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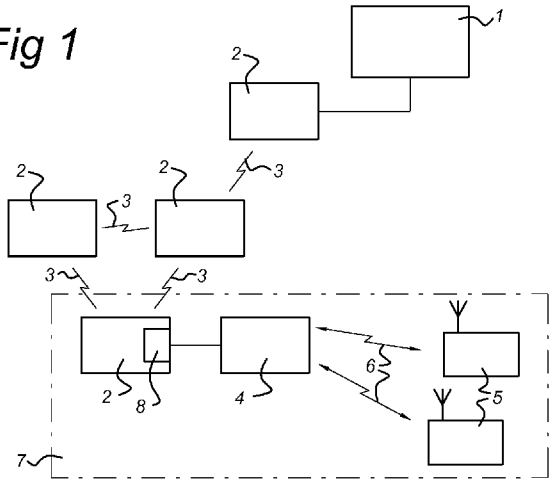
(54) **Title**: LOCATING AND TRACKING SYSTEM

Fig 1



(57) **Abstract**: System for locating an identification unit (5), with a processor unit (1), and a plurality of base stations (2) which together form network connections (3). Each of the plurality of base stations (2) are connected to an associated antenna system (4) and include a received signal strength indication measurement unit (8) for determining a received signal strength indication parameter of a signal transmitted by the identification unit (5). The processor unit (1) is arranged to determine a three dimensional position of an identification unit (5) in a space by processing measurement data and reference data using pattern recognition techniques. The measurement data comprising the RSSI parameter from one of the base stations (2) positioned in the space (7) associated with the signal transmitted by the identification unit (5) and reception data related to the signal from the same identification unit (5) received from another one of the base stations (2).

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Locating and tracking system

Field of the invention

The present invention relates to a system for locating (and tracking) an identification unit.

Prior art

International patent application WO2007/081823 discloses a system using RFID tags for monitoring patients. Both the use of active and passive RFID tags is disclosed. The RFID tags may be connected to a number of further units/devices, such as sensors, PDA's, mobile telephones, etc. The RFID tags are being used in connection with patients, care takers and auxiliary means (such as medicine administration). For a patient, e.g. two RFID tags are being used, one attached to the wrist and one to the ankle, allowing to detect a fall of the patient using antennae positioned on several locations. Antennae are being described in a number of different embodiments, however, these are used for detection in the time domain of the signal emitted by the RFID tags in a very localized area around the antennae, such as a door sill or a part of the floor.

Summary of the invention

The present invention aims to provide an improved system for localisation of one or more identification units, with a higher accuracy allowing application of the system in environments where multiple identification units might be used in limited spaces, e.g. in a hospital or nursing home environment.

According to the present invention, a system as defined in the preamble is provided, wherein the system comprises a processor unit, and a plurality of base stations which together form network connections and are connected to the processor unit for exchanging reception data. Each of the plurality of base stations are connected to an associated antenna system and comprise a received signal strength indication measurement unit for determining a received signal strength indication parameter of a signal transmitted by the identification unit. The processor unit is arranged to determine a three dimensional position of an identification unit in a space by:

processing measurement data and reference data using pattern recognition techniques, the measurement data comprising the received signal strength indication parameter from one of the base stations positioned in the space associated with the signal transmitted by the identification unit and reception data related to the signal from the same identification unit received from one or more of the other base stations.

The system according to the present invention can localize and track multiple identification units (even simultaneously), using the processing technique as described. Having the ability to localize and track multiple identification units allows to monitor e.g. patients, but also medicines or other medical aids. From the monitoring of these identification units, smart processing can be applied to predict certain situations, and to use that information to control (additional) help where needed in a care taking environment such as a hospital or nursing home, in a more efficient manner (help is guided to a place where it is needed at that moment in time).

The reference data comprises one or more of: calibration data, historical measurement data, environmental data in a further embodiment, This may efficiently aid in determining a very accurate position of the identification unit.

In an embodiment of the present system, the associated antenna system comprises a micro-diversity antenna arrangement comprising at least two antennae. The micro-diversity antenna arrangement may comprise a spatial diversity system, polarization diversity system, or a combination of a spatial and polarization diversity system. Such implementations of the antenna system may further enhance accuracy of the system, especially when taking into account the environment and possible different accuracy requirements in different directions.

In further embodiments, the identification unit transmits an RFID signal, and the received signal strength indication measurement unit is arranged to use a predetermined part from the transmitted signal. Using a larger part of a transmitted part than normal for determining the RSSI, a higher accuracy may be obtained.

The identification unit transmits a signal in the sub-GHz range in a further embodiment. This allows to eliminate certain errors in the determination of a position of an identification unit, as in this frequency range, less influence of e.g. building walls and floors may be experienced.

In further embodiments, the identification unit comprises one or more sensor units, and is arranged to include the sensor data from the one or more sensor units in

the transmitted signal, the processor unit being further arranged to extract the sensor data from the transmitted signal. The one or more sensor units may comprise medical data sensor units (heart rate, blood pressure, blood oxygen level, etc.). In a further embodiment, the identification unit further comprises an integrated audiovisual communication system, or optionally an alarm button. Such identification units may be especially suited for application in nursing homes or sheltered accommodations, as the system then allows for efficient (and rapid) application of any required help or assistance.

Short description of drawings

The present invention will be described in more detail below using a number of exemplary embodiments, with reference to the attached drawings, in which

Fig. 1 shows a schematic view of an embodiment of the system for locating and tracking according to the present invention;

Fig. 2 shows a block diagram of a base station according to an embodiment of the present invention;

Fig. 3 shows a flow chart representing the data flows in the system of Fig. 1;

Fig. 4 shows a schematic diagram of an identification unit according to an embodiment of the present invention;

Fig. 5 shows a schematic diagram of a processing unit according to an embodiment of the present invention; and

Fig. 6 shows a schematic diagram of an identification unit according to a further embodiment of the present invention.

Detailed description of exemplary embodiments

The present invention relates to a system that is particularly suitable for use in healthcare, such as in hospitals, nursing homes, etc. The system combines an intelligent and efficient positioning system ("RTLS, real-time location system) and a wireless sensor network ("WSN, wireless sensor network") for tracking, observing and analysing persons and objects. Through small so-called 'tags' (cards, wrist watches) with a small transmitter and several possibilities for sensing, persons and objects can be accurately located, and both physiological / medical and environmental information is collected. The information collected can be used not only to store their status (e.g.

sensor data), but in some cases to predict incidents, leading to improved safety and economy.

Fig. 1 shows a schematic view of an embodiment of the entire system for tracking, observing and analysing persons and objects. Central to the system is a processor unit 1, which is arranged to receive and process all types of data that is received. This is explained in more detail with reference to Fig. 5 below.

The processor unit 1 is connected to a cluster of base stations 2 (or nodes / node, henceforth referred to as cluster radio receiver 2, which together with each other forms a (flexible) network using a predetermined network communications technique. For example, use is made of wireless communication (in Fig. 1 marked with reference number 3) so that a flexible network of base stations 2 can be formed. The base stations 2 may for example be placed in different spaces 7 in a building (e.g. one base station 2 per room as a room, hall, common room).

Each cluster radio receiver 2 is equipped with an antenna array 4 that comprises a special configuration of individual antennae (minimum two) which make the cluster radio receiver 2 suitable for positioning. This part of the cluster radio receiver 2 and antenna array is based on active RFID technologies. The cluster radio receiver 2 communicates via its antenna array 4 with one or more identification units 5 ('tags') using RFID communication (indicated by reference number 6 in the view of Fig. 1).

Each cluster radio receiver, or base station 2, comprises a received signal strength indication measurement unit 8 for determining a received signal strength indication parameter of a signal transmitted by the identification unit 5.

In prior art positioning systems use is made of at least two and usually three antennae each with an associated receiver to determine a location of an identification unit 5 (e.g. using hyperbolic positioning or triangulation). With the embodiments of the present invention one cluster radio receiver 2 is sufficient for accurately determining a location of an identification unit 5 in a specific area 7 in three dimensions. This makes the installation, configuration and calibration much cheaper, faster and easier than with conventional systems.

Each identification unit 5 is uniquely traceable by means of a unique code, as known in RFID technology.

Each cluster radio receiver 2 can both communicate with the identification units 5, and also with other cluster radio receivers 2 to form a network. A possible

embodiment of a cluster radio receiver 2 is shown in the simplified block diagram in Fig. 2. Bi-directional communication between cluster radio receiver 2 is obtained via a network transceiver 22, under control of a first control unit 21 (e.g. in the form of an embedded controller). The first control unit 21 is arranged to comprise a network set up with other cluster radio receivers 2 within range, making it possible to easily form a network having a very large coverage area (e.g. different rooms on different floors of a nursing home). Data are communicated from the identification units 5 via this network through different cluster radio receivers 2 to the (central) processor unit 1.

The data transmission using such a network (mesh network) can be broadband, stable and adaptive. Although the base stations 2 to be used are technically complex, this set-up still provides advantages on a managerial and operational level. Thus, from the (central) processor unit 1 the base stations 2 can be controlled remotely for allowing adaptive configuration and calibration of frequency, transmission power, modulation, etc. It is also possible to synchronize the different data paths (RFID, Mesh networking), in order to have the many asynchronous data transfer cycles perform in a good and effective process.

The base stations 2 can be equipped with hardware and/or software filtering in order to prevent interference between the RFID part and network part of the system. Also, measures can be taken to optimize the data throughput, range and delay times ('latency').

Each cluster radio receiver 2 is also connected to an associated antenna array 4 that has a local coverage area in the space 7. More specifically, each cluster radio receiver 2 comprises an RFID transmitter and receiver system 24, which is driven by a second control unit 23. The first and second control units 21, 23 are also connected to each other. The calculations required for locating an identification unit 5 in a space 7 which is covered by a cluster radio receiver 2 can be implemented in the second control unit 23. Alternatively, relevant data are transmitted, and the actual positioning calculations are implemented and executed in the central processor unit 1.

In a further embodiment, the functionality of the base station 2 (both positioning / sensor interface and network functionality) is combined in a single radio device.

In general terms, the present invention embodiments relate to a system for locating an identification unit 5, comprising a processor unit 1, and a plurality of base stations 2 which together form network connections 3 (e.g. in the form of a mesh

network) and are connected to the processor unit 1 for exchanging reception data, each of the plurality of base stations 2 being connected to an associated antenna system 4 and comprising a received signal strength indication measurement unit 8 for determining a received signal strength indication parameter of a signal transmitted by the identification unit 5, the processor unit 1 being arranged to determine a three dimensional position of an identification unit in a space 7 by:
processing measurement data and reference data using pattern recognition techniques, the measurement data comprising the received signal strength indication parameter from one of the base stations 2 positioned in the space 7 associated with the signal transmitted by the identification unit 5 and reception data related to the signal from the same identification unit 5 received from one or more of the other base stations 2.

The real time location system (RTLS) approach used in the present invention embodiments is RSSI-based (RSSI: Received Signal Strength Indication), which allows for low cost implementations using generally available components. Straightforward RSSI-based RTLS is typically not accurate enough for indoor use, because of hard to predict variations in the relation between RSSI and actual transmitter-receiver distance. Important reasons for these variations are lack of line-of-sight between transmitter and receiver (e.g. walls, floors, cabinets), resulting in signal attenuations, and indirect signal paths via reflections/refractions from objects (e.g. walls, floors, cabinets), resulting in multipath interference.

To solve these issues, pattern recognition techniques are used as mentioned above, where the system 1 e.g. learns about the (often complex) three-dimensional signal propagation variations in the area under observation. If enough reference information is available, the pattern recognition algorithm can effectively deal with the complex relation between received signal strengths and actual distance between transmitter and receivers. Reference information is provided by means of explicit measurements (calibrations) or by learning during operation (e.g. by using inferred location data), or the reference data used are calibration data, historical measurement data and/or environmental data (based on knowledge of surroundings where the system is activated).

The pattern recognition system is based on a supervised classification algorithm using nearest neighbour search for known locations. Known locations are represented by clusters of accumulated sample data and associated confidence values. The space

being represented and searched is an N-dimensional continuous variable space (N equal to the number of cluster receivers) where the variables are processed receiver signal strengths. In this space a proximity search is done to determine the nearest known (stored or learned) location patterns. Proximity to known location patterns is determined by an inverse (Euclidian) distance estimate using confidence weighted averages of samples. Distance estimates include corrections for known receiver characteristics.

A flow chart of an embodiment of such an algorithm is shown in Fig. 3, which algorithm is e.g. implemented in the processor unit 1 as shown in Fig. 1.

From the various base stations 2, reception data is received via the network connections 3 and used as reference data (block 32) and/or measurement data (block 33). For each of these types of data, descriptors are being calculated in blocks 34 and 35. The reference data is stored in a reference storage 37, under the control of a reference storage management unit 36. The measurement data and the stored reference data are used to perform a proximity search (block 38), which results in a (three dimensional) location, together with confidence data (block 39) representing a calculated degree of correctness of the calculated location data.

Further enhancements of the location system can be implemented using e.g. sub-GHz transmitters and receivers where possible (e.g. the identification unit 5, base station 2 in Fig. 1), to minimize attenuation by building infrastructure and to minimize complexity of multipath interference patterns.

In a further embodiment, high quality RSSI measurements are used, which use a larger part of a transmission to determine the RSSI parameter than usual in general purpose equipment. The predetermined part of a transmitted signal actually being used for the RSSI measurement allows a higher accuracy.

In an even further embodiment, the receiver antenna system 4 comprises a micro-diversity antenna arrangement, having at least two antennae. The micro-diversity antenna arrangement uses a scheme including spatial and/or polarization diversity. The actual diversity scheme used can be adapted to specific situations (such as different accuracy requirements in different directions) to reduce cost and complexity. For example, for many indoor applications the requirements for accuracy in horizontal directions are higher than in vertical direction.

In an exemplary embodiment, the antenna system 4 comprises three separate antennae positioned on a line, at a mutual distance of $\lambda/4$, λ being the transmission wavelength. In a further embodiment, a two dimensional antenna array is used, e.g. using five separate antennae in an L shaped configuration, again at a mutual distance of $\lambda/4$.

The multiple antenna signals are combined in each base station 2 (see Fig. 1) in such a way as to approximate the RSSI value as it would have been at the receiver location without multipath fading effects. This does not compensate for other variations in signal propagation (i.e. absolute attenuation and reflection signal strengths).

In Fig. 4 a simplified block diagram is shown of an embodiment of an identification unit 5 as used in the present invention. The identification unit 5 includes a processor 51 (microcontroller) which is connected to and functionally controls other parts of the identification unit 5. An RFID transceiver 52 is connected to a suitable antenna 53, and is able to receive and process interrogations from a cluster radio receiver 2, for example by compiling and transmitting a data packet. Further parts of the identification unit 5 are an (electric) power supply 56 (e.g. a battery), and an input/output unit 57 (e.g. for controlling controls and indicators). Also, the processor 51 of the identification unit 5 is connected to a sensor interface circuit 54. This allows reading data from different types of sensors 55, such as shock, motion, temperature, heart rate and blood pressure sensors.

A number of physiological sensors 55 may be combined in one embodiment of the identification unit 5. Data from these sensors 55 are pre-processed and combined by the local microcontroller 51. Such an intelligent soft-sensor embodiment of the identification unit 5 provides a continuous and hence real-time insight into the welfare of the person wearing the identification unit 5. The sensor information which becomes available is transmitted wirelessly to a central data storage and processing system, such as the aforementioned processor unit 1. This processor unit 1 is then arranged to extract the sensor data from the transmitted signal. Furthermore, the processor unit 1 may use knowledge about the type of data to be expected as reference data in determining the location of the identification unit 5 (see Fig. 3 and description above). Continuous insight and trend analysis of sensor information contributes to understanding the effectiveness of care processes but also can detect prematurely medical or safety conditions and allow preventive intervention. One possible step toward miniaturization

is, for example, integrating temperature, blood pressure, heart rate, SpO_2, humidity and acceleration sensors (or further medical data sensor units) in the identification unit 5 for interactive communication with the central system 1 and from there to the caregivers.

The sensor interface circuit 54 may be suitable for direct connection to sensors 55, for wireless communication with sensors 55 (e.g. via Bluetooth, infrared, ZigBee, etc.). The sensors 55 can be passive or active sensors, and externally powered or equipped with an own power supply, for example in the form of a battery.

The identification unit 5 can be carried out as a small box that can be worn on the person, or according to the precise application is implemented using another suitable housing. Controls or connecting elements with the sensors 55 may be present and vary according to the specific application.

In Fig. 6 a very specific embodiment of an identification unit 5 is shown with a more extensive functionality. This "Communicator" is applicable for use in prevention, safety and reduction of cost of care for the elderly, by allowing direct personal and audiovisual contact with a care-taker or emergency personnel in case of an incident. For this, the identification unit 5 comprises an integrated audiovisual communication system, wherein the communication path is integrated in the data transmission paths 3 (see Fig. 1), or as an independent transmission path. The communicator 5 provides security and allows for longer living at home when possible, while assistance becomes faster, more flexible and more personal. The concept of communicator 5 is an intelligent device, for example in the form of a wristwatch, comprising a processor 61 which is suitable for controlling and managing one or more of the following functional elements.

A microphone 62, speaker 63 and display 64 which communicate with the processor 61 makes the communicator 5 suitable for hands free (video) communications, as available on modern mobile phones. Even a camera can be added.

The processor 61 is also connected to an RF unit 66 which is in communication with an associated antenna 67. This RF unit enables wireless connections (for example based on Wi-Fi, WiMAX, LTE, UMTS, GSM, etc.) to a local or remote station, for example, the above described cluster radio receiver 2. As an alternative existing local networks or mobile networks can be used, or a mix of local (e.g. Wi-Fi) and remote (e.g. VoIP).

The processor 61 is also connected to a localization unit 68, such as a GPS receiver, connected to a suitable antenna 69. This makes traceability possible on location, e.g. via a wireless network in the event of an incident.

Built-in or external sensors 71 are provided, which are in communication with the processor 61 via an interface 70. Sensors 71 with different capabilities may be present, for example detection of falling incidents (acceleration), stress (transpiration / conductance, heart rate), status (heart rate, temperature). For indicators of an incident / emergency, the processor 61 may be programmed to instantly and automatically establish contact with a care-taker or emergency personnel, without an act of the carrier being required (who may not, or no longer, be capable to act accordingly). If the user is still able to communicate the situation can quickly be evaluated by a health-care provider using the (visual) communication capabilities. For that purpose, the processor 61 can be fitted with suitable sensor interfaces and algorithms that can provide an indication of an incident. This may be implemented as a mobile application software (along with associated software in a central processing system, for example, the processor unit 1 of the system shown in Fig. 1), with appropriate interfaces.

When the communicator 5 is designed as a wristwatch, it is possible for one or more of the sensors 71 to be integrated in the housing and so enable contact with the skin of a user.

The processor 61 is also connected to a keyboard 65, which allows function control of the communicator 5, and allows text to be entered, for example a message to be send. In addition, an alarm button 72 may be part of the keyboard 65 for enabling an explicit request for help or assistance.

Various elements of the communicator 5 as described herein are known as such (e.g. in the technical area of mobile phones), allowing the production of the communicator 5 in an affordable and achievable manner. In one advantageous embodiment of the communicator 5 the functionality of a mobile "smart phone", sensors 71 and an alarm button 72 are integrated into a suitable attribute for a target group (e.g. 'the elderly'), such as a wristwatch.

In Fig. 5 a block diagram is shown of the (central) processor unit 1, in which a processing unit 11 (e.g. a microprocessor) is the central element. The processor 11 is connected to a memory 12, in which software instructions are loaded during operation, and (intermediate) data is stored. In addition, the processing unit 11 is connected to

input and output unit 13, for example for connecting a monitor, keyboard and such. Finally, the processing unit 11 is connected to one or more databases 14, 15, in which data can be stored in a structured manner.

The processor 11 of the processor unit 1 may execute software instructions that provide the system with the necessary functionality. This may be positioning software (whereby the position can be tracked from a variety of identification units 5), and software for analysing sensor data obtained. Thus, for example, storage of historical and real-time data to be held in one of the databases 14, 15 may be implemented in the processor 11. Based on these data analysis and forecasts can be carried out.

In one embodiment of the tracking and monitoring system according to the present invention much measurement data from the numerous sensors 55, 71 can be continuously sent to the central system (processor unit 1). These data originating from the sensors 55, 71, are centrally processed and analysed and are continuously compared with historical data from the same person, to quickly detect abnormalities.

Environmental variables such as temperature, time of day, time since last meal, amount of movement and data from the medical background of the person are accounted for in multivariate analysis and modelling in order to obtain as completely as possible an image of the actual situation of the person. The insights as provided using this method are to be presented to care professionals in a useful manner in order to support them in their work. Actions as a result of the analysis and interpretations are also presented to the health professionals who may choose to act thereon.

All data is used centrally in a variety of analysis, correlation calculations and modelling. It will therefore comprise details of the care clients relating to location and sensor data, such as temperature, blood pressure, heart rate, oxygen saturation, moisture, posture, etc.

The present invention embodiments have been described above with reference to a number of exemplary embodiments as shown in the drawings. Modifications and alternative implementations of some parts or elements are possible, and are included in the scope of protection as defined in the appended claims.

CLAIMS

1. System for locating an identification unit (5), comprising a processor unit (1), and a plurality of base stations (2) which together form network connections (3) and are connected to the processor unit (1) for exchanging reception data, each of the plurality of base stations (2) being connected to an associated antenna system (4) and comprising a received signal strength indication measurement unit (8) for determining a received signal strength indication parameter of a signal transmitted by the identification unit (5),
the processor unit (1) being arranged to determine a three dimensional position of an identification unit (5) in a space by:
processing measurement data and reference data using pattern recognition techniques, the measurement data comprising the received signal strength indication parameter from one of the base stations (2) positioned in the space (7) associated with the signal transmitted by the identification unit (5) and reception data related to the signal from the same identification unit (5) received from one or more of the other base stations (2).

2. System according to claim 1, wherein the reference data comprises one or more of: calibration data, historical measurement data, environmental data.

3. System according to claim 1 or 2, wherein the associated antenna system (4) comprises a micro-diversity antenna arrangement comprising at least two antennae.

4. System according to claim 3, wherein the micro-diversity antenna arrangement comprises a spatial diversity system, polarization diversity system, or a combination of a spatial and polarization diversity system.

5. System according to any one of claim 1-4, wherein the identification unit (5) transmits an RFID signal, and the received signal strength indication measurement unit (8) is arranged to use a predetermined part from the transmitted signal.

6. System according to any one of claims 1-5, wherein the identification unit (5) transmits a signal in the sub-GHz range.

7. System according to any one of claims 1-6, wherein the identification unit (5) comprises one or more sensor units (55; 71), and is arranged to include the sensor data from the one or more sensor units (55; 71) in the transmitted signal, the processor unit (1) being further arranged to extract the sensor data from the transmitted signal.

8. System according to claim 7, wherein the one or more sensor units (55; 71) comprise medical data sensor units.

9. System according to claim 7 or 8, wherein the identification unit (5) further comprises an integrated audiovisual communication system (62-64).

10. System according to any one of claims 7-9, wherein the identification unit (5) further comprises an alarm button (72).

Fig 1

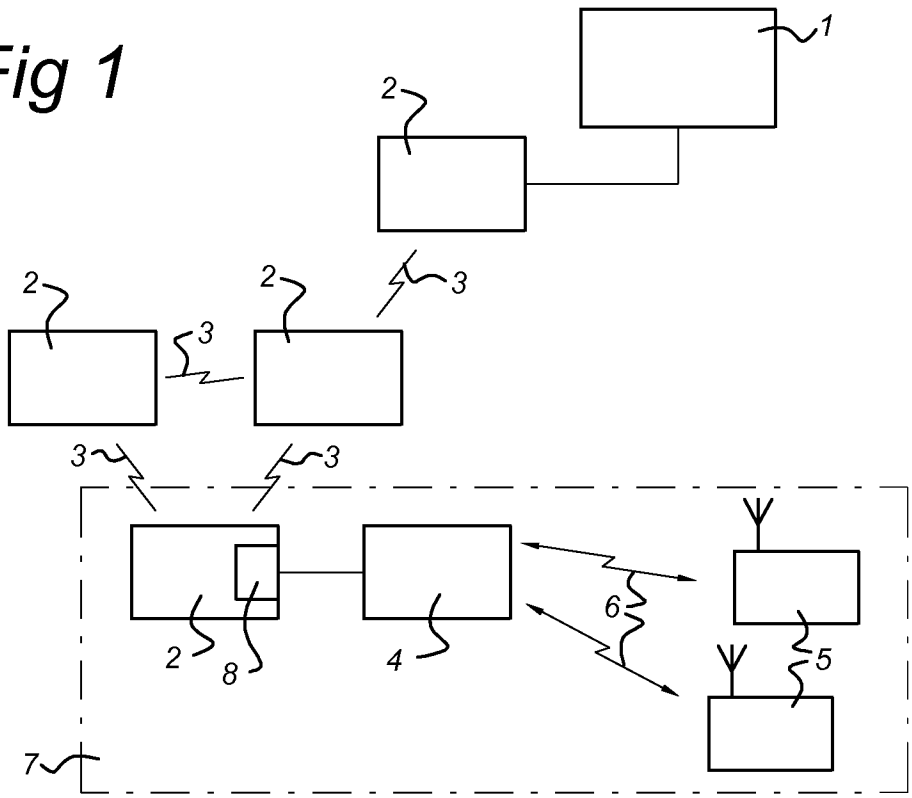


Fig 2

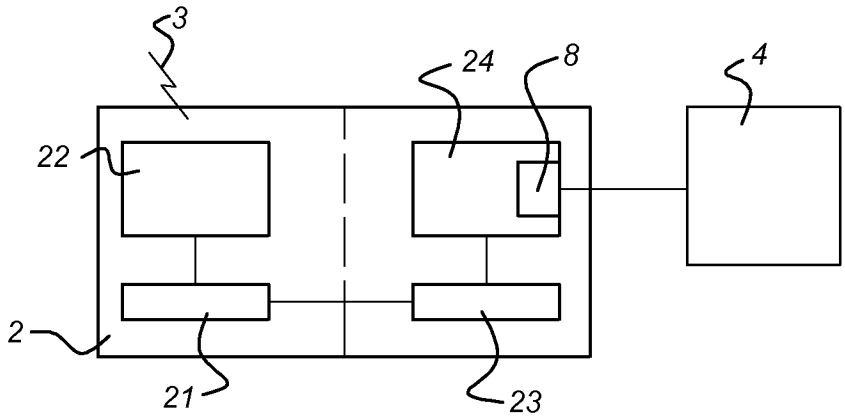


Fig 3

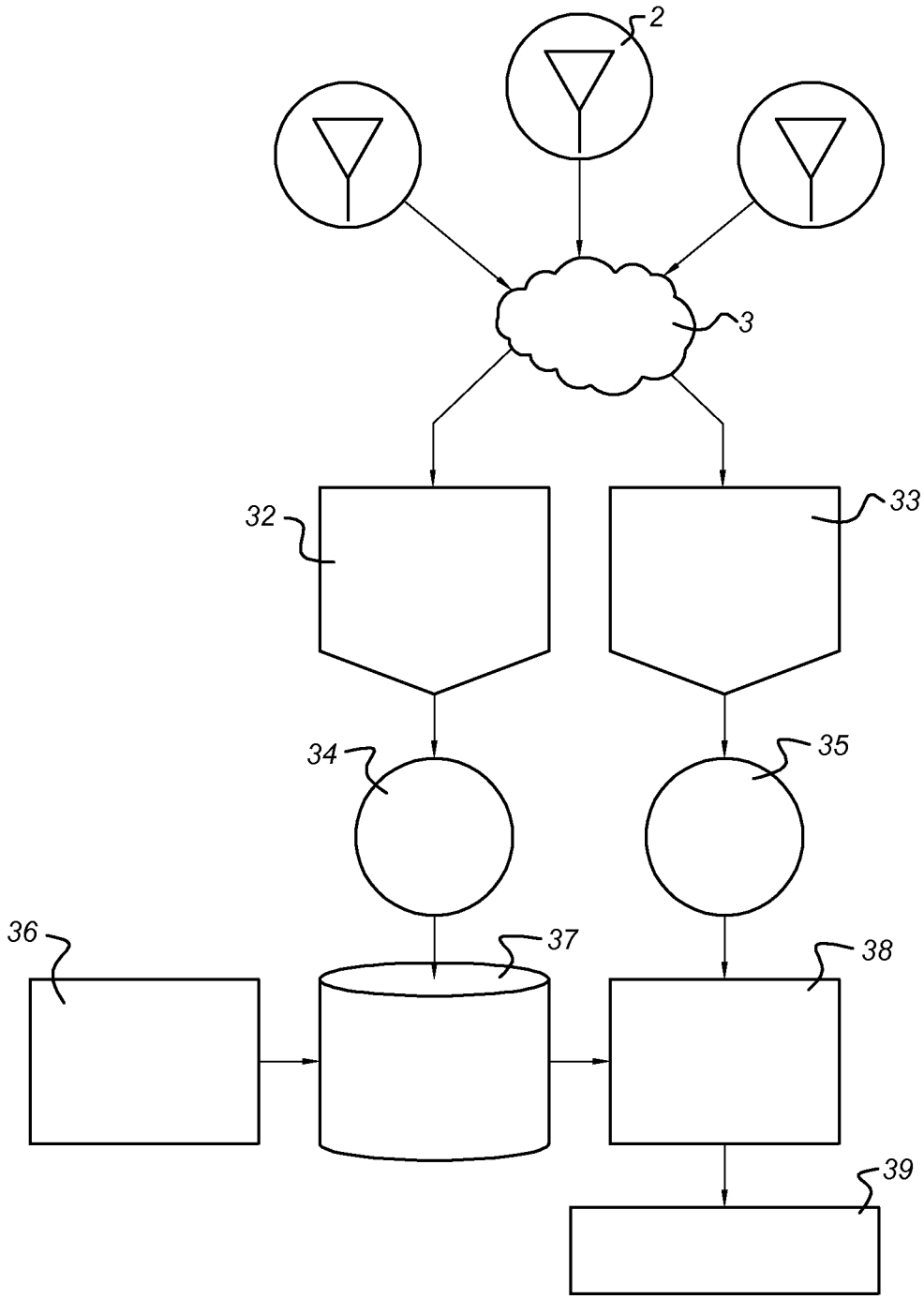


Fig 4

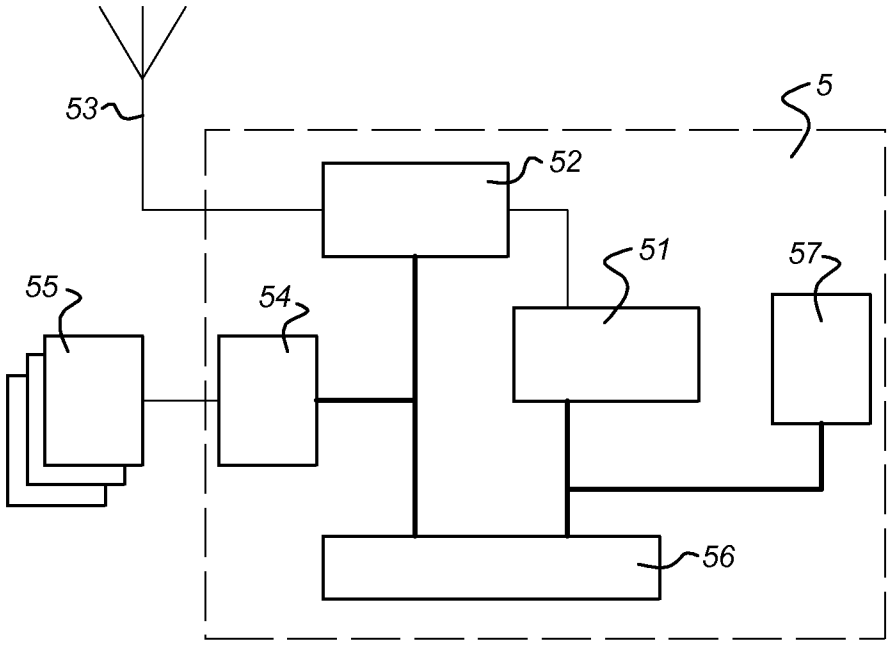


Fig 5

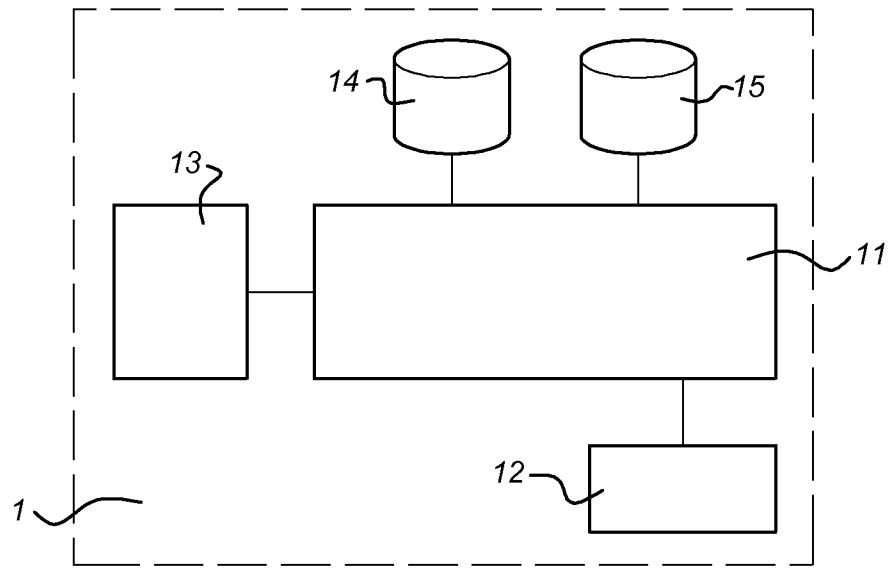
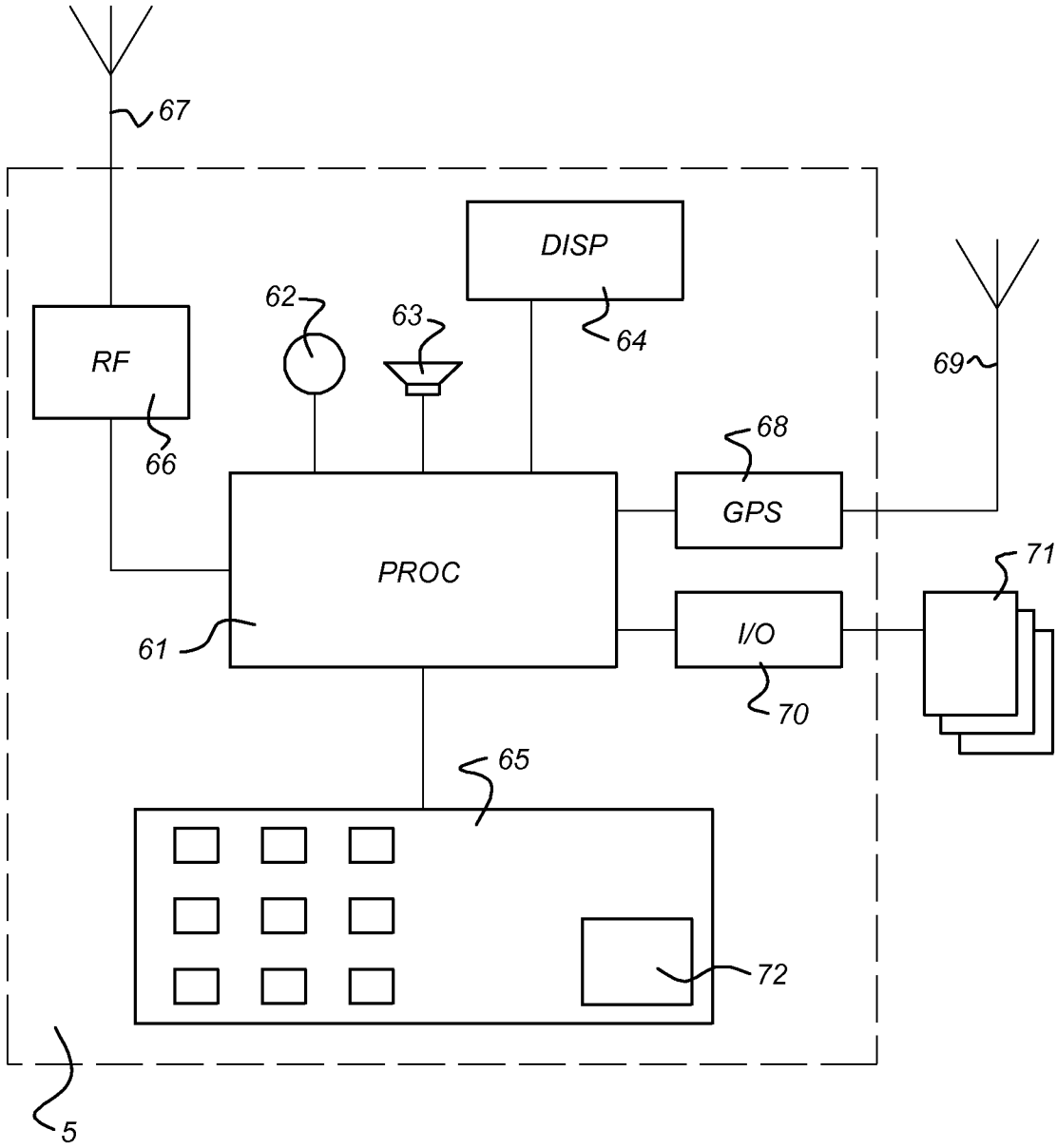


Fig 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2011/050708

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S5/02 G01S13/76
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/174569 A1 (SMITH DEREK M [US] ET AL) 9 July 2009 (2009-07-09)	1-6
Y	paragraphs [0010], [0040], [0064], [0078] - [0081], [0094] - [0098], [0111], [0123] - [0125], [0131], [0134], [0170], [0171] claim 1	7-10
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[X] Further documents are listed in the continuation of Box C.

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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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