



(51) International Patent Classification:

G06K 7/10 (2006.01) G06K 17/00 (2006.01)
G01S 13/75 (2006.01)

(21) International Application Number:

PCT/SK2023/050018

(22) International Filing Date:

22 June 2023 (22.06.2023)

(25) Filing Language:

Slovak

(26) Publication Language:

English

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ,

(54) Title: SYSTEM AND METHOD FOR DETECTING ZONE OCCUPANCY USING PASSIVE RFID TAGS

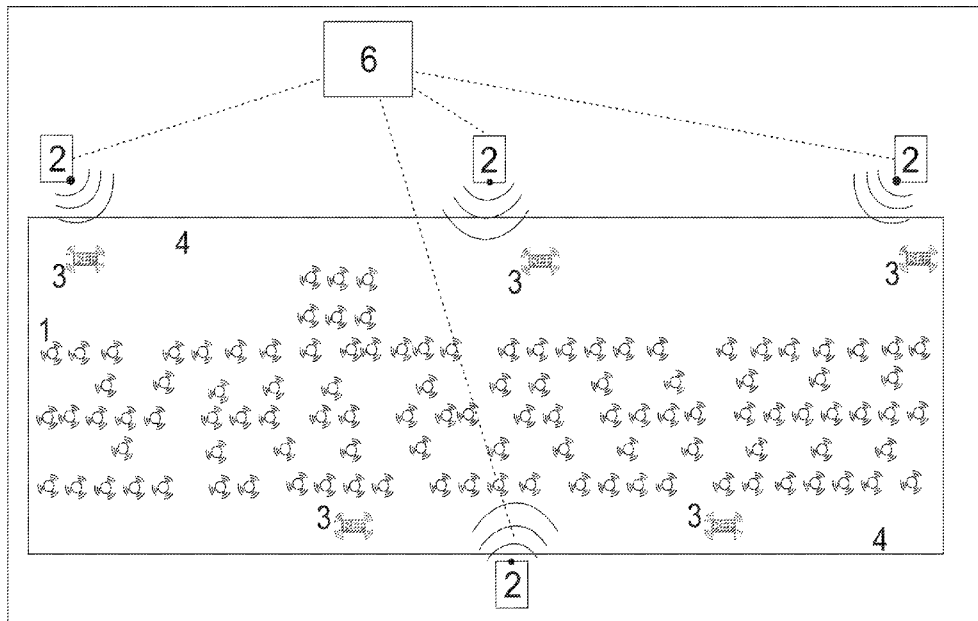


Fig. 1

(57) Abstract: Method for detecting the occupancy of a zone using passive RFIDs performed by a zone occupancy detection system, the method comprising - verification of the presence and faultlessness of the system by reading the identifier of the passive reference RFID transponder (3) at changing intensity of the transmitted RFID radio signal in the UHF band, - detection of the occupancy of the detected zone (4) by reading the identifiers of the passive detection RFID transponders (3) placed in the detected zone (4) at changing intensity of the transmitted RFID radio signal, - determining the occupancy of the detected zone (4) by the absence of a received RFID signal or by a change in the received RFID signal intensity.



RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to the identity of the inventor (Rule 4.17(i))*
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*

SYSTEM AND METHOD FOR DETECTING ZONE OCCUPANCY USING PASSIVE RFID TAGS

Field of the invention

The invention relates to a system and method for detecting the presence of objects in a dedicated site area by means of a variably distributed network of UHF RFID passive tags, excitation signal transmitters, receivers and other necessary control and support elements. The invention falls within the field of zone monitoring.

Background of the invention

Several systems for determining site occupancy are widely known in the global market. These are, for example, systems using active sensors based on multiple physical stimuli. However, these sensors require active power supply. Such a system is represented, for example, by a method for detecting the presence of a motor vehicle in a detected zone with identification of its engine type and a detection device described in the disclosed in the published patent application WO2021230825A1.

Nowadays, more advanced systems for determining site occupancy based on RFID technology are known. Radio Frequency Identification (RFID) is a form of wireless communication with a long history of development. The first working prototypes using RFID technology can be dated back to the 1970s. These were passive systems in which a modulated RF signal was transmitted by a transmitter and subsequently received by a receiver. The receiver was passive, with no energy storage of its own, while the received RF signal provided it with enough energy to respond in the form of a change in its input impedance. The difference in input impedance resulted in signal dissipation, which was interpreted as a response in this form of communication. From that time to the present, the technology has undergone significant evolution, during which several standards of this technology have been adopted.

The initial division can be realized through the frequencies used into low frequency (LF) using 125 to 134 kHz, high frequency (HF) using 13.5 MHz and ultra-high frequency (UHF) using 860 to 960 MHz. In the cases of LF and HF RFID, only short distance communication is possible. In the case of UHF RFID, it is possible to reach distances in the range of 3 to 6 m, but by using appropriate technical solutions they can reach greater distances; however, this depends on the specific device.

Also, solutions using a tag (also referred to as a transponder) are known, which can be passive, active, or semi-passive. Passive transponders are completely powered by the radiated power from the transmitter. Communication with the passive transponder is accomplished by modulating the backscatter of the RF wave. Since they do not contain their own energy storage, passive transponders have unlimited lifetime while maintaining small size, light weight, and low cost. However, fully passive RFID sensor transponders suffer from short communication range. An alternative is passive transponders that, upon receiving an energy signal at a specific frequency, transmit data back via FSK or PSK modulation.

In the case of semi-passive transponders, after the initial reception of energy and the transmission of the response, the power radiated from the transmitter is focused on a specific transponder. By this the implemented energy storage is charged and is capable of powering the electronic elements and sensors. The data thus acquired is stored in memory and broadcast to the reader in the next cycle, as described in document WO2017118914 A1.

As mentioned above, UHF RFID operates in the 960MHz band in the US and in the 865 to 868 MHz band in EU, which is the free band where most IoT networks such as LoRa Sig-Fox, as well meteor stations or alarm or gate lockers transmit. This band is susceptible to interference due to the fact that it is highly used, or interference can occur from the 430MHz band, which is most often used for wireless doorbells, weather stations, tire pressure measurement, etc.

Due to the physical nature of the RF signal, the range of RFID depends on a number of factors, which can be divided into the transmitter influence and environmental influence. Regarding transmitter influences, it is necessary to mention the antenna characteristics. In particular, potential errors in the design or manufacture of the hardware parts contribute to the basic degradation of the signal level. Antenna directivity and transmit power play an important role too.

Environmental influences include the effect of ambient noise and environmental phenomena and influences such as rain, snow, and fog. The impact of noise is dependent on the use of the frequency band in question, or electromagnetic interference caused by the radiation of machines. However, a significant environmental factor is the resulting attenuation on the transmitter-transponder path.

The use of UHF RFID in a retail chain to track inventory and to improve the efficiency of the purchasing process for customers is well known in the state of the art. An example is the

granted patent US11043093B2, which describes an RFID-based retail logistics system using a group of antennas and RFID transceivers attached thereto, using passive RFID transponders placed on objects to accurately locate those objects in a retail store. The objects so localized may even include shoppers carrying their own RFID transponder, for example in the form of a suitable shopping card. The localization of the object itself is determined by localising the transponder associated with this object, which thus does not form an integral part of the detected zone, by means of a number of possible methods described above, for example, by means of a phase shift or time shift of the response signal transmitted from the RFID transponders, received by a number of transceivers, or by determining the distance of the object with the RFID transponder by statistical evaluation of the strength of the response signal of the RFID transponder to the changing strength of the signal transmitted by the RFID transceivers. The system operates with transceivers in the 860-950 MHz band.

The UHF RFID technology is also used to track the movement and behaviour of wild animals in the wild. The granted patent US10628756B1 describes the use of RFID technology to track and monitor livestock, along with monitoring of basic vital signs and behaviour. Individual animals are tagged with RFID transponders, preferably also GPS receivers or altimeters.

The system described further comprises a set of RFID transceivers arranged at individual geographic locations through which the information from the RFID transponders tagging the individual animals are collected, and thus the RFID transponders used do not form an integral part of the geographic locations being monitored. The system then statistically processes the collected data using machine learning methods and evaluates it in relation to other environmental data, such as weather, meteorological and agrotechnical data. The result is information on the behaviour, health, or condition of the animals, including a prediction of the treatment or therapy needed, or information on when the animals will be suitable for sale and other commercial use.

This technology can be used in many sectors of industry as well as everyday life. The first possible uses is logistics and storage of goods. UHF RFID is used to track items and inventory in warehouses, logistics centres, factories, and manufacturing plants. An example is tracking the presence of goods equipped with a passive RFID transponder in logistics storage systems. Chinese document CN212846845U describes a storage system comprising intelligent storage shelves with individual storage locations, wherein an RFID transponder and its antenna are fixedly placed on the inner surface of the top wall of each such storage location, and the

surface of all inner walls of such storage location is treated with an electromagnetically shielding coating, preferably a 20-25 microns thick electrically conductive copper-based coating.

If an object with an RFID transponder is placed in a storage location, the structural arrangement of such a smart shelf together with the electromagnetically shielding coating ensures that the interference of the return signal of the RFID transponder from the object placed in the storage location is minimized by the possible signals of other transponders from objects placed on other adjacent storage locations, thus enabling more accurate localization of the object on the shelf. However, it is true that the RFID transponders are placed on the localized objects themselves and thus are not an integral part of the monitored zone.

A frequently used alternative is represented by various RFID gates detecting the passage of the detection transponder. The disadvantage, however, is the need to embed a gateway in each exit, as well as the implementation of detection transponders on each tracked object. Hence, the flexibility of the declared systems is considerably low, with the system failing to detect objects without detection transponders.

The common denominator of all the cited patent documents but also other examples from the state of the art is the fact that a necessary condition for their operation is the placement of the RFID transponder directly on the localized object. This brings a few of complications in practice, since for the functioning of such systems it is necessary to ensure that the RFID transponders are not separated from the detected objects, which is often difficult, since these objects are subject to logistic operations, during which the transponders may become separated from the localized object or lost. It is also not negligible that it is not always technically possible to ensure the placement of the RFID transponder on the localized object, e.g., when using RFID technology to locate or identify the presence of people in the monitored area. Finally, the financial aspect related to the massive deployment of RFID transponders with a very high number of tracked or localized objects is very important too.

The disadvantages resulting from the above-described state of the art are eliminated by the present technical solution. Using suitable technical means, a system and method for object detection has been developed which does not require the tracked, localized or monitored object to be equipped with a detection tag. It is this feature that increases the flexibility of use for many cases where it is not possible or not appropriate to tag the tracked objects before activating the system.

Summary of the invention

To minimize the shortcomings of occupancy zone detection systems, a sophisticated system and method for occupancy zone detection using passive RFID transponders according to the invention has been proposed, which is based on the use of technical knowledge about the effect of interference of selected materials on the signal transmission from RFID transponders. This information is then used to determine the presence of objects in the detected zone and share it via IoT networks.

If no object with interference is present in the zone, the set of detected signals from the excited UHF RFID transponders is different from the set detected when objects with interference are present in the zone. The system consists of several main components. Priority must be given to the transceiver consisting of a transmitter and receiver of radio signals with directional antennas and a microcontroller. The whole system is highly modular and for it to be functional, at least one transceiver must be used. The distribution of transceivers is multi-directional to potentially increase the coverage of the whole system. The transceiver transmitter has a variable transmit radio signal strength in the UHF band. The transceiver receiver has variable sensitivity to received radio signal in the UHF band. In addition to the transceivers, the system has passive detection RFID transponders, the number of which is typically many greater than the number of transceivers as well as passive reference RFID transponders, the number of which is typically much smaller than the number of passive RFID detection transponders.

The position of the passive reference RFID transponders is chosen during the installation so that there is no potential shadowing of these passive reference RFID transponders, therefore the passive reference RFID transponders are placed above the detected zone on supporting structures such as walls, trees, public lighting, etc. At the same time, the selected position represents the furthest or nearest point of the detection zone. The passive detection RFID transponders are placed in a random or organized pattern in the zone area, such as a parking space, parking stall, or are placed on foot-stones, curbs, etc.

For the purposes of the present invention, the term passive detection RFID transponder (alternatively referred to as a passive detection RFID tag) is to be understood as a carrier for a passive RFID chip and antenna. The same applies to the term passive reference RFID transponder (also referred to as passive reference RFID tag). After defining the detection zone by the pattern of the passive detection RFID transponders, their passivation by a suitable coating takes place. The function of passivation in this case is multi-purpose, whereby the transponder

is protected against weather conditions as well as fixed to a selected vertical or horizontal surface.

For the purposes of the present invention, the term passive detection RFID transponder is to be understood to include an electromagnetically passive coating in which the passive detection RFID transponders are contained and dispersed. The same applies to the term passive reference RFID transponder.

For the purposes of the present invention, the term detected object is to be understood to mean an automobile, vehicle, person, trailer, etc.

For the purposes of the present invention, strict requirements are imposed on the passivation material, wherein the passivation material has the following functions. A fixation function, wherein the passivation material must sufficiently fix the passive detection RFID transponders at a defined surface position. Further, a moisture and water protection function, i.e., the passivation material is impermeable to moisture and water and thus protects the passive detection RFID transponders. Another function is enabling the passage of the RFID signal, i.e., the passivation material must enable the passage of the RFID signal. Another function is electrical non-conductivity, i.e., the passivation material behaves as an electrical insulator. Another function is thermal stability, i.e., the passivation material is resistant to both high and low temperatures and thus allows for long-term fixation of passive detection RFID transponders outdoors. Another function is abrasion resistance, i.e., the passivation material is abrasion resistant and allows passive detection RFID transponders to be fixed even in mechanically stressed locations.

A method for detecting zone occupancy using passive RFIDs is based on the system described above. This method includes the following basic steps:

- verification of the presence and faultlessness of the system by reading the identifier of the passive reference RFID transponder at changing intensity of the transmitted RFID radio signal in the UHF band,
- detecting zone occupancy by reading the identifiers of the passive detection RFID transponders placed in the detected zones at changing intensity of the transmitted RFID radio signal,
- determining the occupancy of the detected zone by the absence of a received RFID signal or by a change intensity of the received RFID radio signal.

The method with the three basic steps described above is preferably extended by the qualitative step of calibrating the transceiver of the received radio signal with the passive detection RFID transponders under changing intensity of the transmitted radio signal for the step of verifying the presence and faultlessness of the system.

It is obvious that prior to the method of detecting the zone occupancy using passive RFIDs, a step of applying a coating with dispersed passive detection RFID tags placed in the detected zone is first performed.

The actual operation of the given system and method is as follows. During the absence of detectable objects, the transceivers transmit a time-synchronized energy pulse. This pulse is modified by appropriate technical means until data is read from the passive reference RFID transponders. The transmit signal is within the permitted frequency range specified by the relevant country-specific legislation (e.g., 865MHz to 868MHz) and the transmitted power (e.g., 500mW) may also be within the maximum permitted values specified by the relevant country-specific legislation.

All the transceivers installed transmit synchronously. In the absence of a response from the passive reference RFID transponders, an indication of a possible system failure is sent to the central control unit. For the purposes of the present invention, the central control unit may also be a remote server.

When the passive RFID reference transponders are read, the next step is loading the passive detection RFID transponders and their half-duplex communication towards the transceivers. The transmission is time-synchronized, and the transceivers create a well-defined set of unoccupied passive detection RFID transponders. After the initial initialization, if there is a change in the transmission strength of some passive detection RFID transponders, or if their response is absent, in the constant presence of the signal from the passive reference RFID transponders, the mentioned passive detection RFID transponders are assigned to the set of occupied ones.

The reading rate of the set of passive detection RFID transponders is on the order of tens of seconds to seconds. The system is thus applicable to the tasks of detecting the presence of static objects, not moving objects.

The advantages of the system and method for detecting zone occupancy using passive RFIDs according to the invention are apparent from the effects thereof, which are manifested externally. The effects are that the number of transceivers is much greater than the number of

passive detection RFID transponders. Thus, only a few transceivers serve a large number of passive detection RFID transponders.

The state of the art also includes systems where the number of transceivers to the number of passive RFID detection transponders is in the ratio of 1:1, which requires additional hardware and software customizations to eliminate their interference with each other. Transceivers with directional antennas are always distributed in such a way that even remote passive detection RFID transponders are covered by the transceivers from multiple directions. The system uses fixed intensity levels of the transmitted signal.

High levels of transmitted signal strength are used to verify the presence and faultlessness of RFID transponders. Low levels of transmitted signal intensity are intended to detect shielding objects. The system is also original in that at least the passive detection RFID transponders are applied in the detected zone in the form of a special coating in which they are dispersed. The coating has sufficient fixation properties, is resistant to moisture and water, enables the passage of the RFID signal, is electrically non-conductive, thermally stable and abrasion resistant.

Brief description of the drawings

The system and method for detecting zone occupancy using passive RFIDs according to the invention will be further explained in the drawings, wherein Figure 1 schematically illustrates an unoccupied zone equipped with a detection system for detecting its occupancy.

Figure 2 schematically illustrates a randomly occupied zone equipped with a detection system.

Figure 3 is a block diagram illustrating a sequence of steps of the method for detecting the occupancy of a zone using passive RFIDs.

Figure 4 illustrates the use of the detection system - detecting the occupancy of public benches.

Figure 5 illustrates the use of the detection system - detecting the occupancy of an outdoor parking area.

Figure 6 illustrates the use of the detection system - detecting the occupancy of a dedicated lane for longitudinal parking on both sides of the street.

Examples of the embodiments

It is understood that the various embodiments of the invention are presented for illustration purposes only and do not limit the solutions.

Example 1

In this example of embodiment, a general system for detecting zone occupancy using passive RFIDs according to the invention is described as illustrated in the basic diagram shown in Fig. 1.

The system is applied in the detected zone 4 and comprises four transceivers 2, whose transmitters have a changeable intensity of the transmitted radio signal in the UHF band and whose receivers have a variable sensitivity to the received radio signal. Further, the system comprises 109 passive detection RFID transponders 1 placed in the detected zone 4 of which they are an integral part. The system further comprises five passive reference RFID transponders 5 used to adjust the transmitting intensities and to verify the correct operation of the whole system during operation.

Since the number of passive detection RFID transponders 1 is much larger than the number of transceivers 2, a plurality of passive detection RFID transponders 1 are assigned to a single transceiver 2. The passive reference RFID transponders 5 are placed above the detected zone 4. The transceivers 2 are variably directional adjustable antennas connected by a wireless data channel to the central control unit 6. The antennas are variably directionally adjustable and can be adapted to local conditions.

In a preferred embodiment, the passive detection RFID transponders 1 in the detected zone 4 are applied in the form of an electromagnetically passive coating 8 in which they are dispersed.

Based on the above-described general system for occupancy detection of the zone 4 using passive RFIDs, a method for occupancy detection of the detected zone 4 using passive RFIDs according to the invention will be further explained as shown in the block diagram in Fig. 3.

After the transceivers 2, the passive RFID reference transponders 5, the central control unit 6 have been installed, and after the passive RFID detection transponders 1 applied in the form of an electromagnetically passive coating 8 have been applied in the detected zone 4, the transceivers 2 continuously evaluate the availability of the registered passive detection RFID

transponders 1 within their range by changing the transmission intensity according to a configurable algorithm.

The quantity of detected passive detection RFID transponders 1 indicating the time, the unit ID and the intensity at which a given quantity of passive detection RFID transponders 1 has been detected is sent by the transceivers 2 via a data link to the central control unit 6. In this way, the presence and faultlessness of the system is verified, by reading the identifiers of the passive reference RFID transponders 3 at changing intensities of the transmitted RFID radio signal in the UHF band. This is followed by calibration of transceiver 2 of the received radio signal with the passive detection RFID transponders 1 at changing intensity of the transmitted radio signal. Then, the occupancy of the detected zone 4 is detected by reading the identifiers of the passive detection RFID transponders 1 placed in the detected zone 4 at changing intensity of the transmitted RFID radio signal.

When the area of the detected zone 4 with the implemented coating 8 containing the passive detection RFID transponder 1 is occupied by the detected object 5, the subject passive detection RFID transponders 1 of the individual transceivers 2 are undetected at different signal intensities. In this way, the system detects the occupancy of specific parts of the zone 4. The central control unit 6 evaluates the jointly acquired data from the plurality of transceivers 2.

Through the central control unit 6 it is possible to set the transmission times and intensities for the individual transceivers 2. During evaluation, the occupancy of the individual areas of the detected zone 4 is determined based on the absence of a received RFID signal or a change in the intensity of the received RFID signal.

Fig. 2 shows a randomly occupied detected zone 4 equipped with a system for detecting its occupancy by detected objects 5. Also illustrated is a certain degree of randomness in the distribution of the passive detection RFID transponders 1, which is caused by the dispersion of the passive detection RFID transponders 1 in the coating 8. The distribution of the passive detection RFID transponders 1 is denser than needed for the detected occupied part of the zone 4. The distribution density of the passive detection RFID transponders 1 is selected according to the size and the degree of randomness of the location of the rotation of the detected objects. This makes the system more robust and versatile. The coating 8 is not shown in Fig.1 and Fig.2 for a reason clarity.

Example 2

In this example of a particular embodiment, a system for detecting occupancy of a detected zone 4 with public benches using passive RFIDs according to the invention is described as illustrated in the Fig. 4.

The system comprises a set of 2 transceivers, the transmitters of which have a variable intensity of the transmitted radio signal in the UHF band and the receivers of which have a variable sensitivity to the received radio signal.

The transceivers 2 are placed on the support structures 7 such as lighting poles along sidewalks or parkways where the benches are arranged. The transceivers 2 are variably directional adjustable antennas connected by a wireless data channel to the central control unit 6. Further, the system comprises a set of passive detection RFID transponders 1 placed in the detected zone 4 at the bottom or top of the benches, of which they are an integral part, and are applied in the form of an electromagnetically passive coating 8 in which they are dispersed. Further, the system comprises a set of passive reference RFID transponders 3 placed on support structures 7 such as trees or other suitable vertical structures and on transceiver 2 boxes.

Since the number of passive detection RFID transponders 1 is much larger than the number of transceivers 2, a plurality of passive detection RFID transponders 1 are assigned to a single transceiver 2. The passive reference RFID transponders 3 are placed above the detected zone 4, namely on trees. The transceivers 2 are variably directional adjustable antennas connected by a wireless data channel to the central control unit 6.

The functionality of the system and the evaluation of the occupancy of the detected zone 4 can be clarified by the fact that the detected objects 5 - persons sitting on the benches - will shield the passive detection RFID transponders 1 in the coating 8 with their bodies. This will reduce the availability of a certain set of registered passive detection RFID transponders 1 in the system at a certain intensity of the transmitted signal from the individual transceivers 2. The information sensed and processed by the transceivers 2 is transmitted in the form of data to the central control unit 6, where it is evaluated in aggregate and the system provides information about which benches are occupied and to what extent.

The individual detection RFID transponders 1 are not shown in Fig. 4 for the sake of clarity, but their location is obvious.

Example 3

In this example of a particular embodiment, a system for detecting occupancy of a zone 4, a dedicated longitudinal parking lane on both sides of a street, is described as illustrated in Fig. 6.

The individual detection RFID transponders 1 are not shown in Fig. 6 for reasons of clarity, but their location is obvious.

The system comprises a set of transceivers 2, the transmitters of which have a variable intensity of the transmitted radio signal in the UHF band and the receivers of which have a variable sensitivity to the received radio signal. The transceivers 2 are placed on support structures 7 such as lighting poles along the street. The transceivers 2 are variably directionally adjustable antennas connected by a wireless data channel to the central control unit 6.

Further, the system comprises a set of passive detection RFID transponders 1 placed in the detected zone 4 in the form of horizontal traffic signs in places where vehicles can park, which is applied in the form of an electromagnetically passive coating 8 in which they are dispersed. Further, they are also present in the coating 8 applied to the support structure 7 of foot-stones along the parking lane on the other side of the street. Alternatively, the coating 8 comprising the passive RFID detection transponders 1 can be applied to the raised curbs along the parking spaces, whereby this solution would replace the deployment of foot-stones on the distant side of the street.

Further, the system comprises a set of passive reference RFID transponders 3 placed on trees or other suitable vertical support structures 7 and on transceiver 2 boxes. Since the number of passive detection RFID transponders 1 is much larger than the number of transceivers 2, a plurality of passive detection RFID transponders 1 are assigned to a single transceiver 2. The passive reference RFID transponders 3 are placed above the detected zone 4. The transceivers 2 are variably directional adjustable antennas connected by a wireless data channel to the central control unit 6.

The functionality of the system and the evaluation of the occupancy of the detected zone 4 can be illustrated by the fact that the detected objects 5 - parked vehicles - that are present shade a certain set of passive detection transponders RFID 1 in the coating 8. This will reduce the availability of a certain set of registered passive detection RFID transponders 1 in the system at a certain intensity of the transmitted signal from the individual transceivers 2. The information sensed and processed by the transceivers 2 is transmitted in the form of data to the

central control unit 6, where it is summarily evaluated, and the system provides information on what part of the lane designated for longitudinal parking is occupied and what part of the lanes is free. The system always verifies the availability of passive reference RFID transponders 3 to determine whether the system is operational.

Example 4

In this example of a particular embodiment, a system for detecting occupancy of the zone 4 - an exterior parking area - is described as illustrated in Fig. 5.

The individual detection RFID transponders 1 are not shown in Fig. 5 for reasons of clarity, but their location is obvious.

The system comprises a set of 2 transceivers, the transmitters of which have a variable intensity of the transmitted radio signal in the UHF band and the receivers of which have a variable sensitivity to the received radio signal. The transceivers 2 are placed on the supporting structure 7 - the lighting columns of the parking area of the detected zone 4. The transceivers 2 are variably directional adjustable antennas connected by a wireless data channel to the central control unit 6.

Further, the system comprises a set of passive detection RFID transponders 1 placed in the detected zone 4 in each parking space in the form of a horizontal marking - a cross - in places applied in an electromagnetically passive coating 8 in which they are dispersed. Further, the system comprises a set of passive reference RFID transponders 3 placed on trees or other suitable vertical support structures 7 and on transceiver boxes 2.

Since the number of passive detection RFID transponders 1 is much larger than the number of transceivers 2, a plurality of passive detection RFID transponders 1 are assigned to a single transceiver 2. The passive reference RFID transponders 3 are placed above the detected zone 4. The transceivers 2 are variably directional adjustable antennas connected by a wireless data channel to the central control unit 6.

The functionality of the system and the evaluation of the occupancy of the zone 4 can be explained by the fact that the detected objects 5 - parked vehicles - that are present shade the passive detection RFID transponders 1 in the coating 8 in the given parking spaces, where they are parked, and in their vicinity. This will reduce the availability of a certain set of registered passive detection RFID transponders 1 in the system at a certain intensity of the transmitted signal from the individual transceivers 2.

The information sensed and processed by the transceivers 2 is transmitted in the form of data to the central control unit 6, where it is summarily evaluated, and the system provides information about which parking spaces are occupied and what part of the parking spaces is free. The system always verifies the availability of passive reference RFID transponders 3 to determine whether the system is operational.

Industrial applicability

The system and method for detecting occupancy of zones using passive RFID according to the invention is useful in logistics and warehouse management, where it is used to track items and inventory in warehouses and logistics systems, as well as to track the movement of goods during transport. It can also be used in retail networks, where it is used to track inventory and to improve the efficiency of the purchasing process for customers. It can also be used in the hunting industry to track the movement and behaviour of wild animals in the wild. It can also be used in port and airport zones, where it is used to track containers and pallets during transport through ports and airports. It can also be used in the automotive industry and industrial parks, where it is used to track items and inventory in factories and production plants. It can also be used in the healthcare industry where it is used to track patients, medical equipment and medical devices.

List of reference

- 1 passive detection RFID transponder
- 2 transceiver
- 3 passive reference RFID transponder
- 4 detected zone
- 5 detected objects
- 6 central control unit
- 7 support structure
- 8 electromagnetically passive coating with at least one dispersed passive detection RFID transponder

CLAIMS

1. A system for detecting zone occupancy using passive RFID transponders, **characterized in that**, it comprises:
 - at least one transceiver (2) comprising an RFID transmitter with variable intensity of the transmitted radio signal in the UHF band, an RFID radio signal receiver in the UHF band, at least one antenna, and a microcontroller,
 - at least one passive reference RFID transponder (3),
 - at least one passive detection RFID transponder (1) placed in a zone (4) of which it is an integral part.
2. The system according to the preceding claim, **characterized in that**, it further comprises a central control unit (6).
3. The system according to any one of the claims 1 to 2, **characterized in that**, the single transceiver (2) is associated with m-passive detection RFID transponders (1) placed in the detected zone (4) as an integral part thereof.
4. The system according to any one of the claims 1 to 3, **characterized in that**, n-transceivers (2) and m-passive detection RFID transponders (1) assigned to the detected zone (4), wherein $n \leq m$.
5. The system according to claim 4, **characterized in that**, n-transceivers (2) and m-passive detection RFID transponders (1) assigned to the detected zone (4), wherein $n < m$.
6. The system according to any one of the claims 1 to 5, **characterized in that**, the passive detection RFID transponders (1) placed in the detected zone (4) are dispersed in an electromagnetically passive coating (8).
7. The system according to any one of the claims 1 to 6, **characterized in that**, the passive reference RFID transponder (3) is placed above the detected zone (4).
8. System according to any one of the claims 1 to 7, **characterized in that**, the RFID radio signal receiver in the UHF band of the transceiver (2) has a variable sensitivity to the radio signal.

9. A method for detecting zone occupancy using passive RFIDs, **characterized in that**, it is carried out using the system according to any one of the claims 1 to 8, comprising the following steps:

- verification of the presence and faultlessness of the system by reading the identifier of the passive reference RFID transponder (3) at changing intensity of the transmitted RFID radio signal in the UHF band,

- detection of the occupancy of the detected zone (4) by reading the identifiers of the passive detection RFID transponders (3) placed in the detected zone (4) at changing intensity of the transmitted RFID radio signal,

- determining the occupancy of the detected zone (4) by the absence of a received RFID signal or by a change in the received RFID signal intensity.

10. The method according to claim 9, **characterized in that**, the step of verifying the presence and faultlessness of the system is preceded by the application of the electromagnetically passive coating (8) with scattered passive RFID detection transponders (1) placed in the detected zone (4).

11. The method according to any one of the claims 9 to 10, **characterized in that**, the step of verifying the presence and faultlessness of the system is followed by calibrating the transceiver (2) of the received radio signal with the passive RFID detection transponders (1) at a varying intensity of the transmitted radio signal.

12. The method according to any one of the claims 9 or 10, **characterized in that**, the detection of the occupancy of the detected zone (4) is performed from the read identifiers of the passive detection RFID transponders (1) by a plurality of RFID transceivers (2) with overlapping ranges.

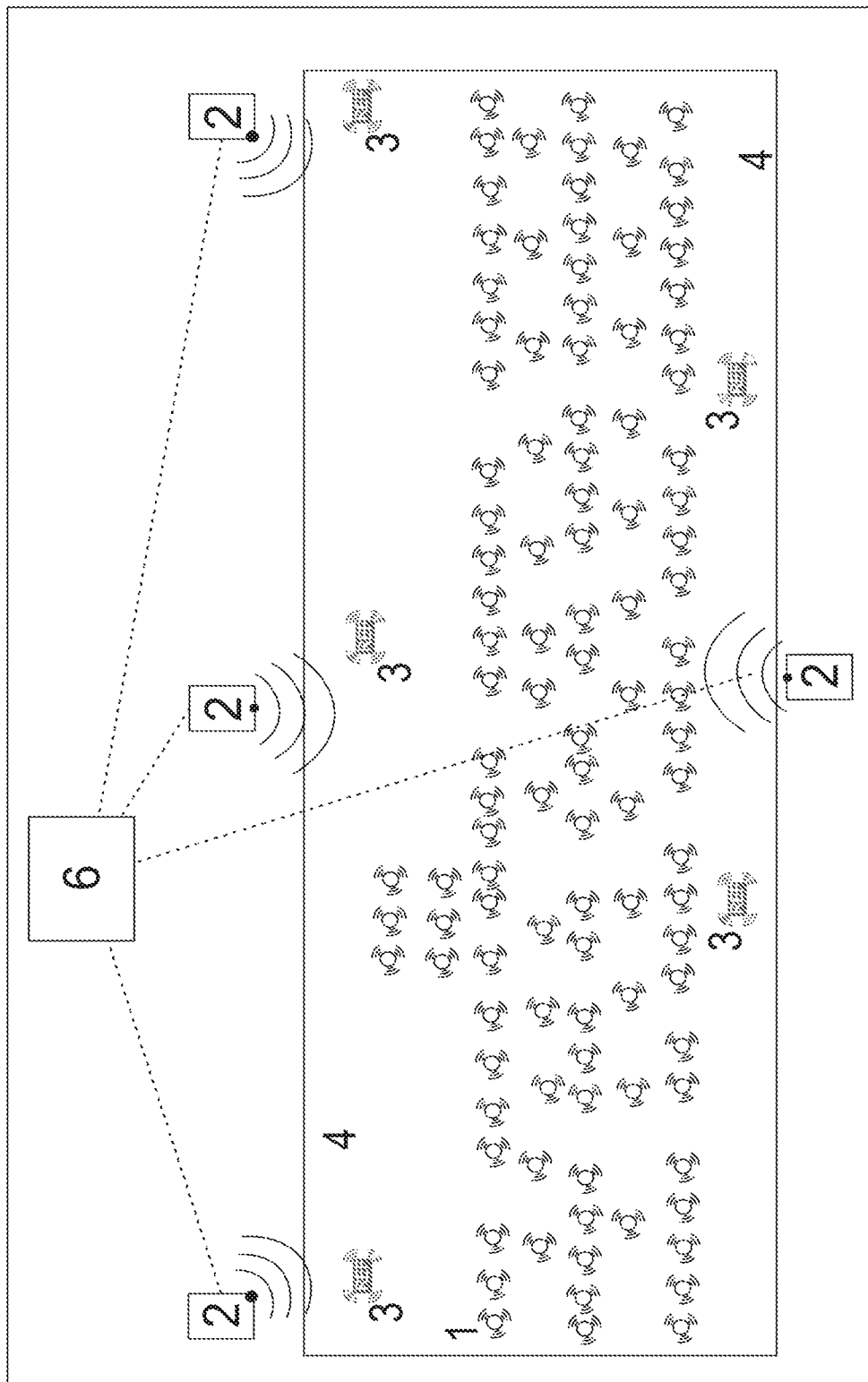


Fig. 1

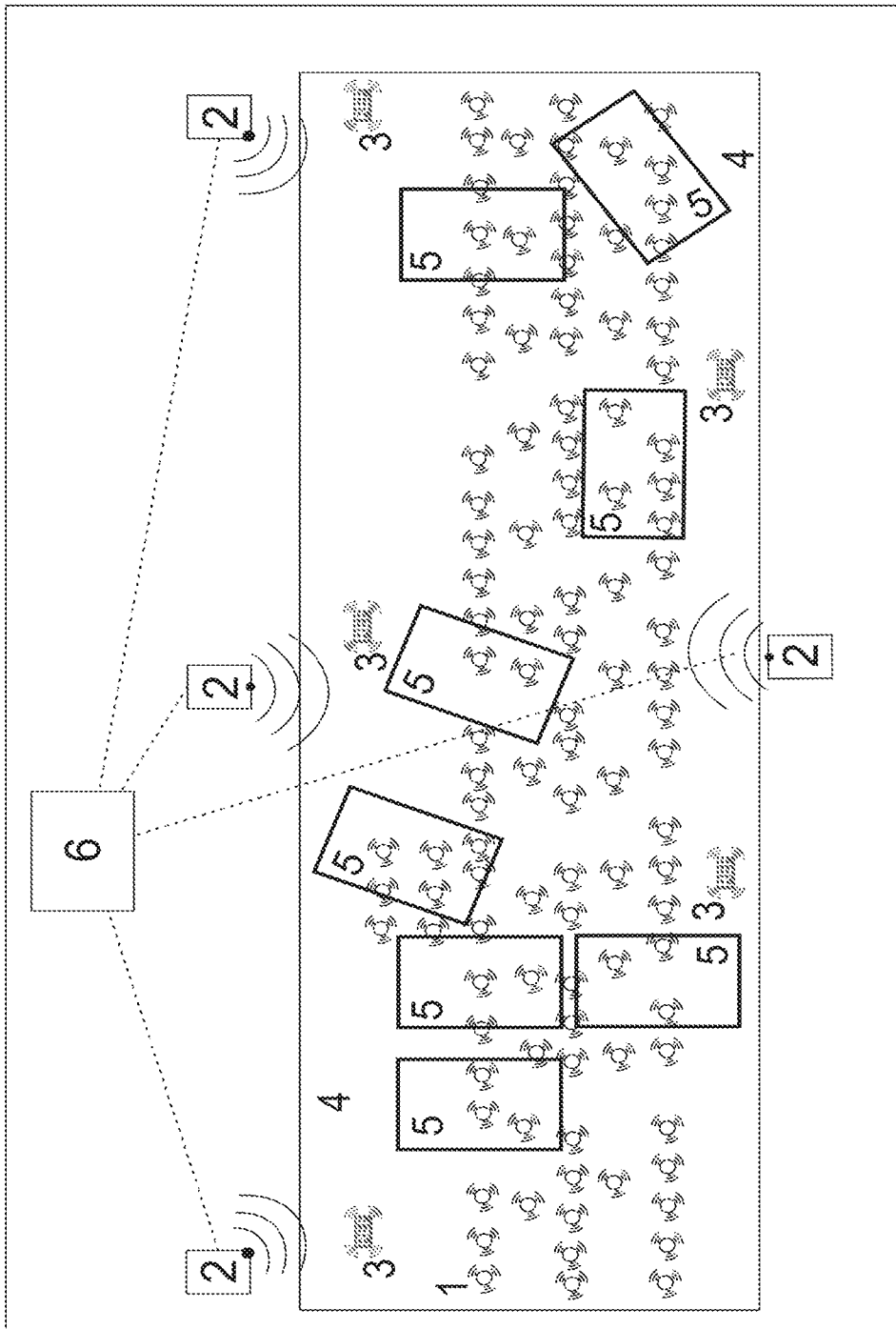


Fig. 2

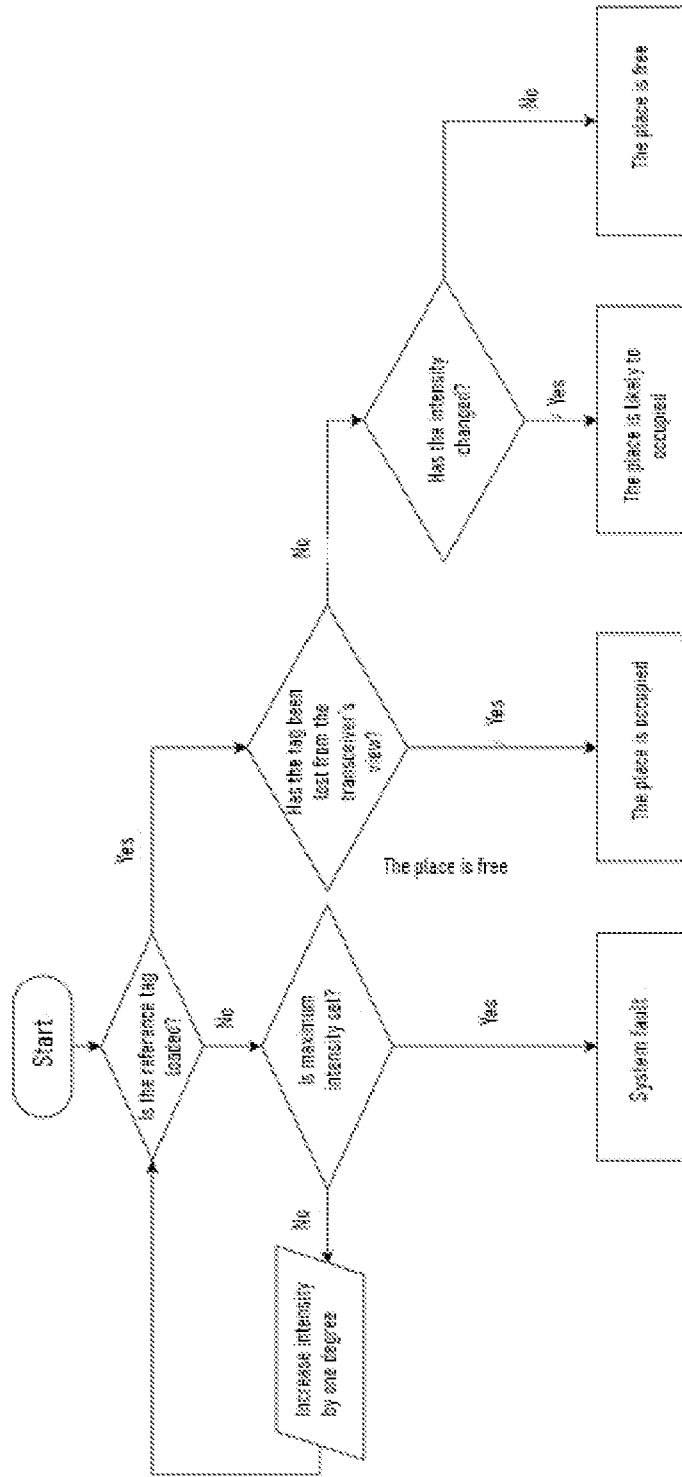


Fig. 3

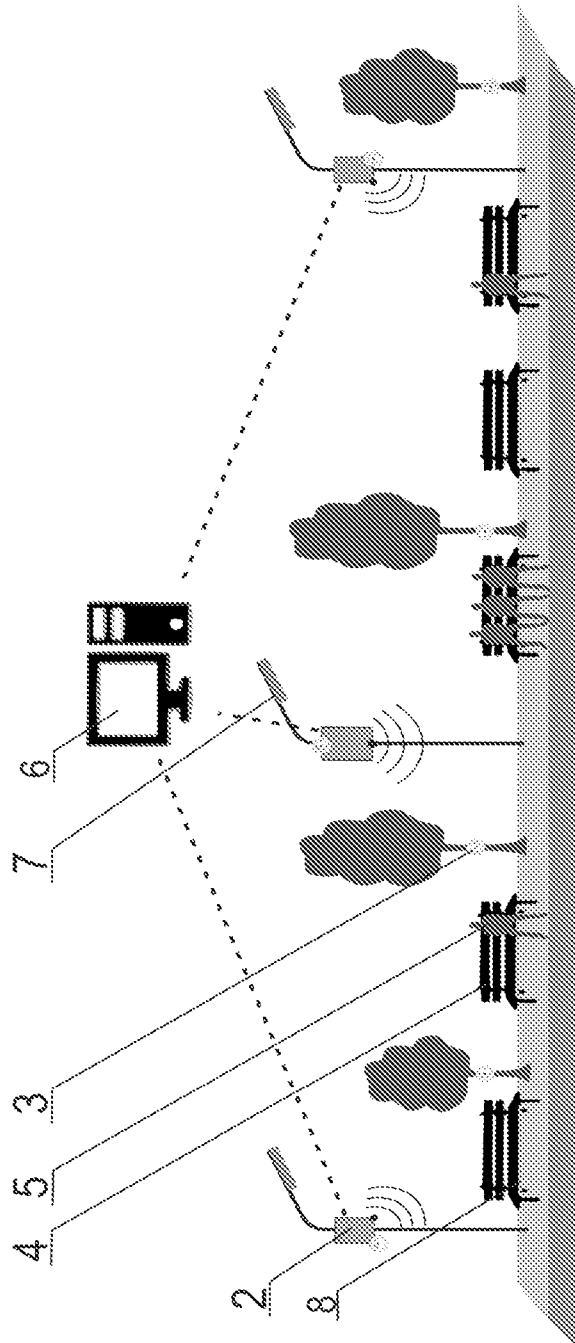


Fig. 4

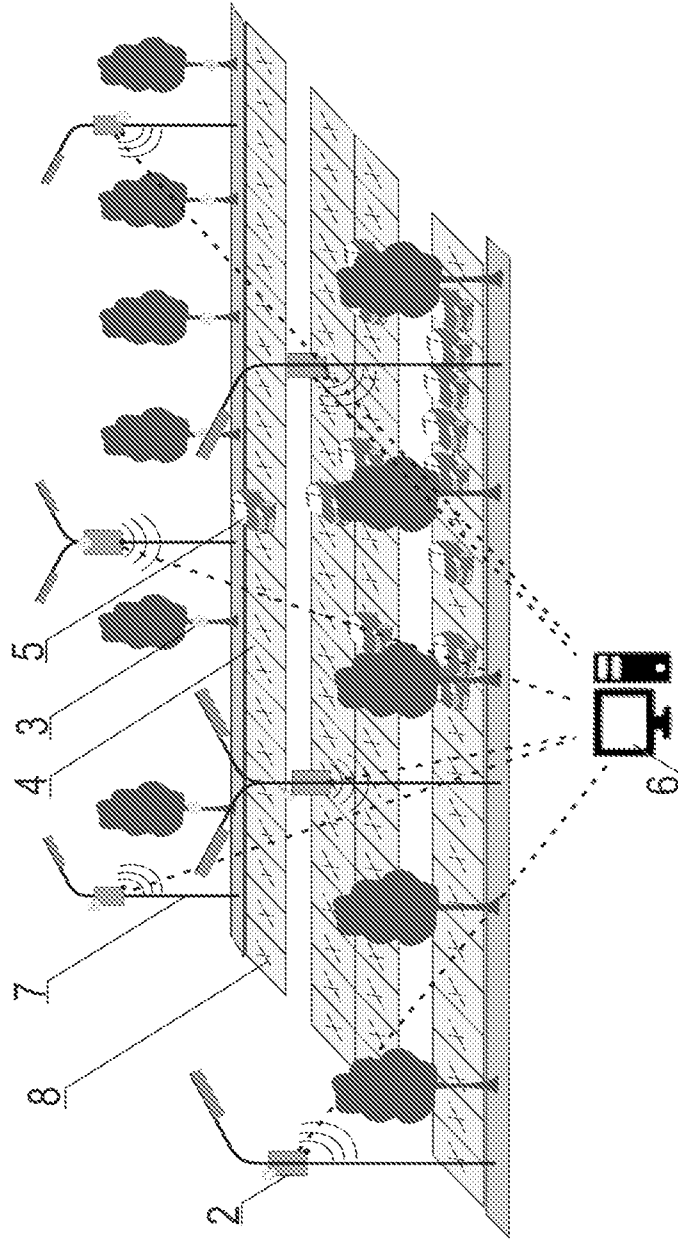


Fig. 5

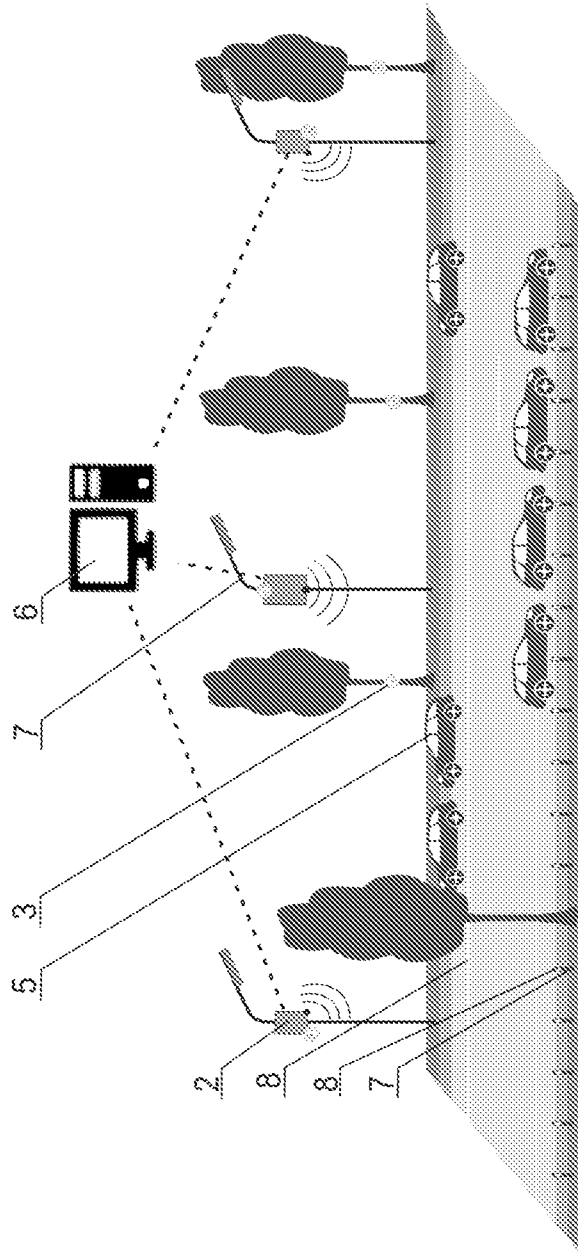
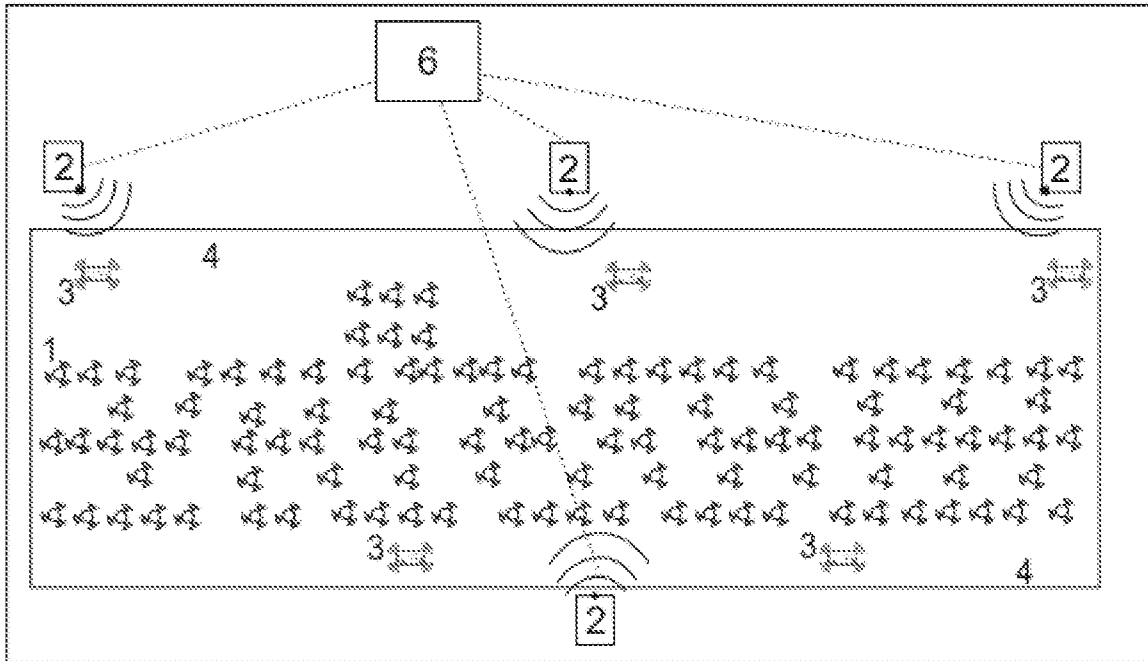


Fig. 6

Figure to annotation (Fig. 1)



INTERNATIONAL SEARCH REPORT

International application No PCT/SK2023/050018
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A. CLASSIFICATION OF SUBJECT MATTER INV. G06K7/10 G01S13/75 G06K17/00 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) G06K 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 practicable, search terms used) EPO-Internal				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	US 2013/076568 A1 (SHOARINEJAD KAMBIZ [US] ET AL) 28 March 2013 (2013-03-28)	1-5, 7-9, 11, 12		
Y	paragraph [0002] - paragraph [0003] paragraph [0107] - paragraph [0122] figures 1-6	6, 10		
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A	----- CN 115 238 717 A (CHINA CONSTR 1ST BUILDING GROUP CORP LTD ET AL.) 25 October 2022 (2022-10-25) the whole document	1-12		
	-/--			
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.				
* Special categories of cited documents : <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; border: none;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family			
Date of the actual completion of the international search		Date of mailing of the international search report		
22 December 2023		09/01/2024		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Bhalodia, Anil		

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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