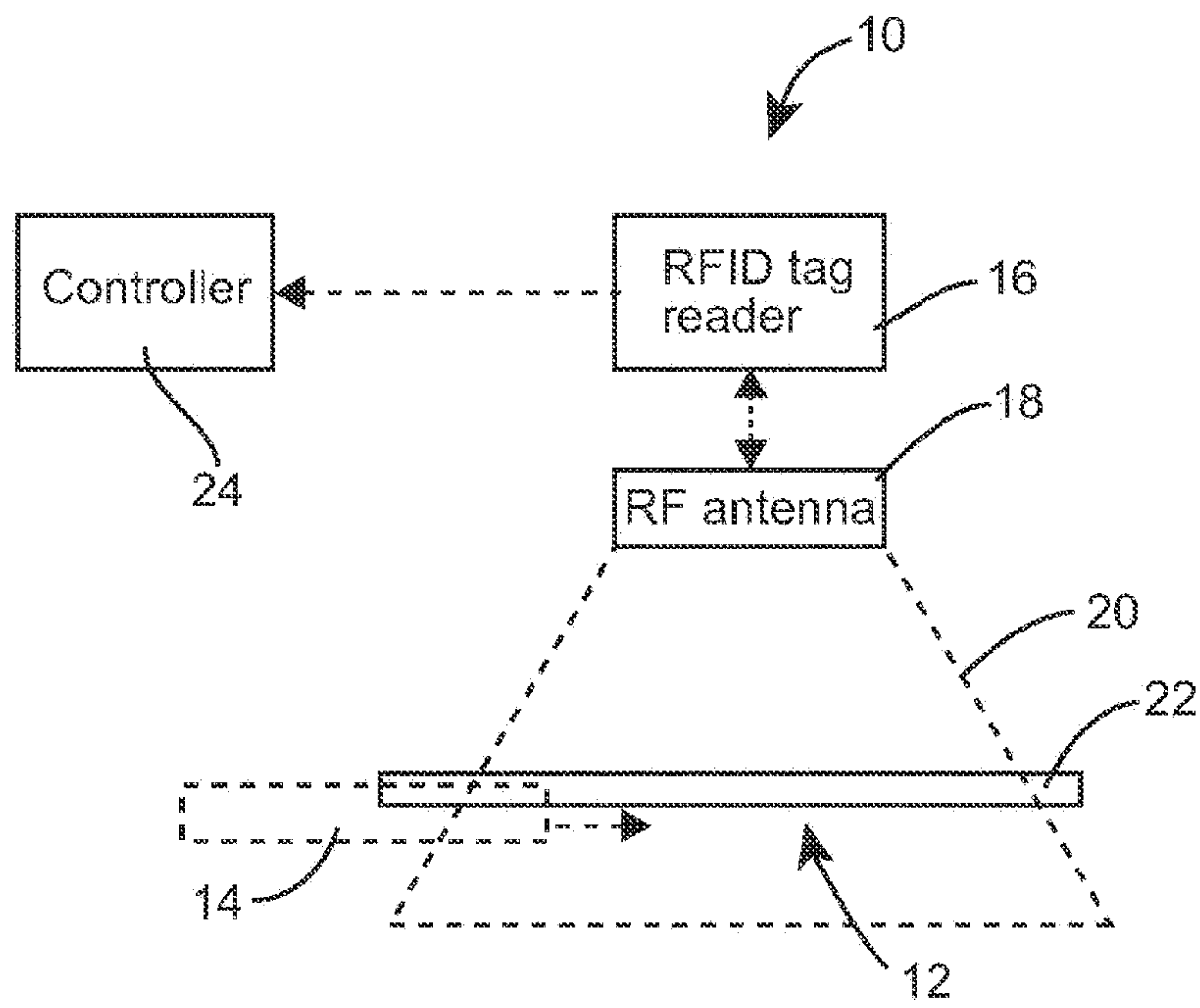


Fig. 1

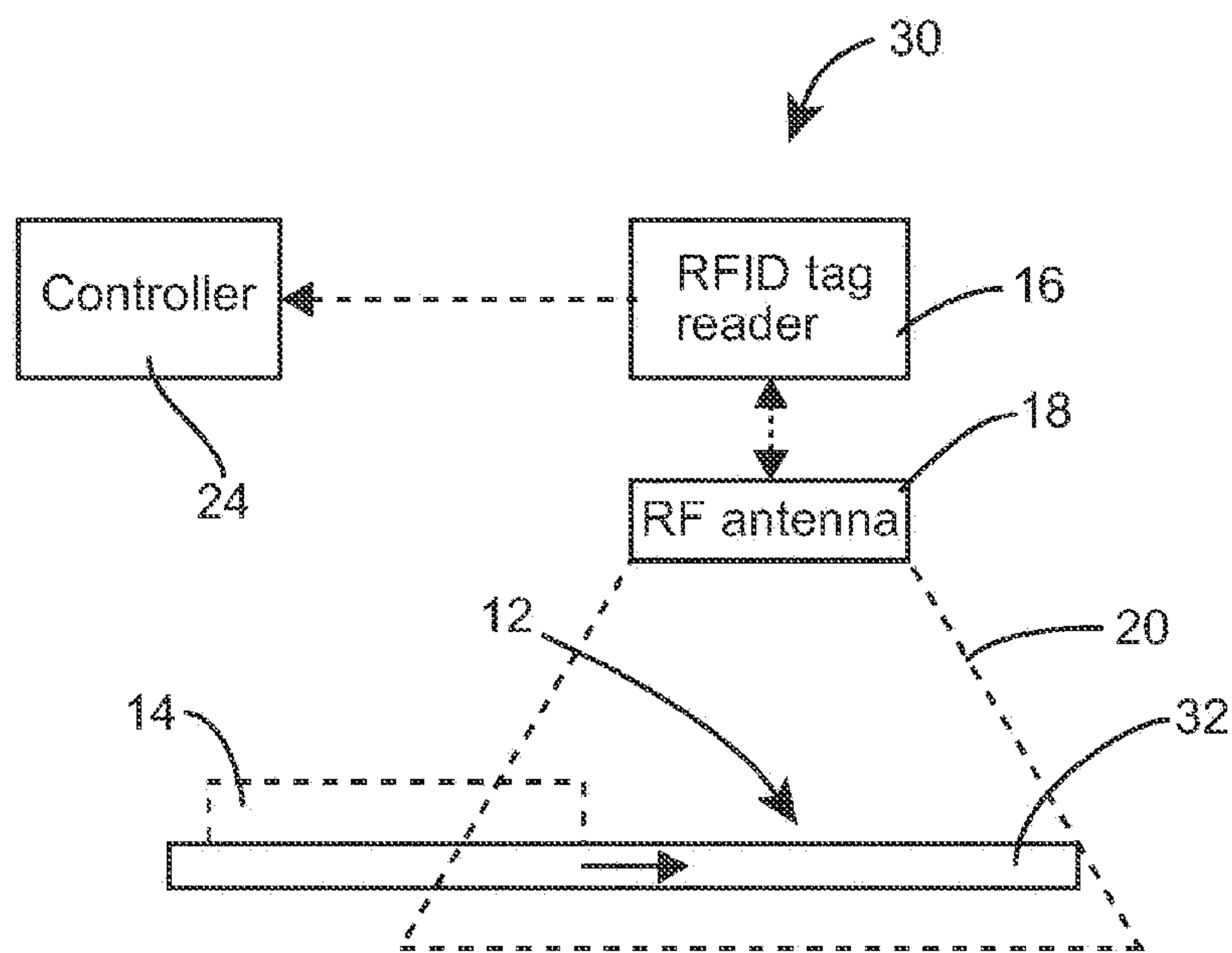
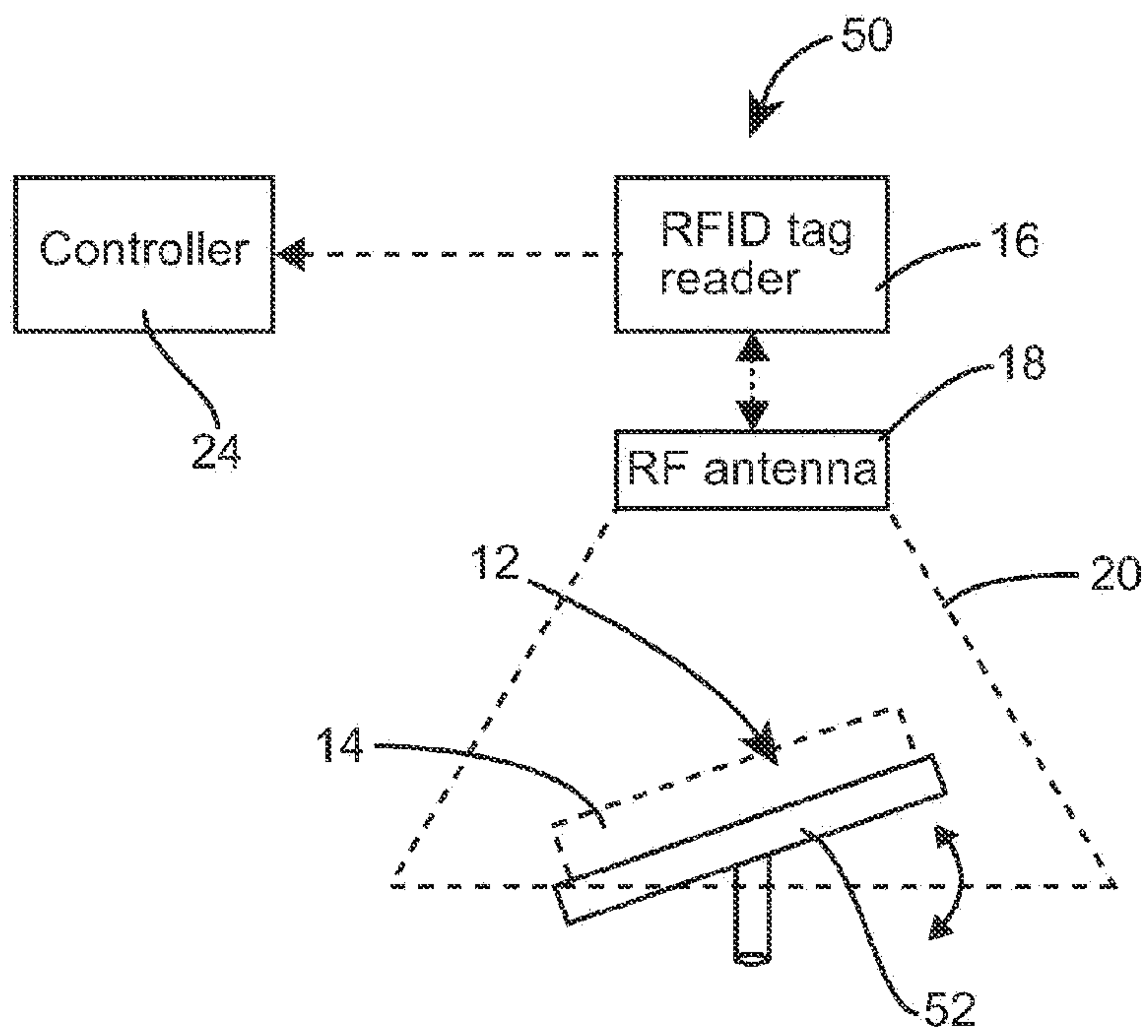
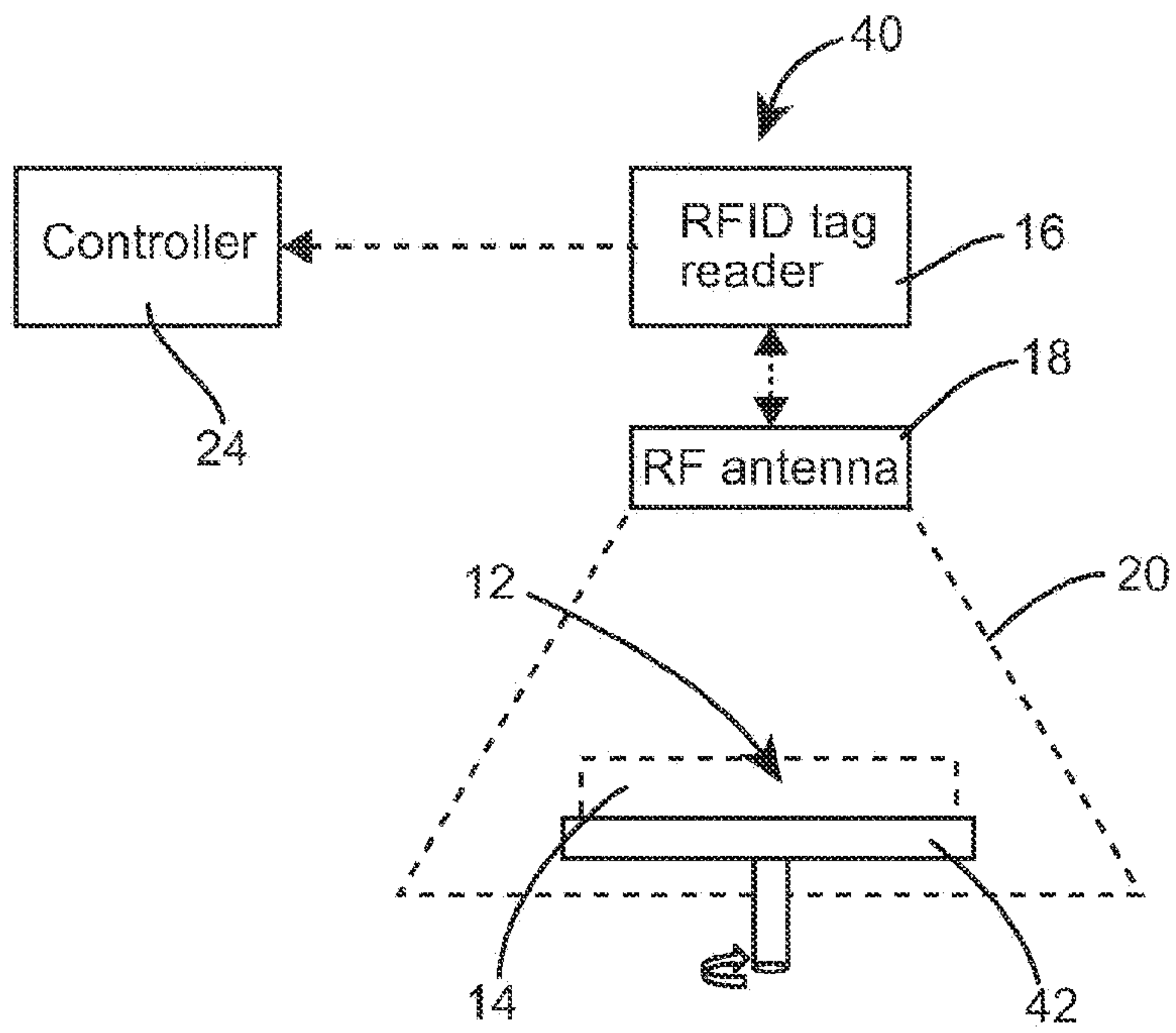
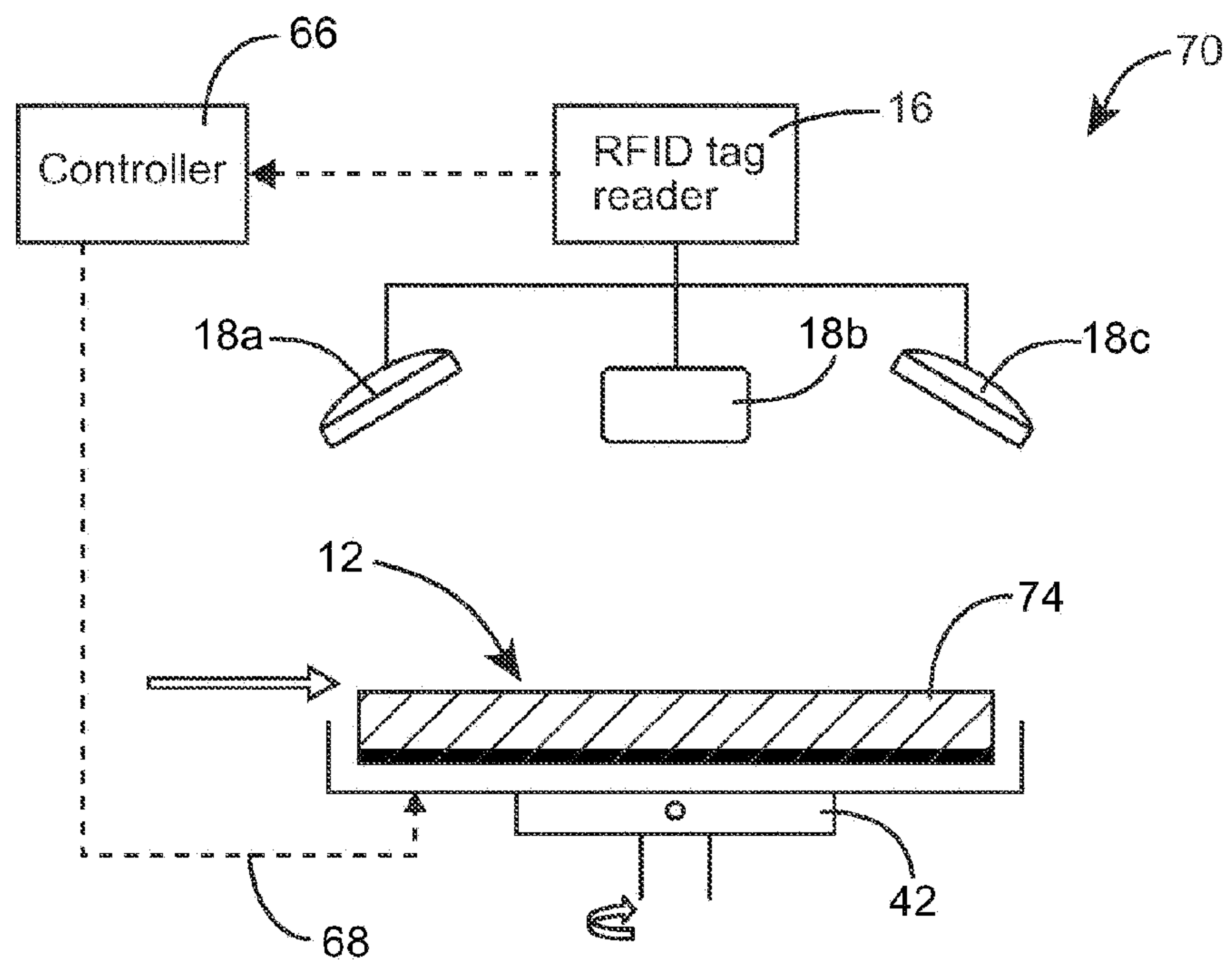
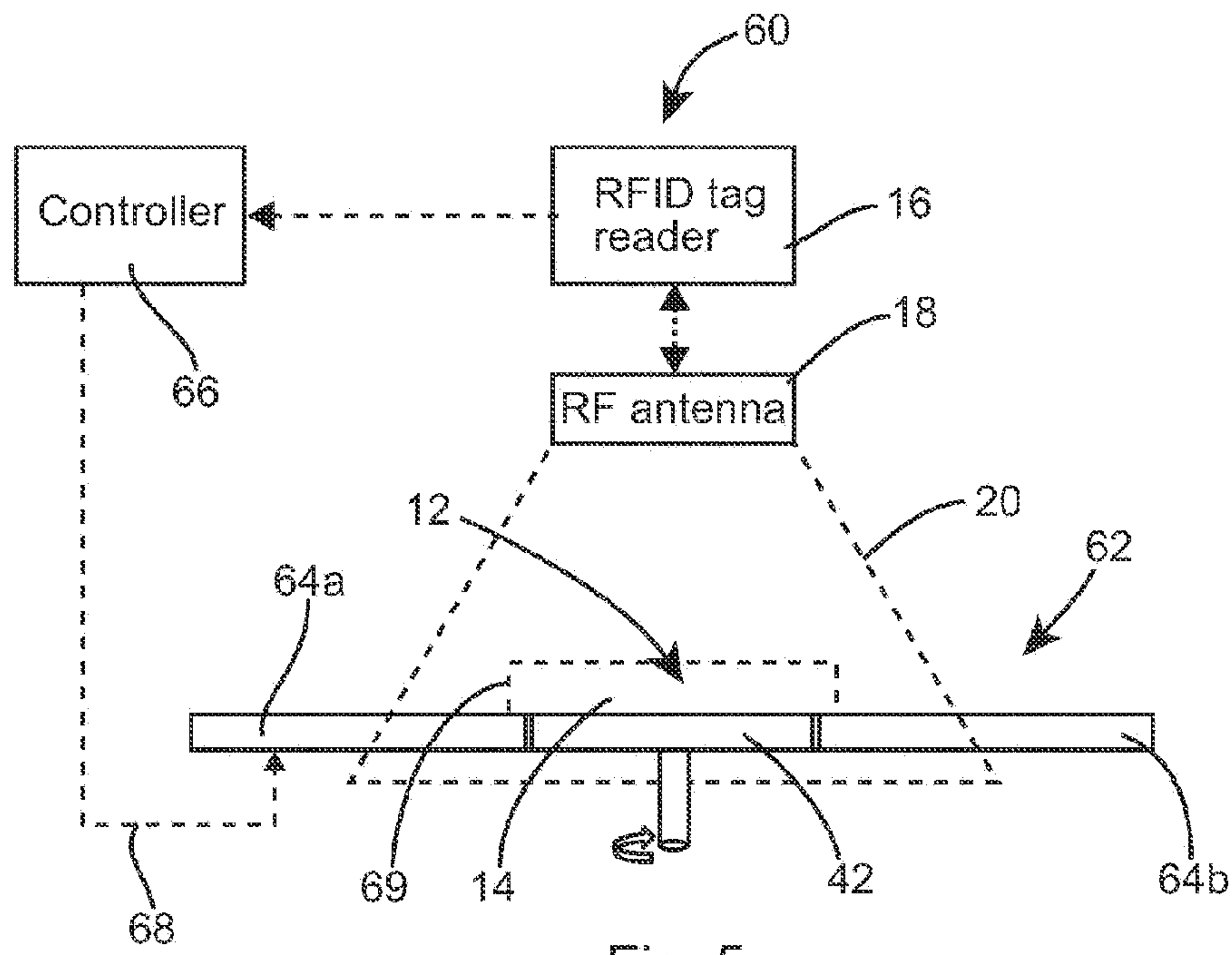
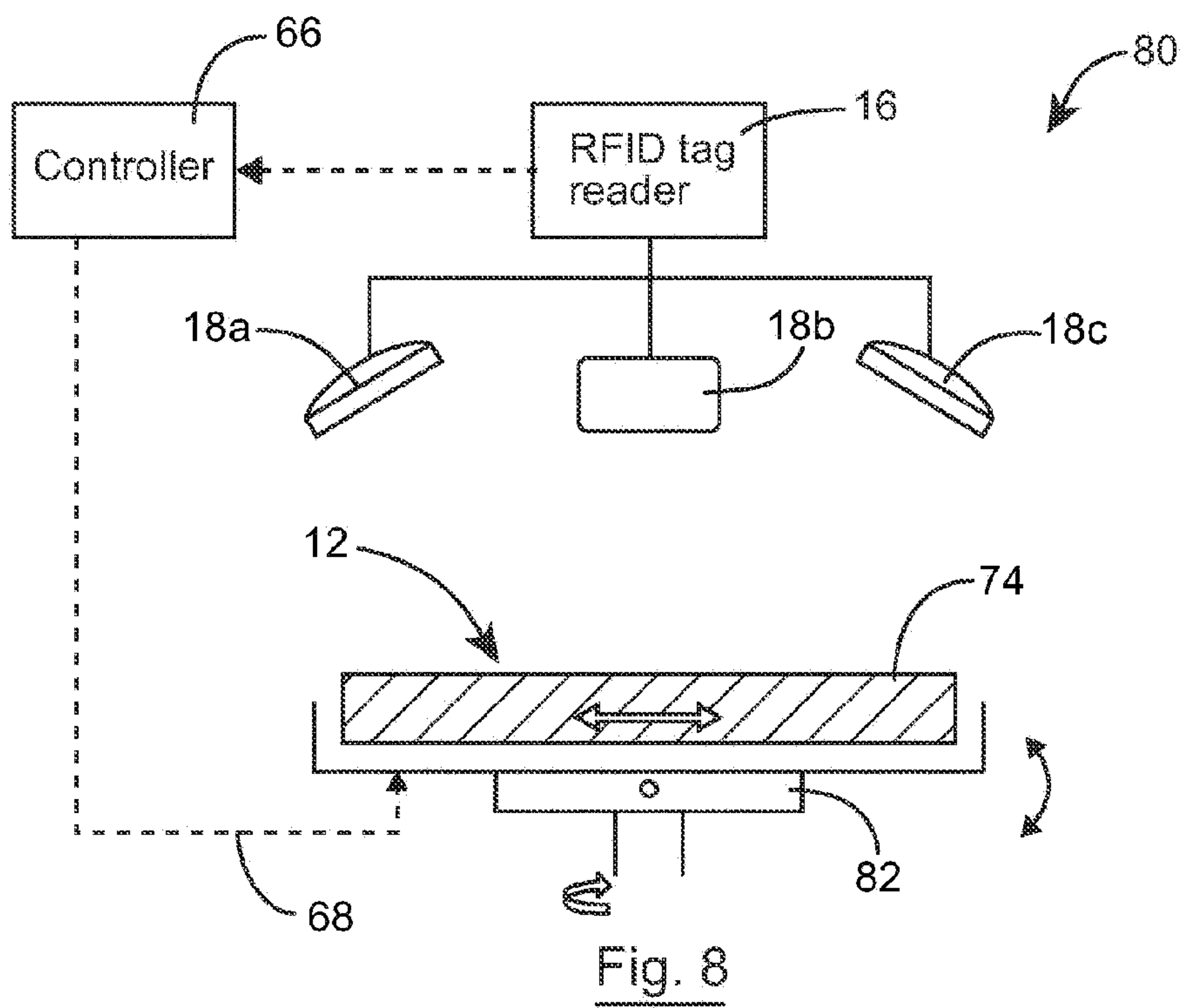
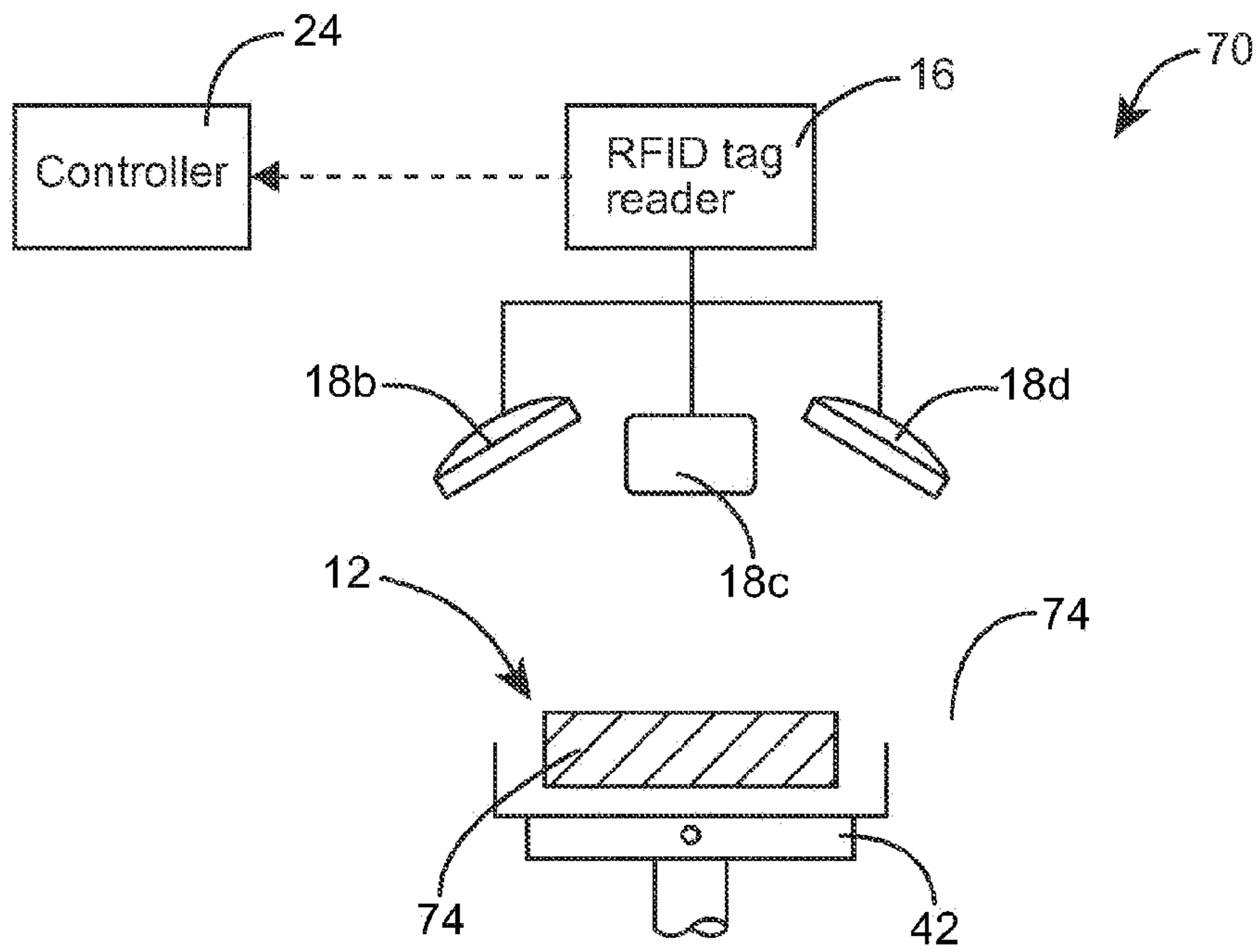


Fig. 2







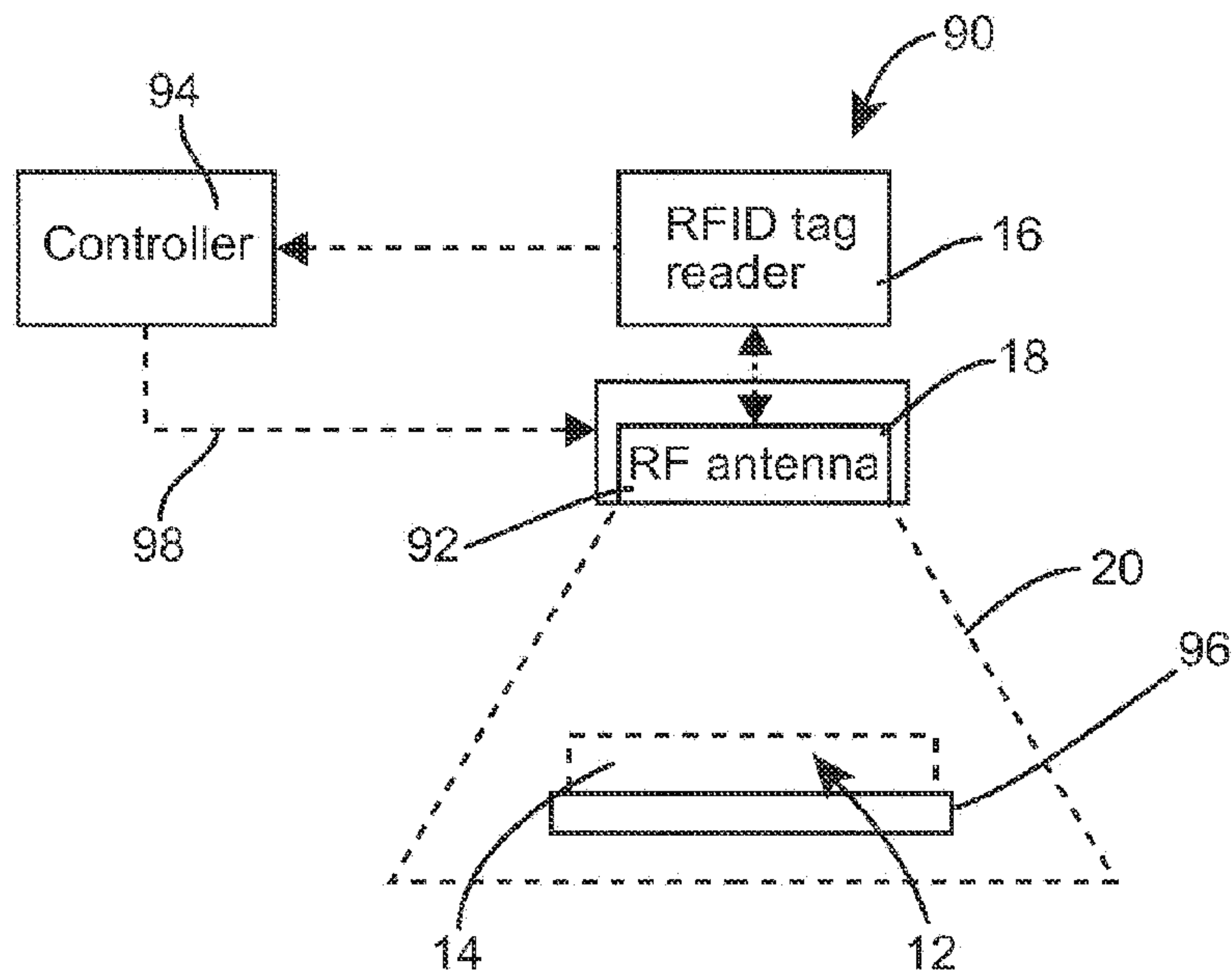


Fig. 9

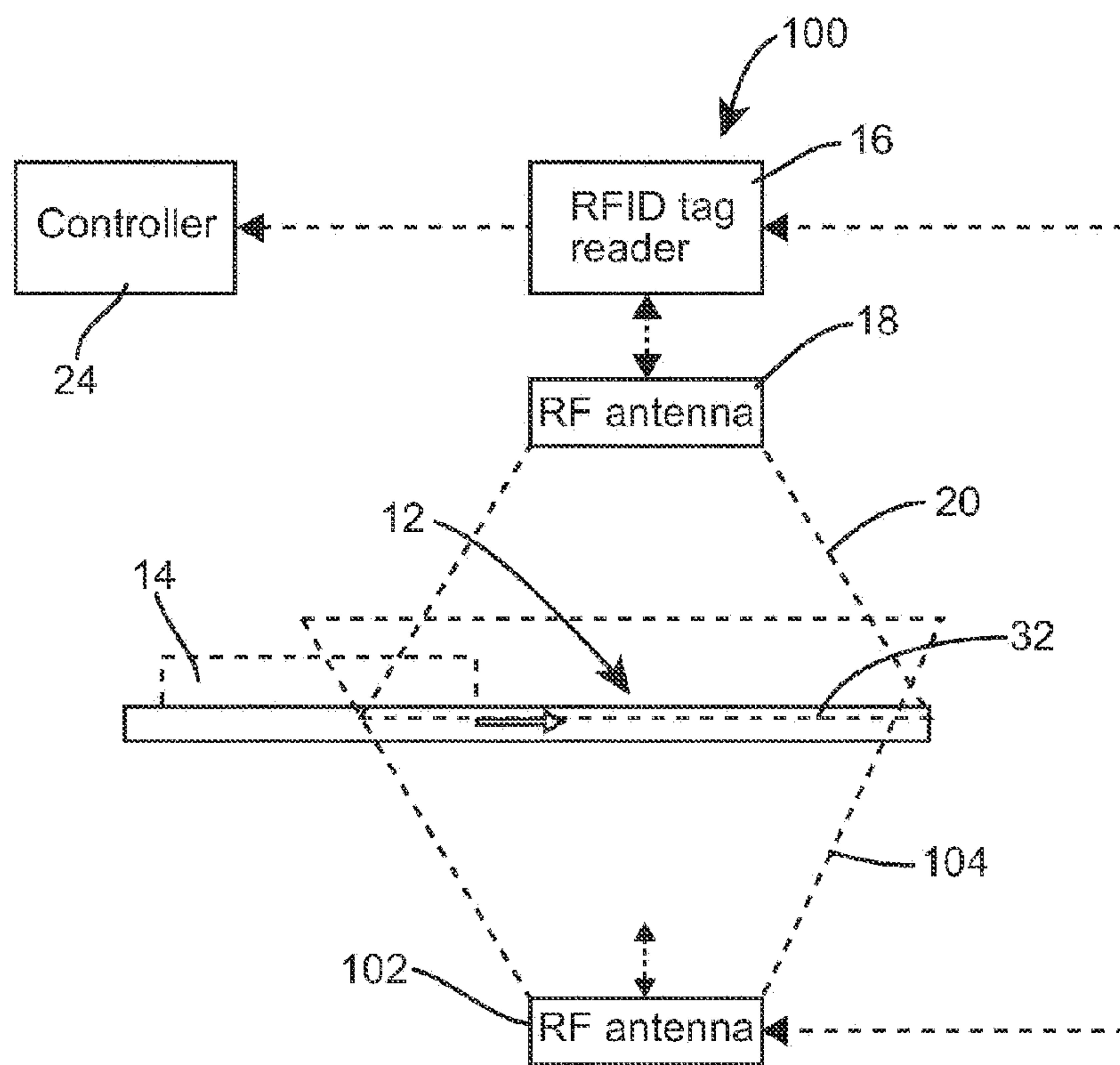


Fig. 10

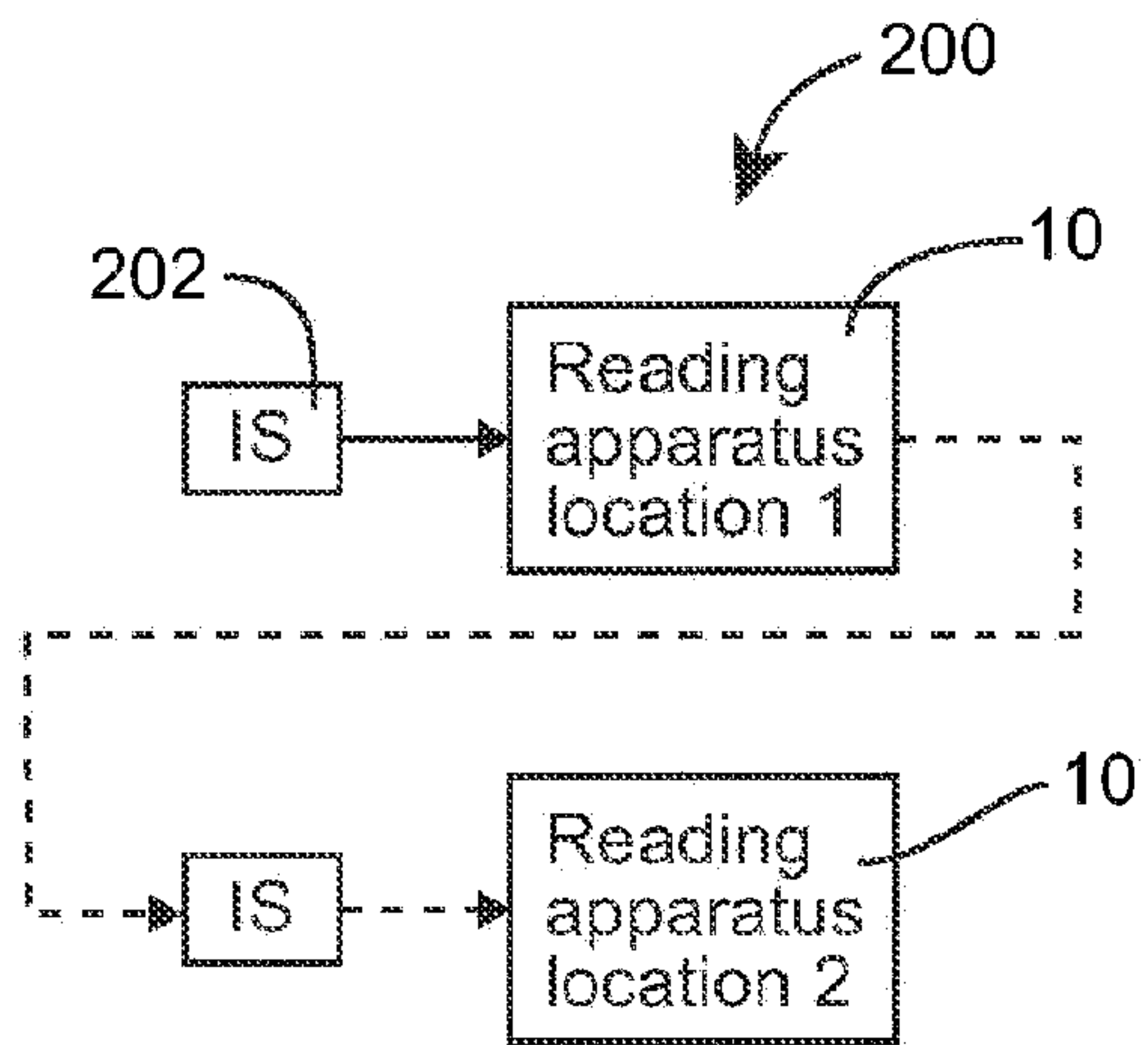


Fig. 11

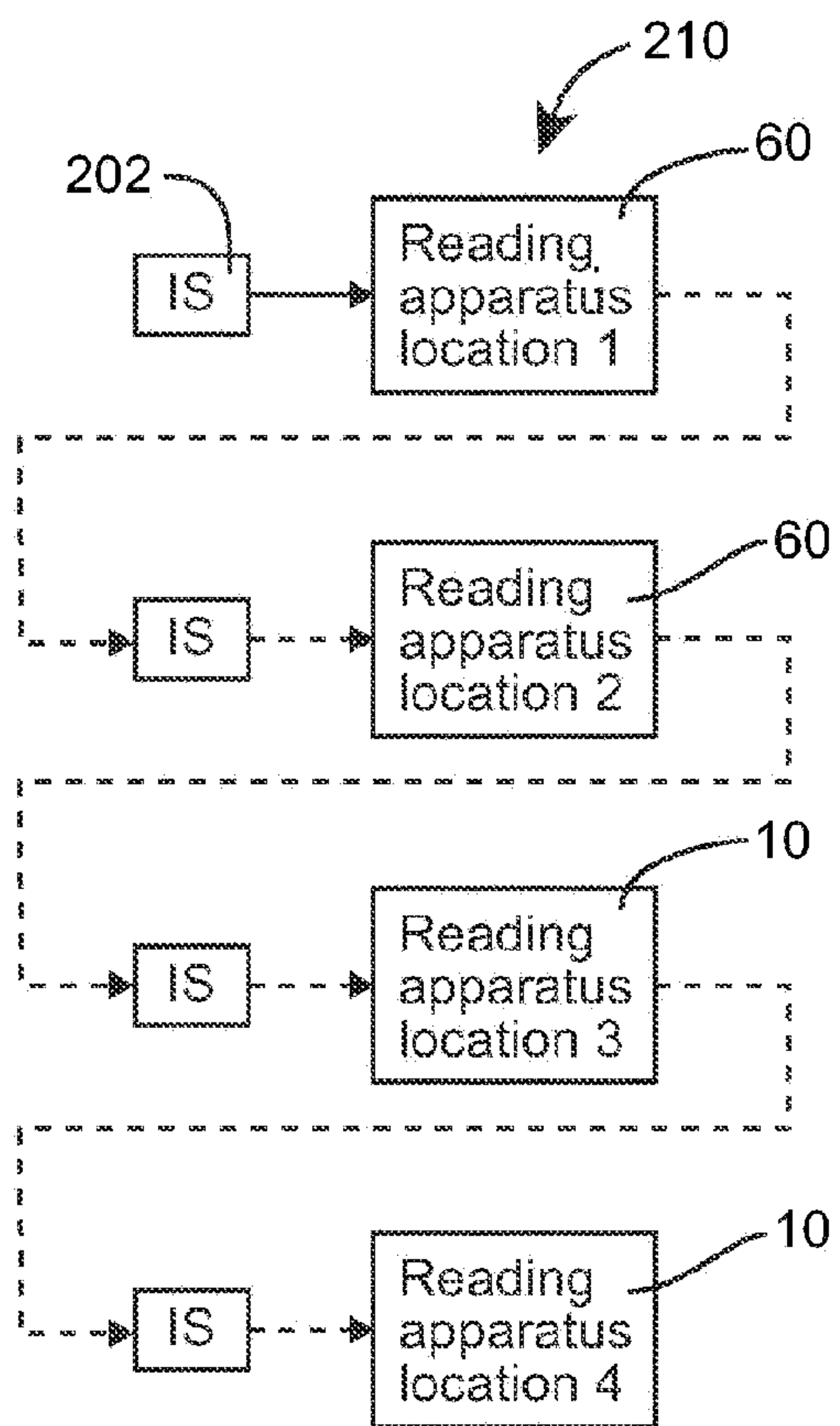
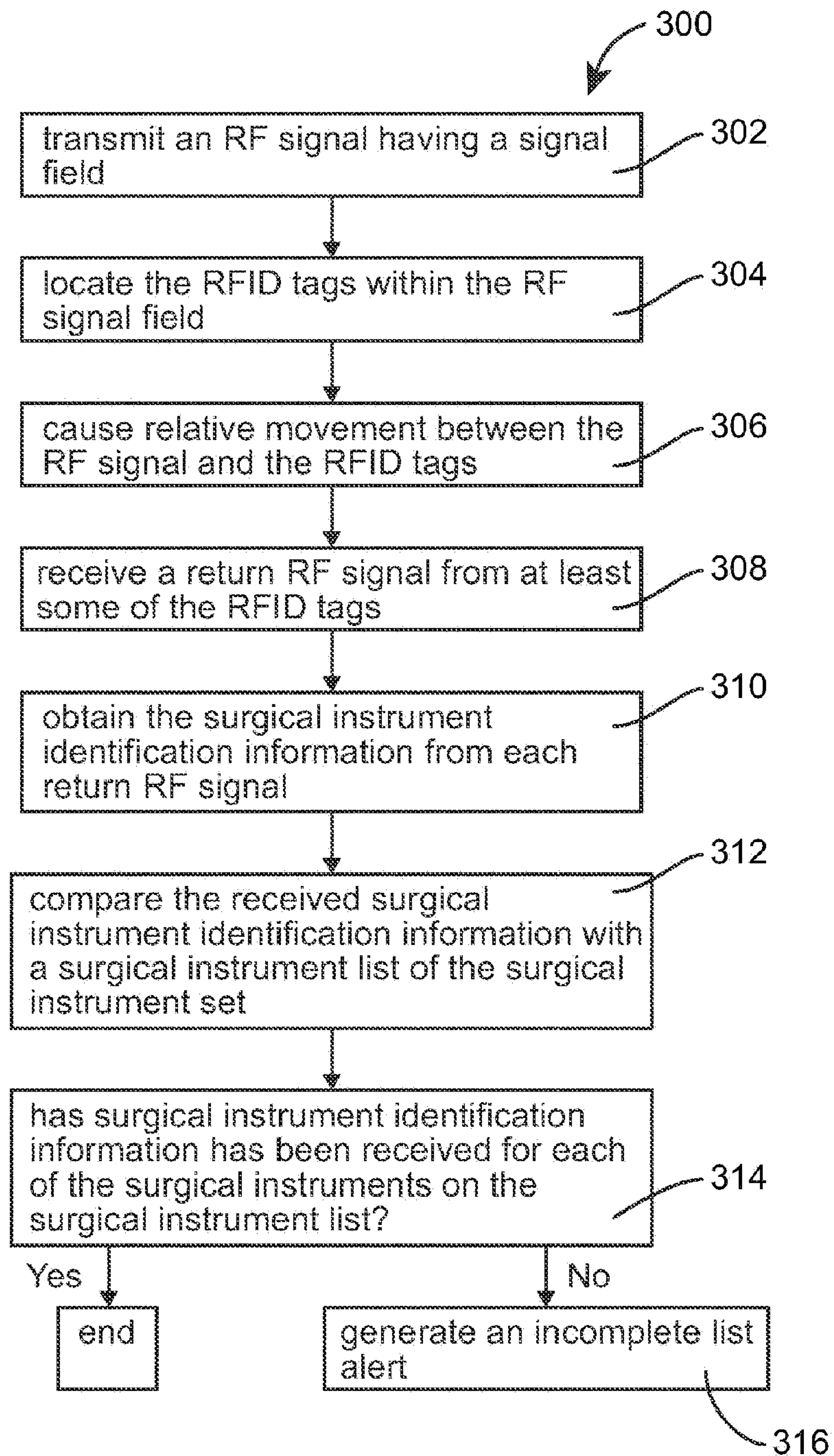


Fig. 12

Fig. 13

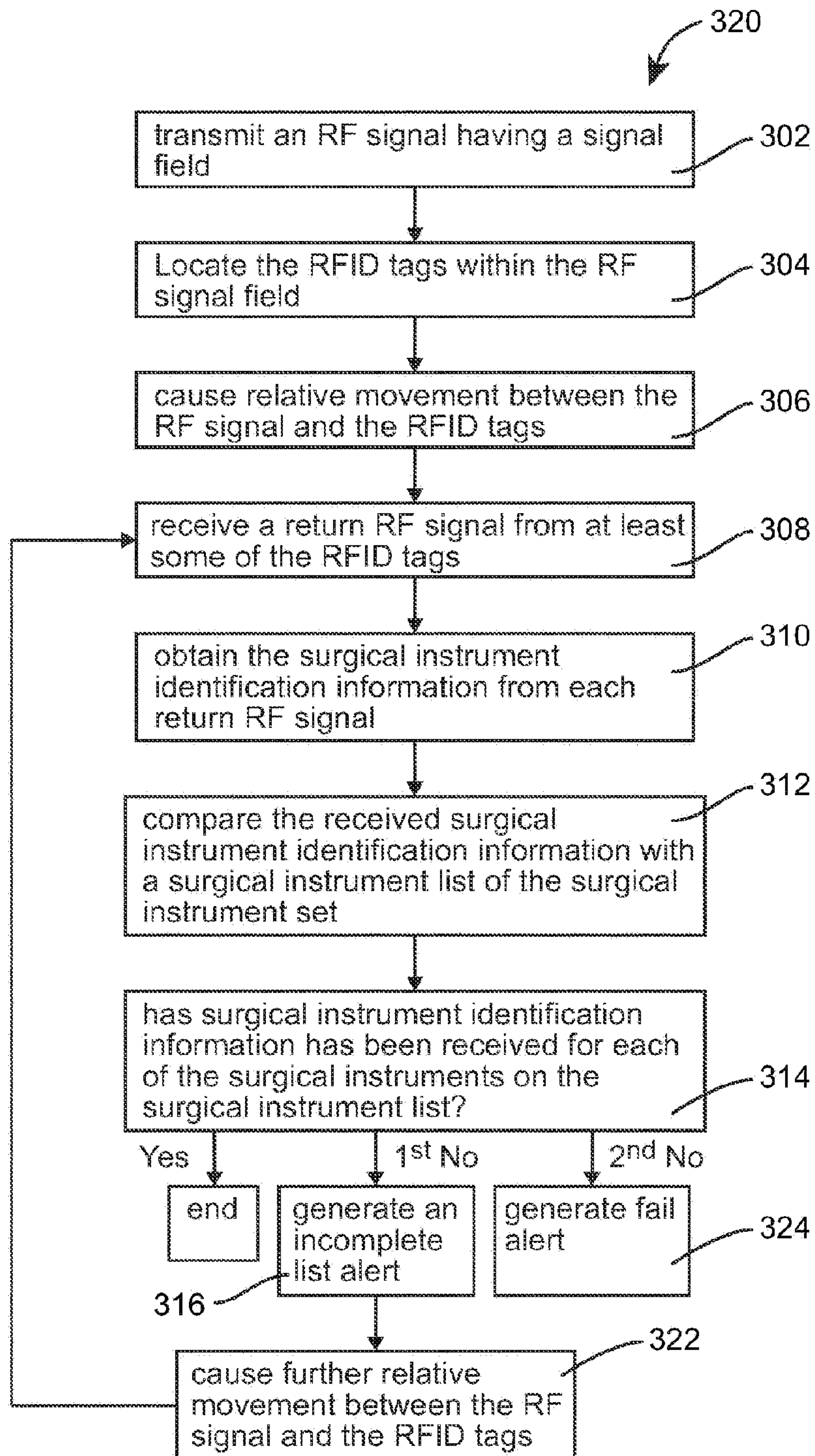


Fig. 14

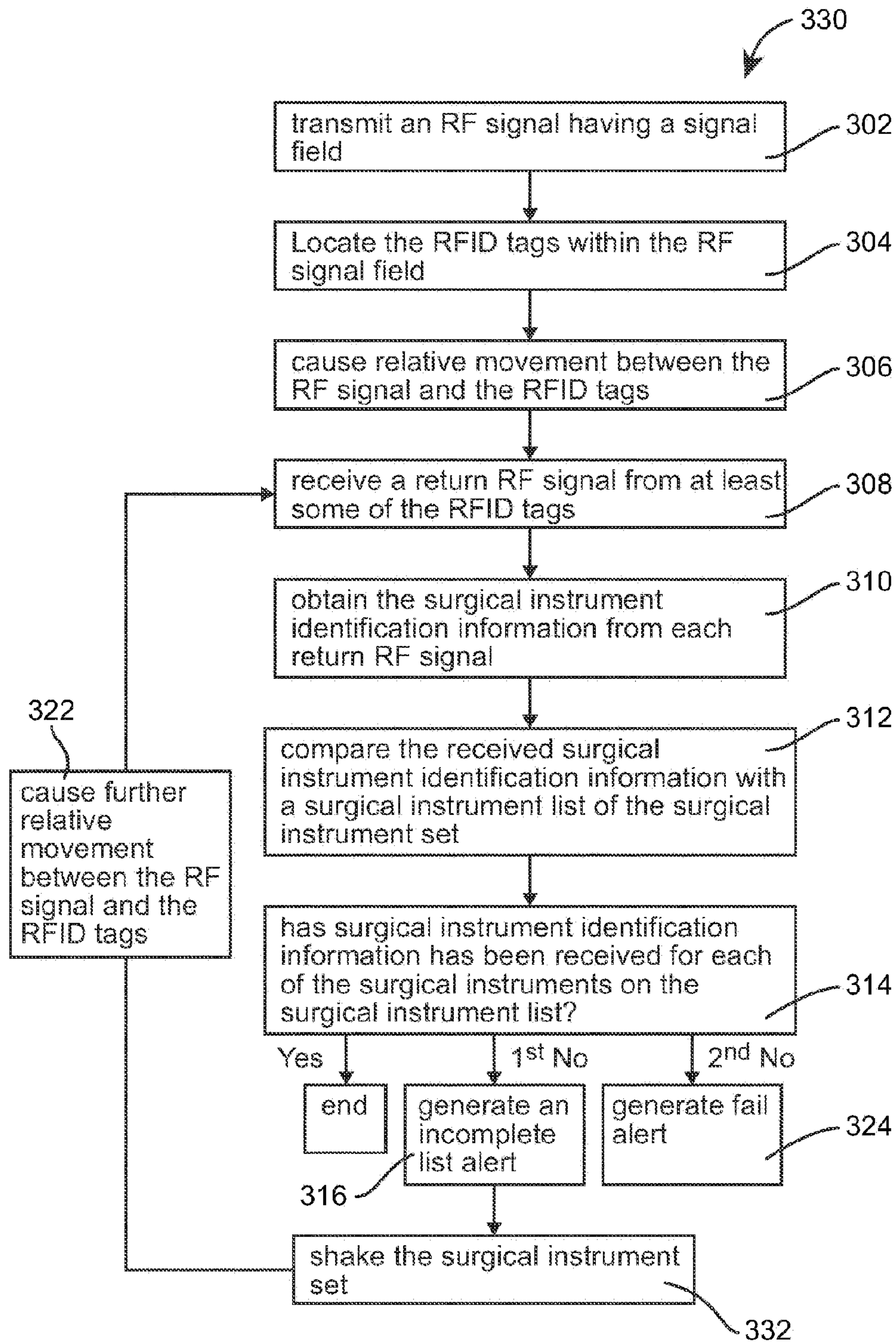
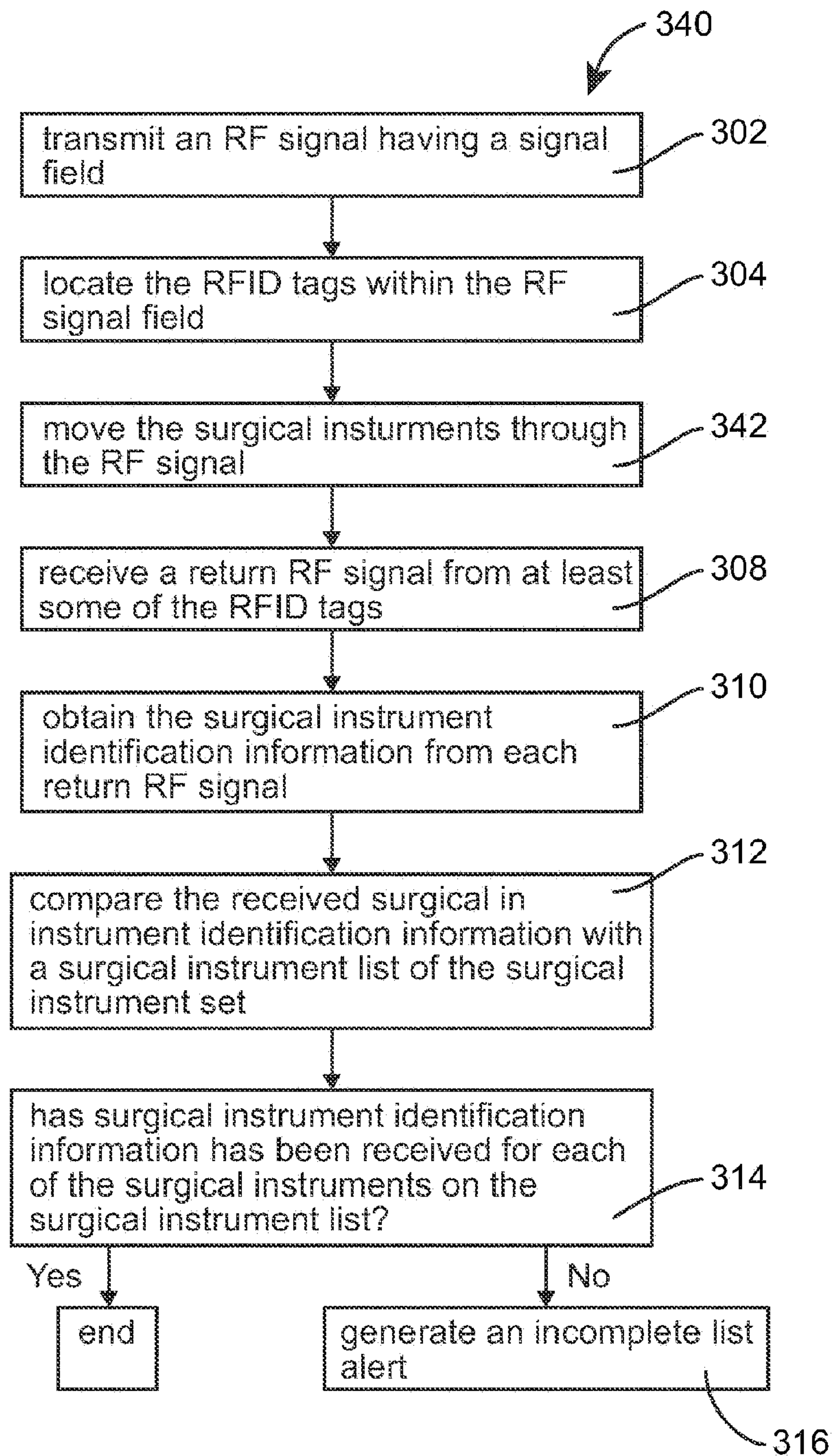
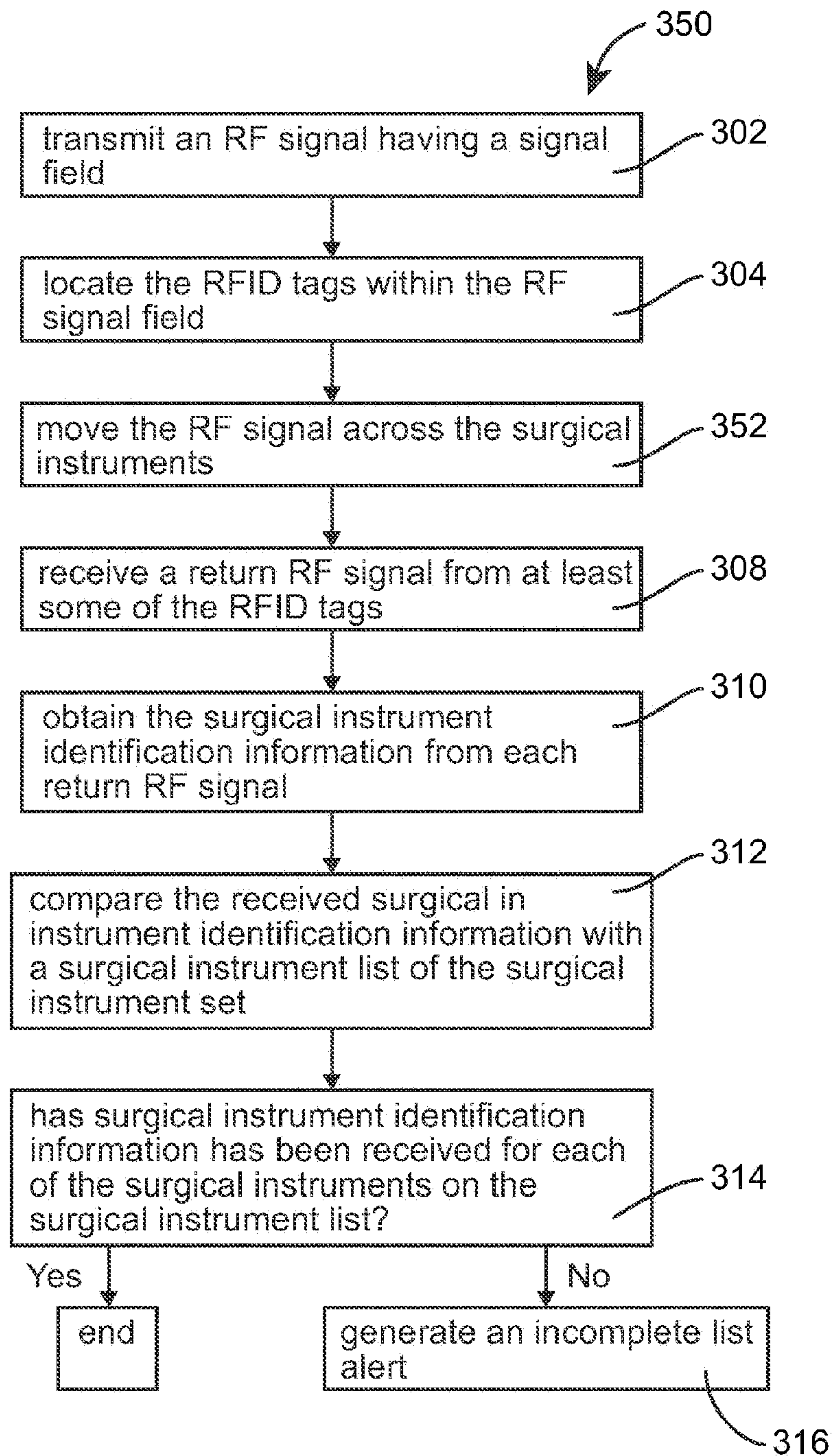


Fig. 15

Fig. 16

Fig. 17

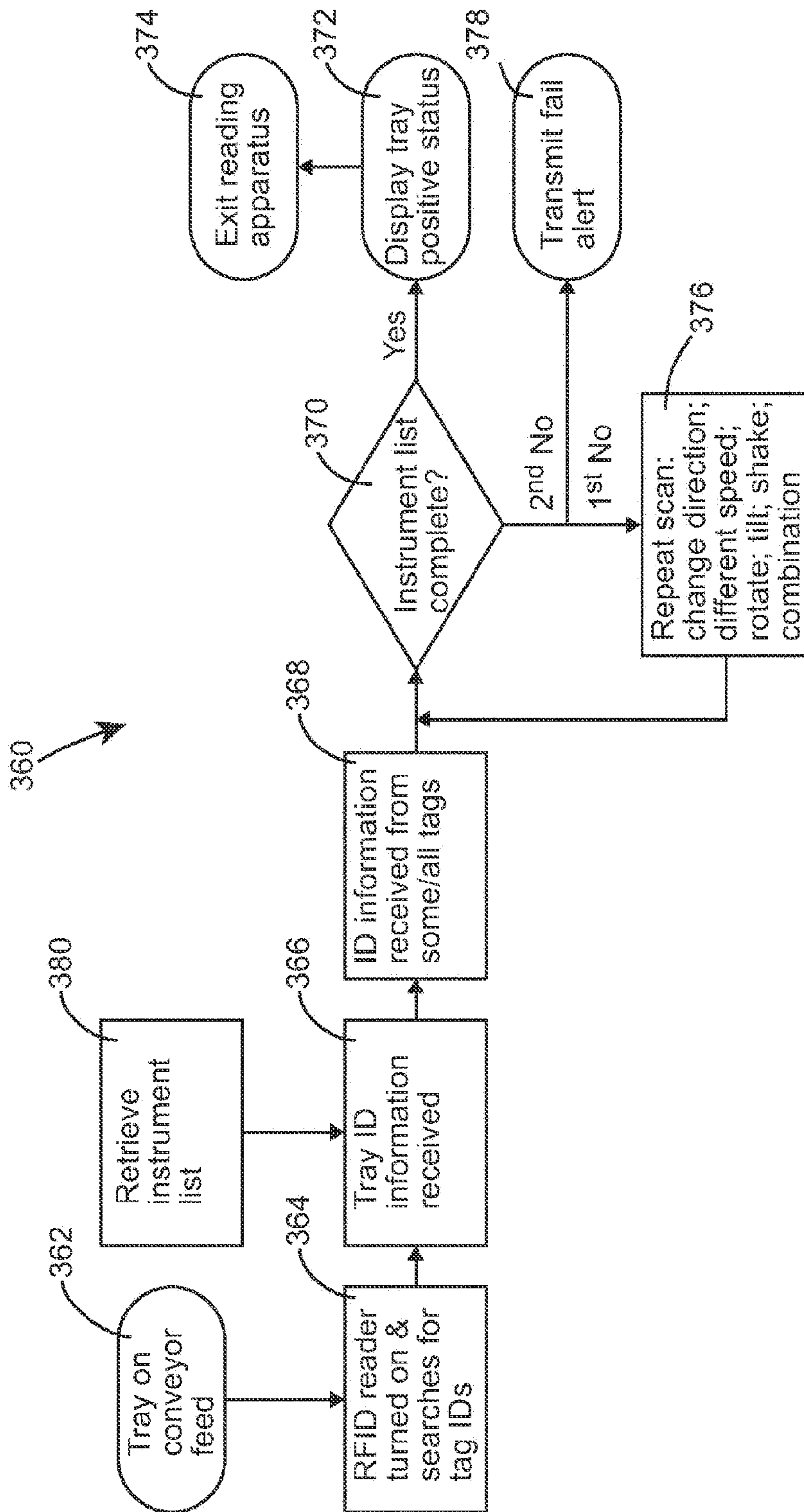


Fig. 18

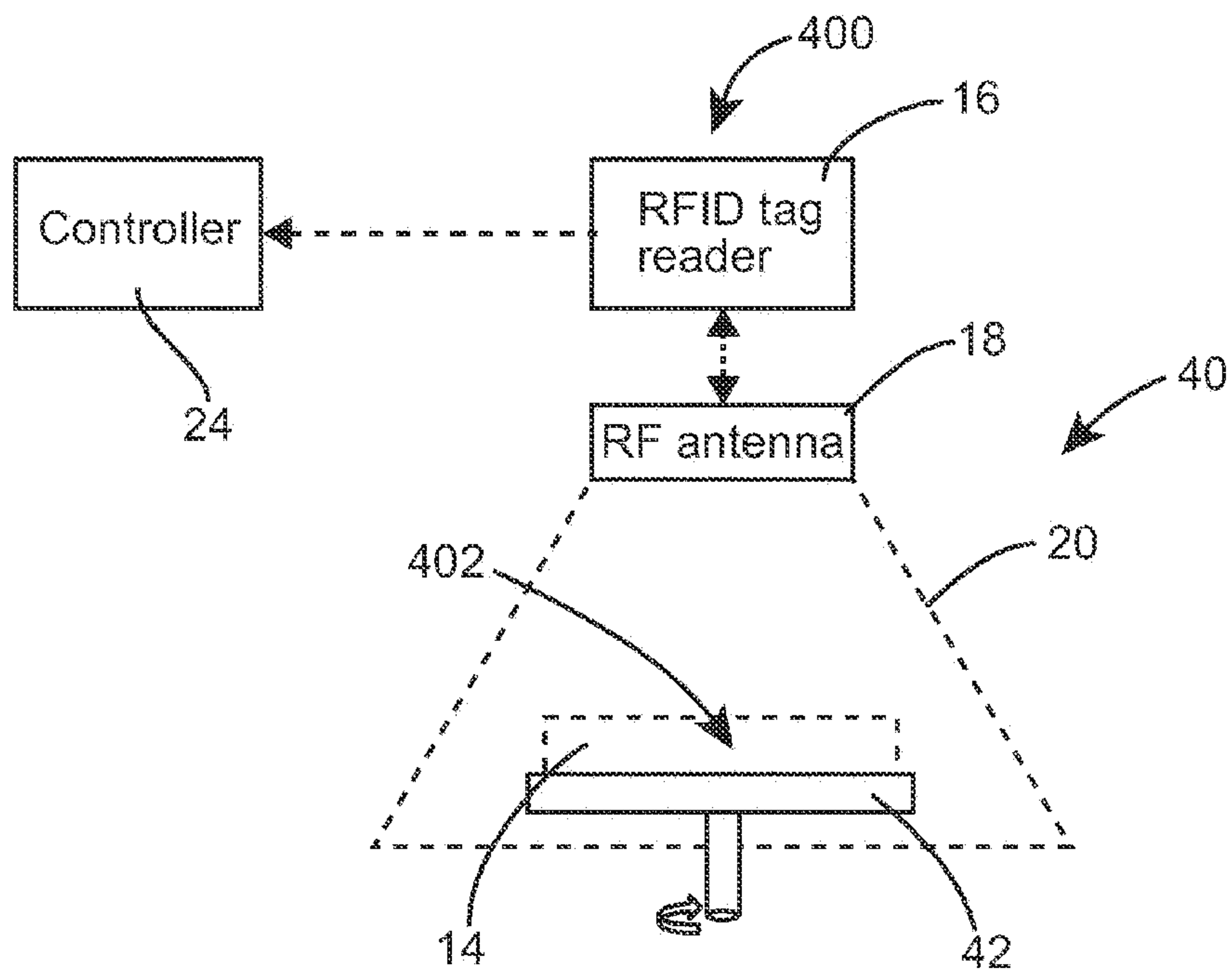


Fig. 19

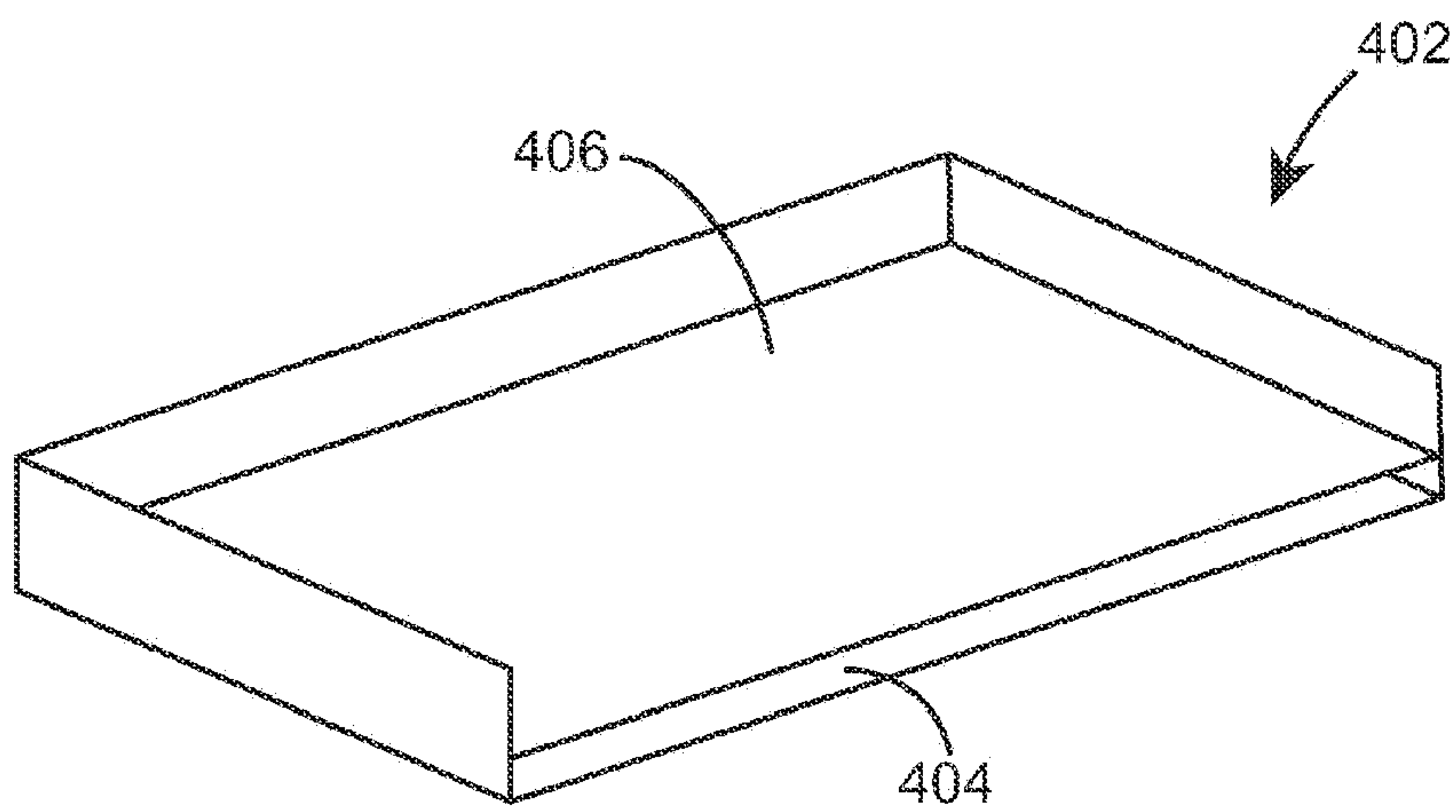


Fig. 20