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(54) **RADAR BASED INVERSE DETECTION  
SENSOR SYSTEM**

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(57) **ABSTRACT**

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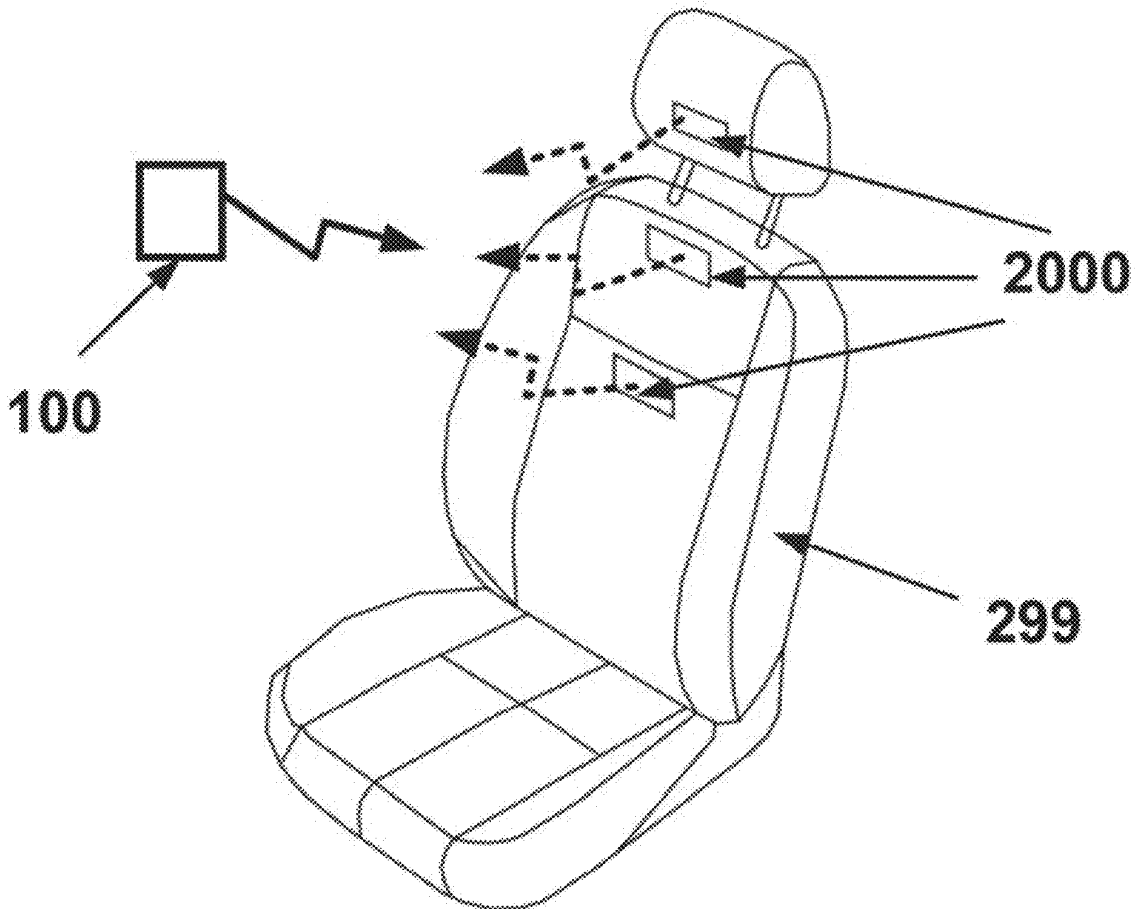
The present invention discloses radar sensor system, operating in 24 GHz to 300 GHz frequency band, and its method of operation, comprising utilization of the passive markers, reflecting radio wave in the direction of illumination advantageously in cross polarization manner. The proposed system can detect if on the vehicle seat a baby, kid or adult average size person is sitting. The proposed system can detect intrusion, non-occupied area, belt speed, rotation speed and if the package is filled with sufficient level of liquids.

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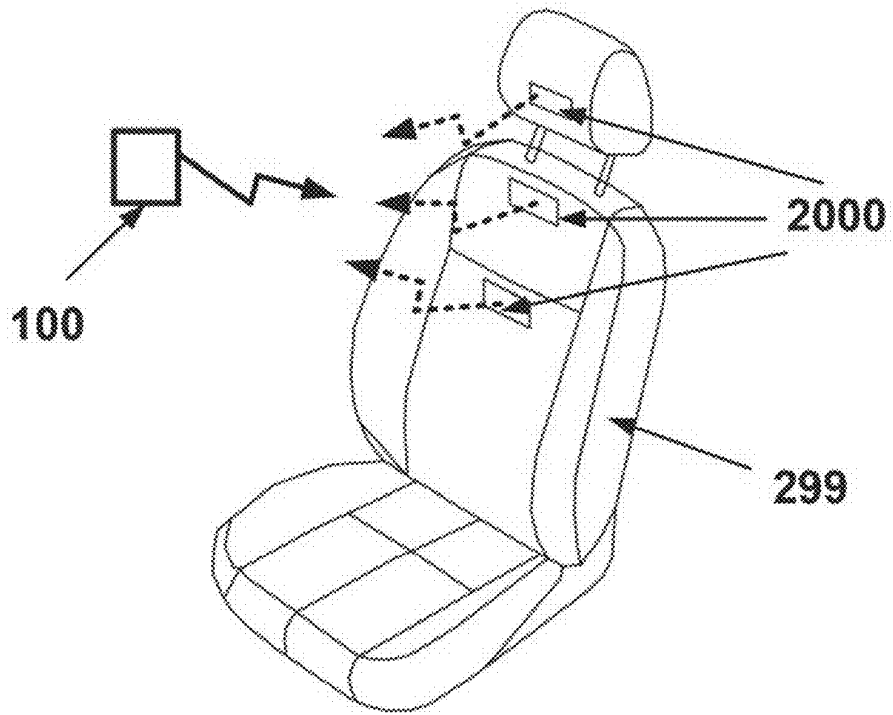


Fig. 1a

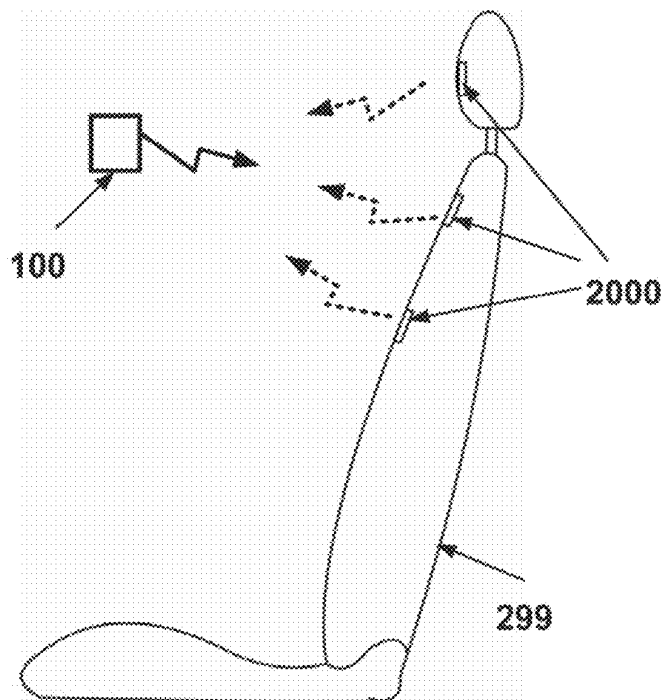


Fig. 1b

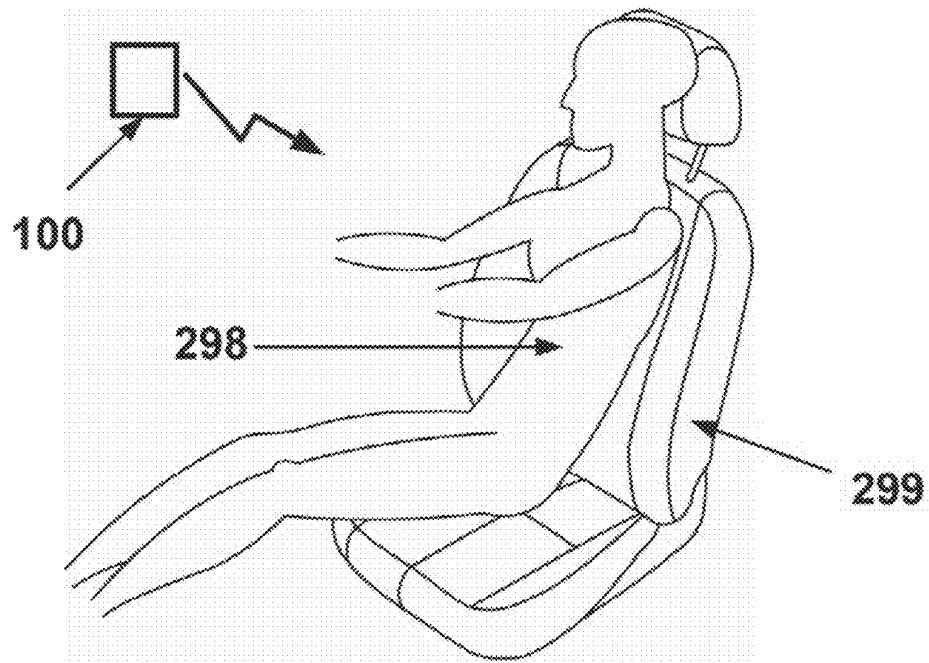


Fig. 1c

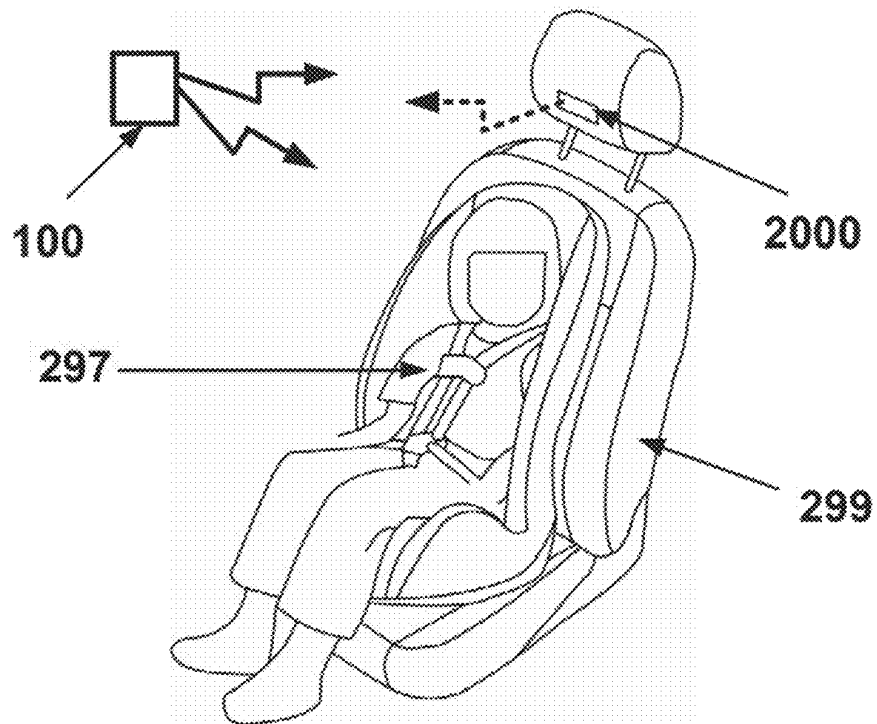


Fig. 1d

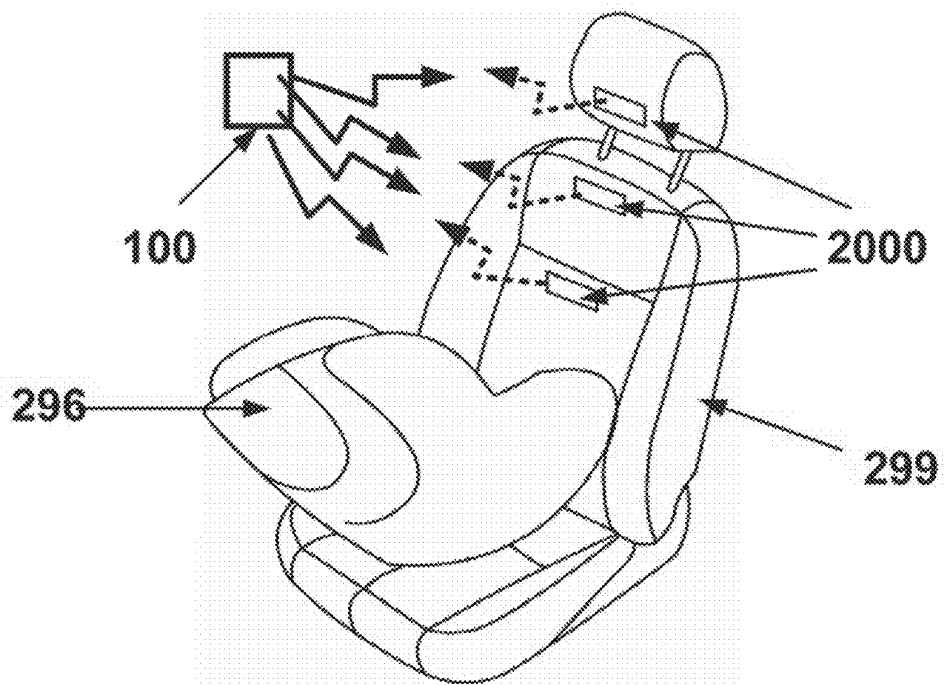


Fig. 1e

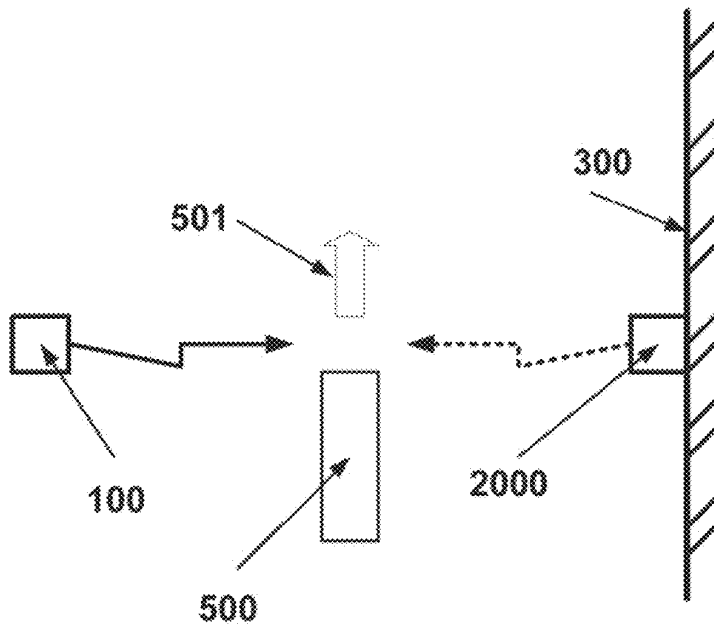


Fig. 2a

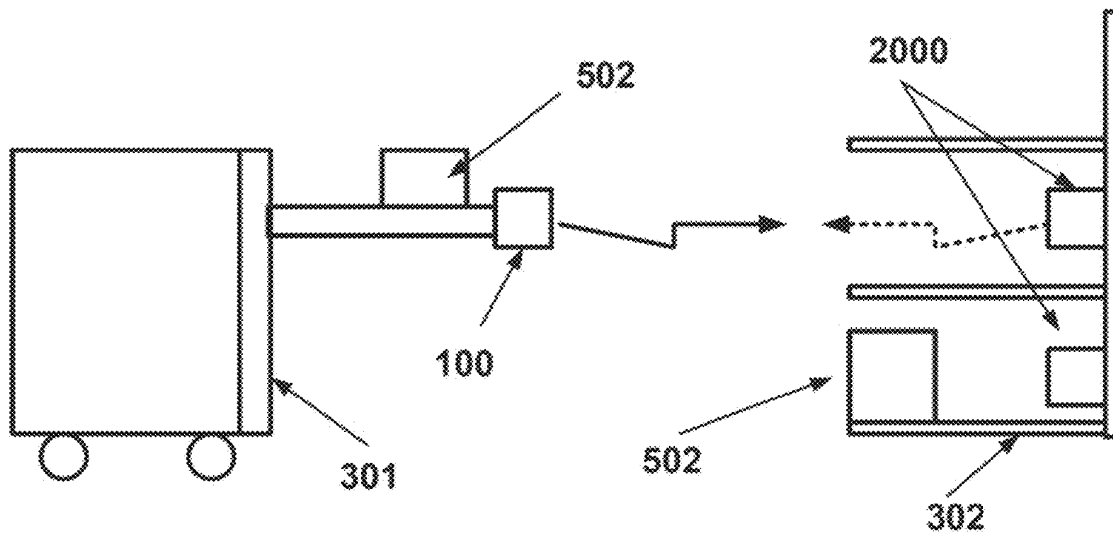


Fig. 2b

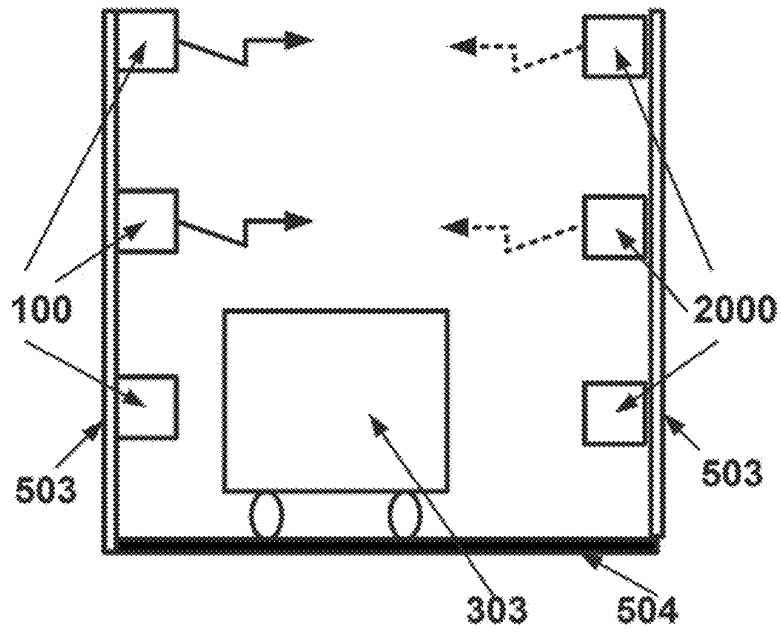


Fig. 3a

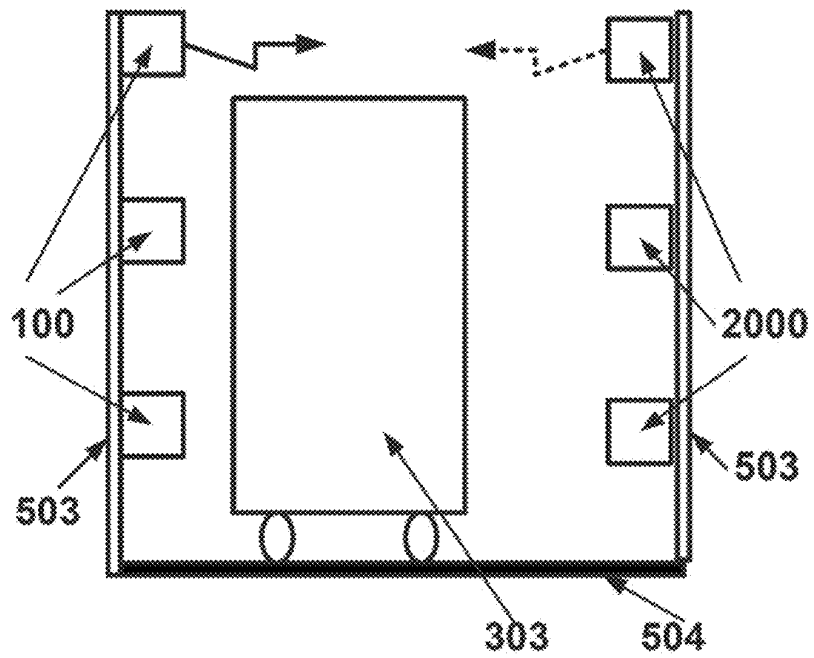


Fig. 3b

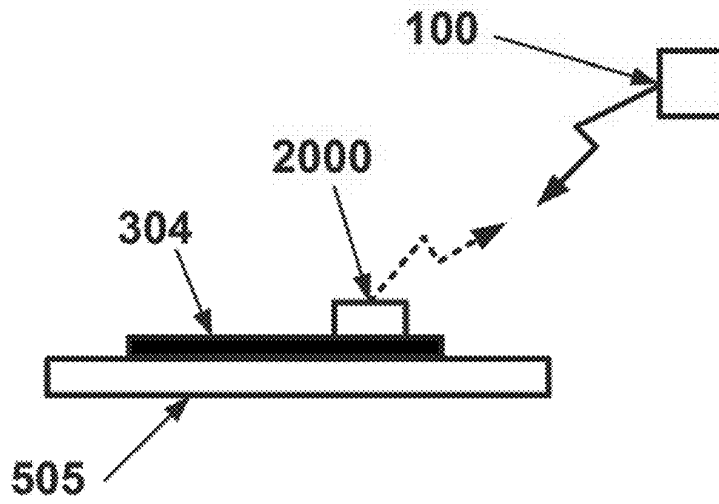


Fig. 4a)

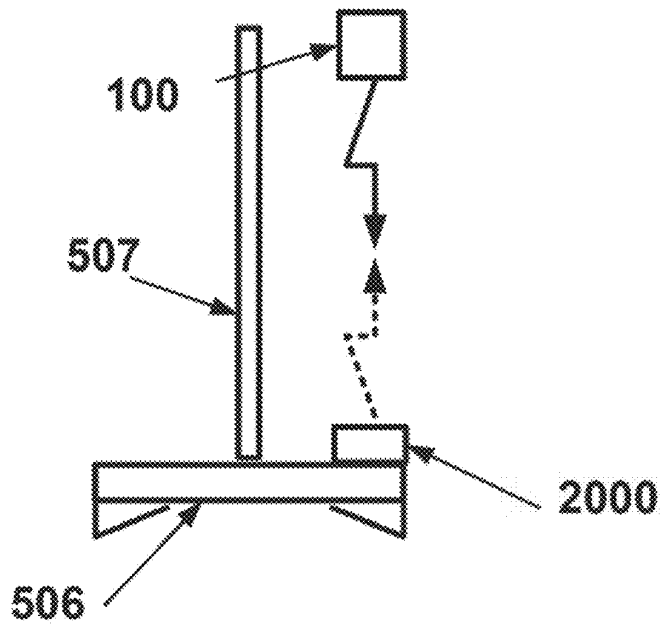


Fig. 4b)

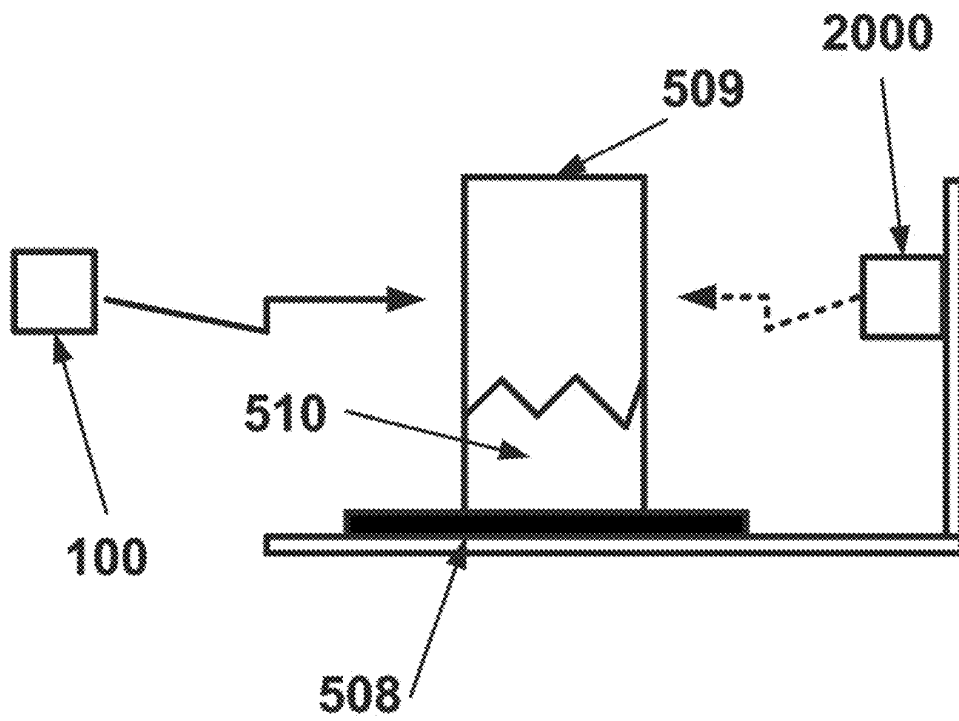


Fig. 5

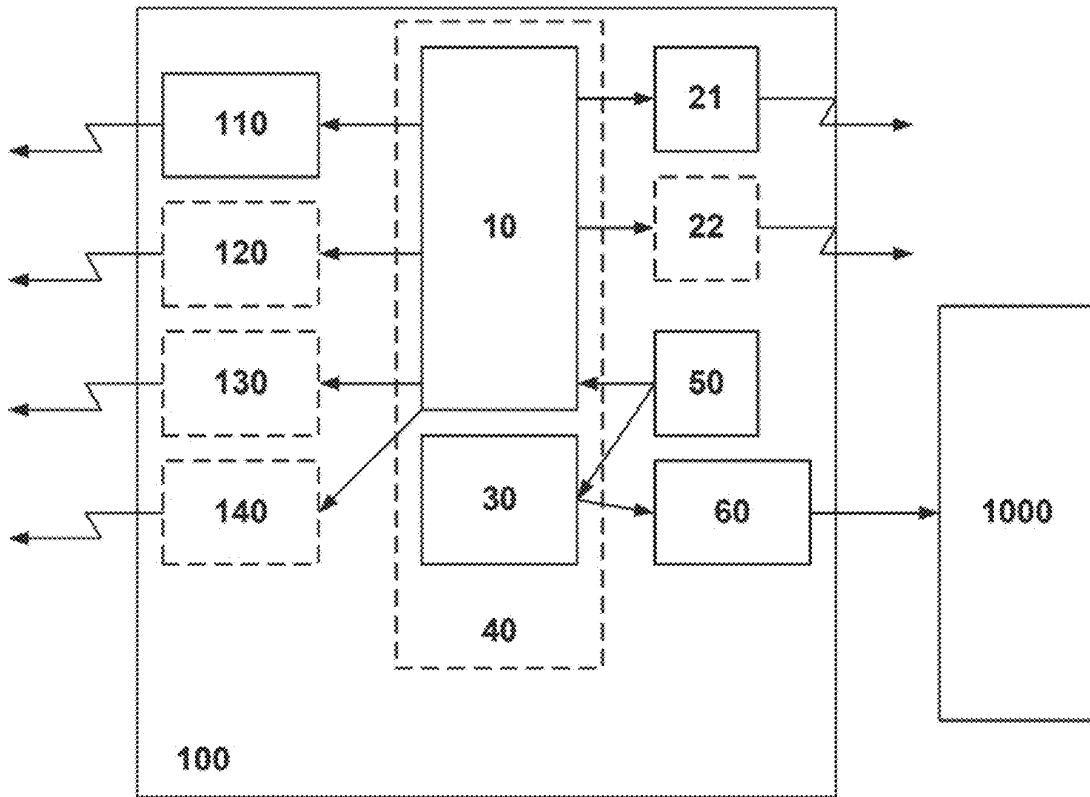


Fig. 6

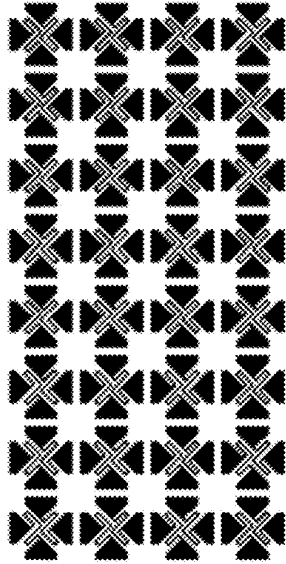


Fig. 7a

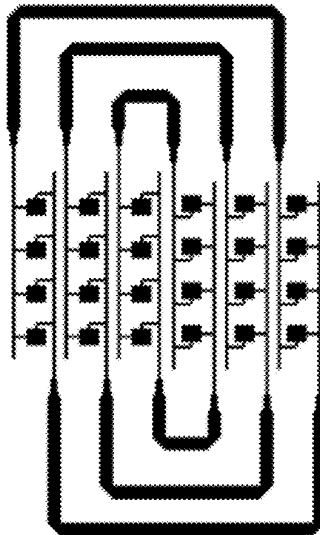


Fig. 7b

## RADAR BASED INVERSE DETECTION SENSOR SYSTEM

**[0001]** MM-wave radar sensor system described by apparatuses and method of operation is proposed addressing several applications. The proposed system is advantageously used for application regarding detection and classification of the human beings on the seats. Classes of the human being using seats detected by the proposed system are: adult, kid, being defined as human person smaller than average size of the human, and baby. The seat does not necessarily have the power supply. The same proposed system can be used for the classification of the objects having different heights and sizes, intrusion control, general space occupation, vehicle height detection and speed detection of latterly positioned objects and liquids.

### TECHNICAL FIELD

**[0002]** Radar sensor system with its method of operation using 24 GHz-300 GHz frequency band is introduced.

### BACKGROUND ART

**[0003]** The specific problems or classifying the people regarding its size is addressed by using mm-wave radar sensor frequencies. The proposed system is advantageously addressing classification of the human being occupying the vehicle seats and other applications.

**[0004]** There is a strong motivation to deploy a new generation of the sensor solution for the following automotive application scenarios, like in FIG. 1:

**[0005]** If the vehicle seat is occupied and acknowledged to:

**[0006]** a) Detect if the human with its average full size is on the seat

**[0007]** b) Detect if human with smaller size or kid is on the seat, where this size may be defined being larger than baby able to seat on the seat extension, to have a full function of the safety belt, and being smaller than human with its average size

**[0008]** c) Detect if the, baby in baby protection bed, is in the seat

**[0009]** Ideally the seat with the human, as a typical rear seat, does not have power supply, and does not have pressure sensor system.

**[0010]** The classification of the passenger in proposed classes as a state of art solution required complex pressure sensor systems, which required power supplies, so that the seats itself are generally more expensive.

**[0011]** There is a strong motivation to measure if the specific space is empty, or if the specific space is not empty: event intrusion, event passing through, event placing human or other object in the specific area, like in FIG. 2.

**[0012]** There is a strong motivation to measure and classify the size of the vehicles on road, like in FIG. 3. In these scenarios the height of the vehicles may be check to avoid road height limitations or traffic control is counting the number of the vehicles passing by having different classes of heights.

**[0013]** The alternative state of the art solution for applications in FIG. 2 and FIG. 3 is usage a laser sensor, which has a drawback to be influenced by dust, vapor other light sources, having hazardous influence to human eyes, it is more expensive compared to proposed system, and in some

cases requests power supply on two sides, in contrast to proposed system having only one side power consumption.

**[0014]** There is a strong motivation to measure rotation speed or belt (angular) speeds in the industrial environments, like in FIG. 4. The alternative state of art solution is laser beam, which has a drawback to be influenced by dust, vapor other light sources and having hazardous influence to human eyes.

**[0015]** There is a strong motivation to measure and classify if the specific package is filled with liquids like in FIG. 5. The state of art solution with ToF (Time of flight) sensor, cannot differentiate if the package is full of liquid being placed on production belt, because the light is not passing through the package.

**[0016]** General state of the art radar sensors are used to detect distance, angle, vibration speed of the object. Typical product like automotive radars and industrial radar sensors are on the market. Proposed system concept differentiates substantially from classic radar sensors by measuring if the reflected radar signals are existing or not, and if they are existing, which class of received signal strength is detected.

**[0017]** The following set of the patent applications and granted patents as well as associated selected publications are describing the state of art in the field.

**[0018]** US20090058638, "Methods and apparatus for a pervasive locationing and presence detection systems", disclosed a locationing system for use in a wireless network generally includes a wireless switch and a global positioning system (GPS) with RFID Network. At least one RFID reader (mobile and/or fixed) is configured to communicate with the access port, and the RFID reader is configured to read an RFID tag and communicate RFID tag data to the wireless switch. RFID reader is sending data and receiving ID from the RFID transponder, taking power from the emitter RF signal strength.

**[0019]** U.S. Pat. No. 9,325,077B2, "Radar level gauge system and reflector", The present invention relates to reflector arrangement for proof test of a radar level gauge and to a radar level gauge system comprising such a reflector arrangement, for automotive tank application.

**[0020]** U.S. Pat. No. 8,350,75282, "Radar level gauge system with bottom . . ." introduces a radar level gauge system, for determining a filling level of a product contained in a tank, the radar level gauge system comprising: a transceiver for generating, transmitting and receiving electromagnetic signals; a propagating device electrically connected to the transceiver and arranged to propagate a transmitted electromagnetic signal towards a surface of the product contained in the . . .

**[0021]** U.S. Pat. No. 5,387,916, "Automotive Navigation system and Method", introduces the responder uses a Van *Ata* array antenna, using for navigation enhancement. The responder includes encoding means coupled to the receiving antenna means for imposing automotive navigation information on the collected interrogation signal, the responder including retrodirective means connected to the encoding means for retransmitting the encoding collected interrogation signal. This interrogator send coded signal by intention, addressing a vehicle travelling along a highway and it is not a part of the classing radar based distance collection systems.

**[0022]** US20150145711, "Retro-reflective radar patch antenna target for vehicle and road infrastructure identification" introduces a system concept where markers have

preferably means of identifications, like RFID systems. The responders are emitting unique return signal so that the central controller identifying the roadway item of interest and determining a responsive action.

[0023] General background sources are explained the reflector planar approaches:

[0024] IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL XX, 2018, "A Passive Re-Directing Van Atta Type Reflector".

#### SUMMARY OF INVENTION

[0025] This invention proposes a system having apparatus part 100 and apparatus part 2000, as well as the method of operation, being able to:

[0026] To detect the height of the passengers seating on the seat, within specific class of heights. This application scenario is shown in the FIG. 1.

[0027] To detect if in the observing specific area, there is an object being placed, where the object can be also a live being. This application scenario is shown in the FIG. 2.

[0028] To detect size of the objects. This application scenario is shown in the FIG. 3.

[0029] To detect the angular speed, like rotating object or lateral speeds like belt or flowing liquids. This application scenario is shown in the FIG. 4.

[0030] To detect if the package which should be filled by liquids, is filled properly with liquids, meaning that if the filling level is lower than determined to detect this event. This application scenario is shown in the FIG. 5.

[0031] The basic features of the apparatus 100 are described in the FIG. 6. Apparatus 100 is radar system having at least one transmitter and two receiver chains with high gain antennas, being connected to the vehicle infrastructure 1000, and being realised by the arbitrary technology solutions. The apparatus 2000 is passive system with the arbitrary realisation options, where passive means that the apparatus 2000 does not have power supply, where the apparatus 2000 has a feature that the incident radio waves to the apparatus receiving surface are reflected by approaching apparatus 2000 in the same angle as received. In the proposed invention apparatus 2000 can advantageously besides reflecting the way in the same direction also change the polarization of the incident ways. In the proposed invention at least one receive antenna of the apparatus 100 can have cross polarisation of at least one Tx antenna of the apparatus 100.

[0032] In the FIG. 7 different apparatus 2000 realization options are outlined, being realized by metalized corner reflectors, or printed planar structures, without and with changing of the incident radio waves polarisation.

[0033] By observing specific object by radar system, the total reflected energy to the radar systems is dependent on the level of the scattered waves in other directions as the direction of the incident waves. Due to the fact, that if the radar is receiving antennas and on the same place where transmit antennas are, the receiving power level from specific reflections is dependent of the level of scattering waves. If the object, would have features to reduce parasitic scattering and would reflect more power in the directions, where it is illuminated, its effective radar cross section would be larger, and receiving antenna at the radar will register more receiving power. With other words object having features for having less parasitic scattering and better reflection of the

illuminated radio power to the direction of the illumination is better visible in the radar signal processing, compared to the environment in its enclosure without this feature. Even if the environment has metalized surfaces, the visibility is larger, if waves may be reflected in the same way where the illumination of the signal is presented.

[0034] If the receiving antenna of the apparatus 100, is receiving cross polarized waves, regarding transmitted radio waves, and if the apparatus 2000 is reflecting waves in the direction of illumination with changing its polarization, the system can differentiate easily by observing receiving signal strength, if the apparatus 2000 is in position or existing at all or not. Due to the physical properties of the cross polarization antenna isolation 30 to 15 dB level differences can be expected. This invention is utilizing proposed innovative idea.

[0035] The key system-relevant components of the proposed apparatus 100 are:

[0036] High-gain planar antenna system, realized by the plurality of the technologies, with at least one receiving antenna system 110, 120, 130, 140 and at least one the transmit antenna systems 21 and 22 each of them having more than one antenna radiation elements, and operation in the mm-wave frequency band.

[0037] Advantageously one of at least one receiving antenna 110, 120, 130, 140, has cross polarisation to at least one Tx antenna 21 and 22.

[0038] Millimetre-wave radar with integrated front end on silicon 10, system on chip, providing analog processing of the mm-wave signal, and the provision of the analog to digital conversion functionality;

[0039] Digital signal processing functionality 30

[0040] Mechanical assembly with power supply interface to power supply infrastructure in the vehicle or front seats, containing mechanically integrated antenna, digital and analog functionalities and having mechanical connection to the vehicle or seat infrastructure

[0041] Supporting circuitry 50 as a part of apparatus 100 may include functionalities like light warning source, by the plurality of the realization options

[0042] Interface sub-system 60 allowing connection to the vehicle infrastructure 1000.

[0043] The choice to use the 24 GHz ISM Band and mm-wave frequency band (30 GHz to 300 GHz) and advantageously to use non-licensed 60 GHz band, ISM 60 GHz Band and 79 GHz Automotive band, is mainly related to the size of the antenna system allowing very small and compact device, even though it contains the high-gain antenna with more than one radiation elements. Usage of higher frequencies enables to have on predefined object more apparatuses 2000, where their radiation size is minimum 4x4 wavelengths under operation, for the practical realization purposes and for enhanced reflectiveness. Due to mm-wave frequencies in the practical applications advantageously more than one apparatus 2000 are utilized.

[0044] Following operation steps, being part of the proposed method of operation are executed:

[0045] In the application scenario, like described by FIG. 1, apparatus 100 is integrated in the vehicle infrastructure 1000. The apparatus 100 is illuminating specific seat 299 and detecting seat occupancy, by evaluating existing vital patterns, and at least two passive apparatuses 2000 are integrated in the seat. If

the apparatus 100 is detecting the human being, the vehicle system is checking if at least one apparatus 2000 is detected. If no, the system concludes that the human body is blocking reflection of at least two apparatuses 2000, and the system is deciding the human in its full size is occupying the seat 299. If yes, the system is checking how many apparatuses are detected, by the plurality of the means: like the total receiving strength, which is larger than two apparatuses 2000 are illuminated than only one apparatus 2000 illuminated, due to the increased effective radar cross section, or by spatial recognition of the two reflection peaks by FMCW and beam forming antenna positions in two different areas of the seats. If only one apparatus 2000 is detected, the system concludes that human with small size, most probably kid, like in FIG. 1 c) is present on the seat. If two or more apparatus 2000 is detected, the system concludes that most probably baby in baby carriage is present on the seat. The vehicle environment 1000 is using event detection results: human average size detected, human with small size being probably kid, or baby in carriage is detected for other vehicle interaction and decision manners, like statistics evaluation, preparation of the specific monitoring functions, including vital signs observation or setting the exploding speed, and activation behaviour of the at least one airbags. Advantageously the apparatus 2000 is reflecting the ways in the direction of illumination but changing polarization. In that case apparatus 100 has at least one receiving antenna with cross polarization mode of the transmit antenna and is receiving the signal being reflected from the apparatus 2000, in the case that radio way can propagate to apparatus 2000, meaning that between the apparatus 100 and apparatus 2000, there is no part of the human body or other object causing the strong reflection.

[0046] In the application scenarios, like described by FIG. 2, FIG. 3 and FIG. 4 apparatus 100 is illuminated radio waves, which are reflected by apparatus 2000, advantageously having cross polarisation. If the reflected radio waves by apparatus 2000 are approaching the apparatus 100 in sufficient strength level, which is related to the distance between apparatus 100 and known radar cross section of the apparatus 2000, we have one event, which is tracked in time. If the reflected radio waves by apparatus 2000 are not approaching the apparatus 100 in sufficient strength level, we have second event, which is also tracked in time. If the changes of the two events are regular, we may use the statistics of their appearance to detection of the more complex events, being related to different end applications.

#### BRIEF DESCRIPTION OF DRAWINGS

[0047] FIG. 1 presents first class of proposed system application scenarios:

[0048] FIG. 1a) empty vehicle seats with integrated apparatuses 2000 in the vehicle seat

[0049] FIG. 1b) empty vehicle seats with integrated apparatuses 2000 in the vehicle seat, lateral view

[0050] FIG. 1c) vehicle seat being occupied by average human size, with no apparatuses 2000 being seen by the apparatus 100.

[0051] FIG. 1d) vehicle seat being occupied by kid or smaller human size, with one apparatus 2000 being seen by the apparatus 100.

[0052] FIG. 1e) vehicle seat being occupied by baby, with two apparatuses 2000 being seen by the apparatus 100.

[0053] where the apparatus 100 is radar system operating in 24-300 GHz range illuminating the vehicle seat having known specific placed along the vehicle height apparatuses 2000 being integrated in the vehicle seat.

[0054] FIG. 2 presents second class of proposed system application scenarios:

[0055] FIG. 2a) Lateral intrusion control scenario

[0056] FIG. 2b) Industrial vehicle good placing in the controlled not occupied area

[0057] FIG. 3 presents third class of proposed system application scenarios:

[0058] FIG. 3a) Hight controlling system, where smaller class of vehicle is passing

[0059] FIG. 3b) Hight controlling system, where larger class of vehicle is passing

[0060] FIG. 4 presents fourth class of proposed system application scenarios:

[0061] FIG. 4a) Detecting speed of the belt being marked with apparatuses 2000

[0062] FIG. 4b) Detecting rotation with rotated platform being marked with apparatuses 2000

[0063] FIG. 5 presents fifth class of proposed system application scenarios:

[0064] Detecting if the package on the moving belt is sufficiently filled with the liquid.

[0065] FIG. 6 presents functional blocks of the proposed Apparatus 100

[0066] FIG. 7 presents possible realisation options of the Apparatus 2000, where:

[0067] FIG. 7a) presents planar passive printed structure changing polarization of reflecting waves in the same direction of incident waves arrival

[0068] FIG. 7d) planar passive printed structure realized by patch type of antennas changing polarization of reflected waves in the same direction of incident waves arrival

#### DESCRIPTION OF EMBODIMENTS

[0069] Radar based system, using frequency range of 24 GHz and 30-300 GHz comprising the one apparatus 100 with HW radar functionality, and at least two apparatuses 2000 being placed physically at the distance from apparatus 100, being integrated in the vehicle seat 299, like in FIG. 1. Apparatus 100 contains:

[0070] At least one high-gain planar antenna for transmitting mm-wave radio signals 21, where the high-gain planar antenna has at least two radiation elements;

[0071] At least one high-gain planar antenna for receiving mm-wave radio signals 110, where the high-gain planar antenna has at least two radiation elements; and has cross polarization, compared to antenna 21;

[0072] Integrated radio front end 10, implemented in arbitrary semiconductor technology, having on-chip integrated mm-wave voltage control oscillator, mm-wave power amplifier, at least one mm-wave IQ demodulator, digital control interface, power supply;

[0073] Digital processing functionality 30 with arbitrary hard wired and SW digital processing capability, being able to digitally process the signal coming out of the entity 10, including controlling functionality and

- calculation and memory capacity for performing digital signal processing by arbitrary type of the realization options
- [0074] Wired communication interface **60** to connect first Apparatus **100** to the vehicle infrastructure entity **1000**, being outside the apparatus **100**, being released by the plurality of the technologies and communication protocols
- [0075] Supporting circuitry **50**, including mechanical interface to vehicle infrastructure environment **1000**, where the first Apparatus **100** is connected to the infrastructure environment, and supporting electronic circuitry for provide the power supply from the vehicle environment **1000** to the first apparatus **100**.
- [0076] where the second apparatuses **2000** are a passive, without power supply, and without capability of charging by the Illumination of the radio waves being released by plurality of realization options, having a key feature to reflect the incident radio waves coming from apparatus **100** by changing its polariton to be cross polarized, in the same direction, where radio waves are approaching the apparatus **2000**.
- [0077] At least two apparatuses **2000**, are integrated in the vehicle seat **299**. The Method of operation related to the FIG. **1** where method of operation comprising three operation steps: “detecting seat occupancy” being declared as a first operation step, “detection of apparatuses **2000**, by apparatus **100**” being declared as second operation step, to be executed after the first step is executed, and “method for calculating human being classification”, being declared as third operation step to be executed after the second step is executed,
- [0078] where the first operation step has following sub-set of operations:
- [0079] Detecting by apparatus **100**, if the human being is on the seat by using plurality of the approaches
- [0080] where the second operation step has following sub-set of operations:
- [0081] Transmission of radio waves signals generated in **10** using **21**;
- [0082] Receiving radio waves signals reflected by apparatus **2000** area using at least one receiving antenna **110**;
- [0083] Signal processing and detection at least three classes of the information:
- [0084] Class one: no signal level detected above specific pre-defined threshold one
- [0085] Class two: signal level detected above specific pre-defined threshold one, and lower than pre-defined threshold two, where the predefined threshold two is larger than predefined threshold one
- [0086] Class three: signal level detected above specific pre-defined threshold three, where the pre-defined threshold two is larger than predefined threshold two
- [0087] where third operation step being executed after the second operation step, has following sub-set of operations:
- [0088] Mapping detected class of signal level to the event detection of the human being classification, according to the following rules:
- [0089] If Class one is detected: average size human being is on the seat, like in FIG. **1c)**
- [0090] If Class two is detected: smaller human being size, most probably a kid is on the seat, like in FIG. **1d)**
- [0091] If Class three is detected: smaller life being is on the seat, most probably baby, like in FIG. **1e)**
- [0092] Detected event is communicated to the vehicle environment **1000**, by means of entity **60**.
- [0093] In FIG. **2** further proposed application scenarios are proposed. FIG. **2a)** shows a case where apparatus **100** is connected to the fixed non-moving infrastructure with provided power supply. Apparatus **100** is facing apparatus **2000** connected to the wall or other fixed non-moving infrastructure **300**. The distance between apparatus **100** and apparatus **2000** is known and does not change in the scope of the system operation. Apparatus **100** is constantly receiving reflected signals from the apparatus **2000**. In the case when moving object, human, or life being defined as intruder **500** is passing in direction perpendicular or with direction having trajectory component **501**, being perpendicular to radio connection between apparatus **100** and apparatus **2000** connection, the reflected signal coming from apparatus **2000**, cannot be registered by the apparatus **100**. In that case the system declares the event as intrusion and initialise related actions, such as communication the event with a specific time stamp to the world outside of the apparatus **100**. Since the reflected waves from the apparatus **2000** are cross polarized, and intruder is reflecting radio ways in the same polarization, the falls alarms are small. The same principle can be used for people counting passing corridor, or to object counting passing controlled area. FIG. **2b)** shows a case where apparatus **100** is connected to the moving platform **301** with provided power supply. This platform can be transportation vehicle, building machinery vehicle or production and logistic related small industrial vehicle. Apparatus **100** is connected on the moving part of the vehicle **301**, transporting load **502**. Load **502** is intended to be stored in the fixed infrastructure area **302** used for storage. Vehicle **301** is trying to off-load the load **502** in the free area. Coming close to the storage area the apparatus **100** is activated and the apparatus **100** is checking if the received signal from apparatus **200** being integrated at the end part of the storage area can be detected. If yes, the system decides that the area is free and load **502** can be off-loaded, if not like lower part of the storage area **302**, the apparatus **100** cannot detect reflected waves from apparatus **2000**, because apparatus **2000** is blocked by the load already been there. Today state of the art logistic systems with autonomous platforms, are offloading goods related to the data base, without checking if the related area is occupied or not. They are presuming that no one has access to the logistic area or that the data base has not mistakes and that the data base is up to date. In the proposed application scenario thy system can additionally improved the total safety and contribute to the full optimisation of the logistic process.
- [0094] FIG. **3** shows application scenario related to the traffic infrastructure. Vehicles **303** are driving over the roads **504**. We are prosing installation of the fixed infrastructure **503** across roads **504**. On the Infrastructure **504** each pars of the apparatuses **100** and apparatuses **2000** on the same height are installed. At least one system in upper part of the structure is installed. In FIG. **3 b)** Apparatus **100** is checking permanently the reflected signal from the associated apparatus **2000**. If the signal is broken, the event that the vehicle excided the prescribed height is detected, and the apparatus

**100** is sending an alert with the time stamp over entity **60** to the traffic infrastructure information system, which initialize related actions. FIG. 34) addresses applications where more sets of the sensors are used simultaneously, which allows to make categorization of the vehicles in the height classes, and their counting.

[0095] FIG. 4 shows application scenario related to system being capable to measure lateral and rotation speed. In the FIG. 4a industrial infrastructure **505** is having rolling belt **304**, having more than two integrated apparatuses **2000**, advantageously at the same distance. Apparatus **100** has a fixed position in the industrial environment and it is measuring if the reflected waves from apparatuses **2000** can be detected. Having information about two successive appearances of the apparatuses **2000** and knowing their distances on the belt **304**, the lateral speed of the belt is calculated. This proposed principle can be applied for all moving object being marked by the apparatuses **2000**, passing close to the controlling point with the installed apparatus **100**. FIG. 4b) shows rotation platform **506**, having rotation axes **507**. Rotation platform **506** has at least one apparatus **2000** being integrated in **506**. Apparatus **100** is measuring the time between two appearances from reflected signals coming from apparatuses **2000**, and knowing their radial position, rotation speed can be calculated.

[0096] This system can be used for angular encoders.

[0097] This system can be used as a sensor for measuring liquids flow, where the rotation road **507** is fixed, and the moving platform has wings, influencing the rotation of the platform proportional to the speed of the moving liquids. The special case of water flow measurements is acknowledged.

[0098] FIG. 5 shows application scenario typical for food industry, where juices, water, wine, milk and other liquids are packed. There is a problem that due to the damages in the production line, the package, which should contain liquid, is not full according to the pre-defined liquid level. So special sensor is requested, to detect packages which are not filled properly. The proposed system for this application scenario consists of apparatus **100** and apparatus **2000** being on the same height and the specific predefined distances. Between them the rolling belt **508** with packages **509** are passing by, each having liquid level **510**. Apparatus **100** is observing reflected signals from apparatus **2000**, and due to the known speed of the belt **508**, the apparatus **100** is not receiving the reflected signals from apparatus **2000** when the package full of liquid is filled in the proper and prescribed ways. If apparatus **100** is receiving signals when non-receiving time is to be detected, that means reflected ways are passing through package because the liquid level is too small. Therefore, the information with the time stamp is sent by the entity **60** outside apparatus **100**, to initialize specific actions, like omitting as quality measured delivering the package to the customers without prescribed level of the filled liquids.

[0099] Furthermore, to described applications, where proposed system, being defined through its apparatuses and method of operation, is used, the calculated information and events may be used for the statistical evaluation of the data.

[0100] This includes:

[0101] Statistic evaluation what classes of the passengers and with which percentage are using dedicated seats, providing profiling of the seat occupancy

[0102] Statistic evaluation of how many intruders passes control points, in specific merits of time.

[0103] Statistic evaluation of the lateral or rotation speed profiles of the object under observation

[0104] Statistic evaluation of the vehicle classes passing through roads

[0105] Statistic evaluation of the large vehicle with the probability to endanger safety on the roads

[0106] Statistic evaluation of the packages do not comply the quality standards of liquid filling level

[0107] By using artificial intelligence algorithms, with machine learning in the place, the proposed system, being defined by its apparatuses and methods of operations, can be advantageously used for Improving decision quality in the corner cases, close to toady hard and empiric hard predefined sets of decision thresholds, which may be exchanged with soft type of the thresholds.

1: The System operating in 24 GHz to 300 GHz frequency band comprising one apparatus **100** with HW radar functionality, and at least two apparatuses **2000** being placed physically at the distance from apparatus **100**,

where first apparatus **100** contains:

At least one high-gain planar antenna for transmitting mm-wave radio signals **21**, where the high-gain planar antenna has at least two radiation elements;

At least one high-gain planar antenna for receiving mm-wave radio signals **110**, where the high-gain planar antenna has at least two radiation elements; where at least one high planar antenna, operating in 24 GHz to 300 GHz frequency band, **110** has a cross polarization compared to at least one transmit antenna **21**

Integrated radio front end **10**, implemented in arbitrary semiconductor technology, having on-chip integrated voltage control oscillator, power amplifier, at least one IQ demodulator, digital control interface, power supply;

Digital processing functionality **30** with arbitrary hard wired and SW digital processing capability, being able to digitally process the signal coming out of the entity **10**, including controlling functionality and calculation and memory capacity for performing digital signal processing by arbitrary type of the realization options

Wired communication interface **60** to connect first Apparatus **100** to the vehicle infrastructure entity **1000**, being outside the apparatus **100**, being released by the plurality of the technologies and communication protocols

Supporting circuitry **50**, including mechanical interface to vehicle environment **1000**, where the first Apparatus **100** is connected to the infrastructure environment facing vehicle seat under observation, and supporting electronic circuitry for provide the power supply from the vehicle environment **1000** to the first apparatus **100**.

where the second apparatus **2000**:

is a passive, without power supply, and without capability of charging by the illumination of the mm-waves, being realized by plurality of realization options, having a key feature to reflect the incident waves coming from apparatus **100**, in the same direction, with cross polarization, compared to the incident radio waves polarization, where radio waves are approaching the apparatus **2000**.

- Where at least one apparatus **2000** is integrated in the vehicle seat **299**, facing in the direct view apparatus **100**, being integrated inside vehicle cabin facing the seat **299**
- 2:** System according to claim **1**, where where apparatus **100** is connected to the fixed non-moving infrastructure with provided power supply where at least one apparatus **2000** is positioned at fixed non-moving infrastructure **300** with fixed distance to the apparatus **100** where both apparatus **100** and **2000** are not inside of the vehicle.
- 3:** System according to claim **1**, where where apparatus **100** is connected to the moving infrastructure **301** with provided power supply, where moving infrastructure **301** is vehicle where at least one apparatus **2000** is positioned at fixed non-moving infrastructure **302**
- 4:** System according to claim **1**, where where at least one apparatus **100** is placed at the traffic infrastructure **503**, with provided power supply where at least one apparatus **2000** is placed at the traffic infrastructure **503**, at the same height as corresponding apparatus **100**, with fixed distance to the apparatus **100**, across the road **504**
- 5:** System according to claim **1**, where where at least one apparatus **100** is placed in the industrial environment facing moving belt **304** where at least one apparatus **2000** is integrated in the moving belt **304**
- 6:** System according to claim **1**, where where at least one apparatus **100** is placed in the industrial environment facing rotating platform **506** where at least one apparatus **2000** is integrated in the rotating platform **506**
- 7:** System according to claim **1**, where where apparatus **100** is placed in the industrial environment facing apparatus **2000** at the same height positioned across the moving industrial belt **508**, transporting packages **509**, each containing **510** level of liquids inside of the package **509**
- 8:** Method of operation, utilizing the System being described in claim **1** where method of operation comprising three operation steps: “detecting seat occupancy” being declared as a first operation step, “detection of apparatuses **2000**, by apparatus **100**” being declared as second operation step, to be executed after the first step is executed, and “method for calculating human being classification”, being declared as third operation step to be executed after the second step is executed, where the first operation step has following sub-set of operations:  
 Detecting by apparatus **100**, if the human being is on the seat by using plurality of the approaches where the second operation step has following sub-set of operations:  
 Transmission of mm-wave signals generated in **10** using **21**;  
 Receiving radio signals reflected by apparatus **2000** area using at least one receiving antenna **110**, having cross polarization compared to the antenna **21**, operating in 24 GHz to 300 GHz frequency band;  
 Signal processing and detection at least three classes of the information:  
 Class one: no signal level detected above specific pre-defined threshold one  
 Class two: signal level detected above specific pre-defined threshold one, and lower than pre-defined threshold two, where the predefined threshold two is larger than predefined threshold one  
 Class three: signal level detected above specific pre-defined threshold three, where the predefined threshold two is larger than predefined threshold two  
 where third operation step being executed after the second operation step, has following sub-set of operations:  
 Mapping detected class of signal level to the event detection of the human being classification, according to the following rules:  
 If Class one is detected: average size human being is on the seat  
 If Class two is detected: smaller human being size, most probably a kid is on the seat  
 If Class three is detected: smaller life being is on the seat, most probably baby  
 Detected event is communicated to the vehicle environment **1000**, by means of entity **60**
- 9:** Method of operation, utilizing the System being described in claim **2** where method of operation comprising three operation steps: “detecting visibility of apparatuses **2000**, by apparatus **100**” being declared as a first operation step, “observing cut in the visibility of apparatuses **2000**, by apparatus **100**” being declared as second operation step, to be executed after the first step is executed, and “method for calculating signal is broken”, being declared as third operation step to be executed after the second step is executed, where the first operation step has following sub-set of operations:  
 Transmission of mm-wave signals generated in **10** using **21**;  
 Receiving mm-wave signals reflected by apparatus **2000** area using at least one receiving antenna **110**, having cross polarization compared to **21**  
 Detecting by apparatus **100**, if the apparatus **2000** is visible  
 where the second operation step has following sub-set of operations:  
 Transmission of mm-wave signals generated in **10** using **21**;  
 Receiving mm-wave signals reflected by apparatus **2000** area using at least one receiving antenna **110**;  
 Detecting by apparatus **100**, if the apparatus **2000** is starting to be not visible, which is defined by using pre-defined threshold;  
 Memorising time of un-visibility detection  
 where third operation step being executed after the second operation step, has following sub-set of operations:  
 Detected event of un-visibility detection is reporting with time step of its calculation, by means of entity **60** to the world outside of apparatus **100**
- 10:** Method of operation, like in claim **9**, related to the System described in claim **5**, and claim **6** where the third operation step has additional sub-set of activities to calculate frequency of switching visibility and no-visibility, and sending this information over entity **60** to the world outside of apparatus **100**.
- 11:** Method of operation like described in the claim **9**, related to the System described in claim **3**, where the first

operation step “detecting visibility of apparatuses **2000**, by apparatus **100**” is initialized by the moving platform **301**, when the moving platform **301** is approaching the area, where the load **504** should be placed by the moving platform **301**, and where the moving platform **301** will off-load **504**, if the apparatus **2000** is visible, and will not off-load the load **504** if the apparatus **2000** is not visible.

**12:** Method of operation, utilizing the System being described in claim **7** where method of operation comprising three operation steps: “observing if the apparatus **2000** is visible, by apparatus **100**” being declared as a first operation step, “observing if the visibility of apparatuses **2000**, by apparatus **100** appears” being declared as second operation step, to be executed after the first step is executed, and “method for calculating liquid level in not sufficiently large”, being declared as third operation step to be executed after the second step is executed,

where the first operation step has following sub-set of operations:

Initialising Transmission of radio signals generated in **10** using **21**; in the time slot when the package **509** is passing between apparatus **100** and apparatus **2000**, operating in 24 GHz to 300 GHz frequency band

Receiving radio signals reflected by apparatus **2000** area using at least one receiving antenna **110**, operating in 24 GHz to 300 GHz frequency band

Detecting by apparatus **100**, if the apparatus **2000** is not visible

where the second operation step has following sub-set of operations:

Transmission of radio signals generated in **10** using **21**, operating in 24 GHz to 300 GHz frequency band;

Receiving radio signals reflected by apparatus **2000** area using at least one receiving antenna **110**, having cross polarization compared to **21**, operating in 24 GHz to 300 GHz frequency band;

Detecting by apparatus **100**, if the apparatus **2000** is starting to be visible, which is defined by using pre-defined threshold;

Memorising time of visibility detection

where third operation step being executed after the second operation step, has following sub-set of operations:

Event of insufficient liquid level inside package **509** is mapped to the event the visibility of apparatus **2000** is detected in the time slot, where the package is regularly passing between apparatus **100** and apparatus **2000**, and after the event is reported together with time step of its calculation, by means of entity **60** to the world outside of apparatus **100**, where pre-defined actions are further initialized by the world outside if apparatus **100**.

**13:** Method of operation, utilizing the Method of operation like in claim **8-11**, where machine learning process by the plurality of the applied algorithms are used to optimise the decision making pre-defined thresholds in the second operation step.

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