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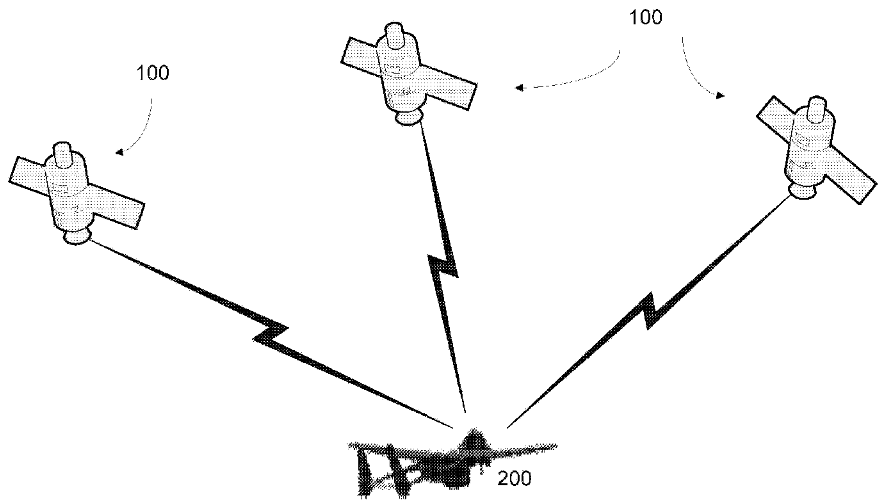

Fig. 1

(57) Abstract: According to the presently disclosed subject matter, it is suggested to use beacon signals as a navigational aid. More specifically, a platform equipped with a suitable communication antenna (e.g., beyond line of sight (BLOS) communication antenna) can search for a plurality of beacon signals, identify the signals, and determine the position of the platform using techniques such as triangulation.

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POSITIONING USING SATELLITE BEACON

FIELD OF THE PRESENTLY DISCLOSED SUBJECT MATTER

The presently disclosed subject matter relates to positioning methods and systems.

BACKGROUND

Mobile platforms, including manned and unmanned aerial, land, and marine vehicles, are commonly equipped with different navigation instruments that enable self-positioning and navigation of the platform. These systems include GPS positioning units which determine the position of the platform based on data received from a plurality of GPS satellites (normally 4 or more).

While GPS systems often play a central and sometimes crucial role in navigation of mobile platforms, GPS signals are many times unavailable, due to various reasons, including the inherent GPS signal instability as well as GPS signal spoofing or jamming. As unavailability of GPS signals precludes GPS based navigation, alternative positioning methods are desired.

GENERAL DESCRIPTION

Various types of satellites exist in addition to GPS satellites (also known as navigation satellites) including for example, earth observation satellites, communication satellites, weather satellites, and space telescopes. These satellites operate independently of GPS satellites.

Many of the satellites transmit a beacon signal having a fixed frequency which helps to monitor the general health of the satellite and also assist stations to properly align their antennas with the satellite transmitting the signal to maximize gain of the received signal.

A certain frequency band is allocated for beacon signals and each beacon signal transmitting satellite is assigned with a fixed and unique frequency for its beacon signal within this frequency band. The difference in frequency assigned to the different satellites can be used for identifying a respective transmitting satellite (e.g. by a ground station). According to the presently disclosed subject matter, it is suggested to use beacon signals as a navigational aid. More specifically, a platform equipped with a suitable communication antenna (e.g., beyond line of sight (BLOS) communication antenna) can search for a plurality of beacon signals, identify the signals, and determine the position of the platform using techniques such as triangulation.

According to an aspect of the presently disclosed subject matter, there is provided a method of determining position of a mobile platform using satellite beacon signals, the method comprising executing a positioning process:

pointing an antenna onboard the platform for receiving at least two beacon signals, each beacon signal transmitted by a respective satellite;

upon detection of a beacon signal:

determining pitch and yaw angles of the antenna relative to the respective transmitting satellite;

determining a pointing vector from the platform to the respective transmitting satellite; and

calculating an estimated position of the platform using two or more pointing vectors.

In addition to the above features, the method according to this aspect of the presently disclosed subject matter can optionally comprise one or more of features (i) to (xiii) below, in any desired combination or permutation:

i. Wherein the antenna is a beyond line of sight antenna (e.g., BLOS antenna).

ii. wherein determining a pointing vector from the platform to the respective transmitting satellite further comprises:

determining orientation of the platform (e.g. using inertial navigation system (INS) onboard the platform);

transforming pitch and yaw angles in antenna frame to platform frame; and determining the pointing vectors from the platform to respective transmitting satellite.

iii. wherein determining a pointing vector from the platform to the respective transmitting satellite further comprises:

determining orientation of the platform (e.g. using inertial navigation system (INS) onboard the platform);

determining the pointing vectors from antenna to respective transmitting satellite;

determining the estimated position of the antenna using two or more pointing vectors; and

transforming pitch and yaw angles in antenna frame to platform frame to thereby obtain the position of the platform.

iv. The method further comprising:

scanning the atmosphere with the antenna to locate the at least two beacon signals.

v. The method further comprising:

obtaining data indicative of an estimated current position of at least one beacon transmitting satellite; and using the position data for pointing the antenna in the direction of the satellite.

vi. The method further comprising: autonomously initiating the positioning process following determination that one or more conditions are met.

vii. wherein the conditions include loss of GPS signals for a period longer than a certain length.

viii. wherein the conditions include obtaining an indication of suspected GPS signal spoofing or suspected GPS signal jamming.

ix. The method further comprising:

using a GPS positioning unit onboard the platform to determine GPS positioning data; comparing between the GPS positioning data and the estimated position of the platform and validating the GPS positioning data based on the result of the comparison.

x. The method further comprising:

repeatedly determining the orientation of the mobile platform; and

updating the pointing vectors and the estimated position of the platform according to changes in the orientation.

xi. The method further comprising:

obtaining altitude of the platform and determining a three-dimensional positioning data of the platform.

xii. The method further comprising:

switching the antenna between two modes, where in the first mode the antenna is used for receiving beacon signals and in the second mode the antenna is used for communication.

xiii. Wherein the platform is a vehicle, including any one of: unmanned or manned aerial vehicle; unmanned or manned ground vehicle; and unmanned or manned marine vehicle.

According to another aspect of the presently disclosed subject matter there is provided a positioning unit mountable on a mobile platform, the positioning unit is operatively connected to anantenna (e.g., BLOS antenna) (e.g., beyond land of sight antenna) onboard the mobile platform and comprises a processing circuitry configured to:

generate instructions for causing the antenna to point in a direction of a beacon transmitting satellite to enable receiving a respective beacon signal;

upon detection of a beacon signal:

determine pitch and yaw angles of the antenna relative to the respective transmitting satellite;

determine a respective pointing vector from the platform to the respective beacon transmitting satellite;

upon detection of at least two pointing vectors, each to a different beacon transmitting satellite, calculate an estimated position of the platform using the at least two pointing vectors.

According to another aspect of the presently disclosed subject matter there is provided a positioning system mountable on a platform comprising: an antenna (e.g., BLOS antenna), an INS and a beacon positioning unit operatively connected to the BLOS antenna; the beacon positioning unit comprises a processing circuitry configured to:

generate instructions for causing the antenna to point in a direction of a beacon transmitting satellite to enable receiving a respective beacon signal;

upon detection of a beacon signal:

determine pitch and yaw angles of the antenna relative to the respective transmitting satellite;

determine a respective pointing vector from the platform to the respective beacon transmitting satellite;

upon detection of at least two pointing vectors, each to a different beacon transmitting satellite, calculate an estimated position of the platform using the at least two pointing vectors.

According to another aspect of the presently disclosed subject matter there is provided a vehicle carrying the system, where in some examples the vehicle is an aircraft, and in further examples it is an unmanned aircraft.

According to another aspect of the presently disclosed subject matter there is provided a computer-readable memory device tangibly embodying a program of instructions executable by the computer for executing a method of determining position of a mobile platform using satellite beacon signals, comprising instructions for:

pointing a beyond line of sight antenna (e.g., BLOS antenna) onboard the platform for receiving at least two beacon signals, each beacon signal transmitted by a respective satellite;

upon detection of a beacon signal:

determining pitch and yaw angles of the BLOS antenna relative to the respective transmitting satellite;

determining a pointing vector from the platform to the respective transmitting satellite;

calculating an estimated position of the platform using two or more pointing vectors.

The positioning unit, the system, the vehicle and the program storage device disclosed in accordance with the presently disclosed subject matter can optionally comprise one or more of features (i) to (xiii) listed above with respect to the method, mutatis mutandis, in any desired combination or permutation.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the presently disclosed subject matter and to see how it may be carried out in practice, the subject matter will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of a scenario, according to an example of the presently disclosed subject matter;

Fig. 2 is schematic block diagram of systems and components mounted onboard a platform, according to an example of the presently disclosed subject matter;

Fig. 3 is a flowchart showing an example of operations which are carried out according to examples of the presently disclosed subject matter; and

Fig. 4 is a schematic block diagram of a beacon position unit, according to an example of the presently disclosed subject matter.

DETAILED DESCRIPTION

In the drawings and descriptions set forth, identical reference numerals indicate those components that are common to different embodiments or configurations. Elements in the drawings are not necessarily drawn to scale.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "determining", "calculating", "transforming", "obtaining", "comparing" or the like, include actions and/or processes of a computer that manipulate and/or transform data into other data, said data represented as physical quantities, e.g. such as electronic quantities, and/or said data representing the physical objects.

The terms “computer” or "processing unit" should be expansively construed to include any kind of hardware-based electronic device with a data processing circuitry (e.g. digital signal processor (DSP), a GPU, a TPU, a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), microcontroller, microprocessor etc.). The processing circuitry can comprise, for example, one or more processors operatively connected to a computer memory, loaded with executable instructions for executing operations as further described below. Components of the system disclosed below with reference to Fig. **2**, including, navigation unit, antenna control unit, beacon positioning unit, etc., are each a computer, or include a computer, or are operatively connected to a computer.

As used herein, the phrase "for example," "such as", "for instance" and variants thereof describe non-limiting embodiments of the presently disclosed subject matter. Reference in the specification to "one case", "some cases", "other cases" or variants thereof means that a particular feature, structure or characteristic described in connection with the embodiment(s) is included in at least one embodiment of the presently disclosed subject matter. Thus, the appearance of the phrase "one case", "some cases", "other cases" or variants thereof does not necessarily refer to the same embodiment(s).

It is appreciated that certain features of the presently disclosed subject matter, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the presently disclosed subject matter, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

In embodiments of the presently disclosed subject matter, fewer, more and/or different stages than those shown in Fig. **3** may be executed. The presently disclosed subject matter contemplates any combination of operations which are described separately with reference to Fig. **3**, into a single process.

Figs. **2** and **4** illustrate a general schematic of the system architecture in accordance with an embodiment of the presently disclosed subject matter. In other embodiments of the presently disclosed subject matter, the system may comprise fewer, more, and/or different (e.g. distributed differently) functional elements than those shown in Figs. **2** and **4**. For example, division in platform **200** into the specified functional elements is provided for the sake of example only and should not be construed as limiting in any way. For instance, functional elements drawn as nested within other functional elements may be otherwise designed as independent functional units.

It is noted that reference in the present description to an unmanned aerial vehicle (UAV) is made by way of example only, and the same principles and similar functional elements described in relation to a UAV can be likewise applied to a piloted aircraft configured with an auto-pilot flight, as well as to other types of vehicles, including manned and unmanned ground and marine vehicles.

In some examples, in case platform **200** is a UAV, it can be designed to comply with the requirements of STANAG 4586 which is the NATO specification for implementing a core UAV control system (CUCS, comprising both ground and aerial UAV control components). According to STANAG 4586, a control system, configured to remotely monitor and control the UAV, comprises a client module (operator console) connected in sequence to the application servers unit, vehicle specific module and primary B/LOS ground data terminal (B/LOS GDT).

The application servers unit comprises one or more computerized devices (e.g.

computer servers) configured to enable the execution of various tasks. Each server is a computerized device with appropriate computer memory and one or more computer processors providing the required data processing capabilities.

The application servers unit can include by way of non-limiting example: flight control server configured for controlling the UAV's flight and various data acquisition servers operatively connected to a respective data acquisition device (e.g. camera, radar, communication intelligence device, etc.) installed on the UAV.

B/LOS GDT is configured to communicate with the UAV via a respective aerial data terminal (B/LOS ADT) which is part of the UAV onboard systems. Communication between GDT and ADT can be line of sight communication (LOS), or satellite based beyond line of sight communication (BLOS). For example, communication unit **227** can comprise or be otherwise operatively connected to an aerial data terminal (B/LOS ADT) and communicate with a ground data terminal (B/LOS GDT) located at a ground control unit.

Attention is now drawn to Fig. **1**, which schematically illustrates an operational scenario, according to an example of the presently disclosed subject matter. Fig. **1** shows a platform **200** (e.g. UAV) in midair. As mentioned above, an airborne mobile platform and specifically a UAV is provided herein as a non-limiting example only, while the principles disclosed herein can be likewise applied to other types of mobile platforms. UAV **200** may comprise one or more navigation instruments including a GPS system and an inertial navigation system (INS). According to one example, following loss of reception of GPS signals (e.g. for a period longer than a certain length) a beacon navigation aid is activated and used for determining navigation data instead of the GPS system. As further explained below, a beacon navigation aid, mounted on the UAV, is configured to use beacon signals received from two or more satellites **100** for the purpose of determining position of the platform. Satellites **100** include any type of civilian and non-civilian satellite that transmits a beacon signal, for example a communication satellite or an Earth observation satellite. For clarity, these satellites are referred to herein as "beacon transmitting satellites".

Fig. **2** is a schematic block diagram illustrating components onboard a mobile platform, according to some examples of the presently disclosed subject matter.

In the illustrated example, a UAV is shown comprising a platform navigation unit **220** that includes various navigation instruments, including for example GPS unit, INS unit, altimeters, pitot tubes, etc. Platform navigation devices are configured to assist in the determination of the current position of the platform, generally defined relative to some frame of reference (e.g. ECEF). According to the presently disclosed subject matter, the platform further comprises a beacon positioning unit **230** operatively connected to at least one antenna (e.g., BLOS satellite communication antenna) onboard the platform and configured to determine the position of the platform based on satellite beacon signals. Beacon positioning unit **230** comprises or is otherwise operatively connected to a processing circuitry configured to control the antenna and direct it towards a different beacon transmitting satellite and determine self-position of the platform using a plurality of beacon signals. To this end the processing circuitry can be configured to execute several functional modules in accordance with computer-readable instructions implemented on a non-transitory computer-readable storage medium. A schematic example of a beacon position unit is provided in Fig. **4** below.

Navigation unit **220** can further comprise a navigation computer **221** configured to generate navigation instructions. Navigation instructions are generated, based on the positioning data obtained from the navigation devices, and provided to platform control device **222** to control the platform e.g. maintain a course along a desired progression path. In case of an aerial platform, control devices **222** include, for example, throttle, flaps, alerions, rudder, wheels, elevators, etc. The UAV may comprise various control units, each dedicated to controlling the operation of a respective control device. When operating in autonomous mode, navigation unit **220** is configured to autonomously control the platform (e.g. flight of the UAV). More specifically, navigation computer **221** can determine the position of the UAV (e.g. its geolocation) and a desired destination, and generate flight instructions designated for leading the aircraft to the desired destination. Determination of the position of the platform can be accomplished using the navigation devices mentioned above, including GPS and INS and/or the beacon positioning unit **230**, as further explained below.

The UAV further comprises a communication unit **227** operatively connected for example to at least one line of sight (LOS) antenna, configured to enable communication over a line-of-sight communication link, and at least one beyond line of sight antenna (e.g., BLOS antenna), configured to enable communication over a beyond line-of-sight communication link including for example, satellite communication. The antennas, can be attached for example to a pan and tilt assembly, where in some examples, the beacon positioning unit **230** can be configured to control the viewing angle of the antenna. For example, when searching for a beacon signal, as explained below, the beacon positioning unit **230** is operated for controlling the pan and tilt assembly to thereby move the antenna and scan the atmosphere in search for beacon signals, or point the antenna in the direction of a known position of a beacon transmitting satellite.

The platform generally comprises various other devices and units, including for example different payloads, e.g. a surveillance system comprising one or more sensing devices such as image sensors and radars.

Fig. **3** is a flowchart of operations carried out for navigation using beacon signals. While operations according to Fig. **3** are described herein with reference to components shown in Figs. **2** and **4** this is done for the sake of clarity of the description alone and should not be construed to limit the scope of the disclosed subject to the specific design or components illustrated in Figs. **2** and **4**.

At block **301** the beacon signal positioning process is initiated. The beacon signal positioning process can be activated manually by a human operator or be activated autonomously. For instance, beacon positioning unit **230** can be autonomously activated for executing the beacon signal positioning process in response to determination that certain conditions are met. Beacon positioning unit **230** can be configured to monitor incoming GPS signals from GPS satellites and autonomously activate the beacon signal positioning process in response to loss of

GPS data for a certain period longer than some preset length. In other examples, beacon position unit **230** can be activated alongside a GPS positioning unit for the purpose of validating the GPS positioning data. To this end, the output of the beacon signal positioning process is compared to GPS based positioning output, and in case the difference between the two outputs is greater than a certain threshold, the GPS signal is suspected as being corrupt. For example, the beacon positioning process can be autonomously activated by the beacon position unit **230** in response to data indicating suspected GPS signals spoofing or GPS signals blocking. The estimated position obtained by the beacon position unit **230** is used to confirm or deny the suspected spoofing or blocking. In further examples, beacon positioning unit **230** can periodically activate the beacon signal position process to routinely validate that GPS positioning (or by some other navigation aid) is correct.

At the onset of the beacon navigation process, an antenna (e.g., BLOS antenna) onboard the platform is controlled for searching the atmosphere for beacon signals transmitted by different satellites including low orbiting (LEO) satellites such as communication satellites and Earth observation satellites.

In some examples, if during activation of the beacon positioning process, the LOS antenna is being used for communication and the BLOS antenna is available, the BLOS antenna can be operated for the purpose of beacon signal positioning. Otherwise, in some examples, if the BLOS antenna is being used for communicating with the platform, the BLOS antenna can be repeatedly switched for short periods between serving for communication and serving for beacon positioning, and vice versa. To this end, beacon position unit **230** can comprise a switching unit **401** configured to switch the BLOS antenna between two operational modes, where in the first mode the BLOS antenna is used for receiving beacon signals, and in the second mode the BLOS antenna is used for communication.

As mentioned above, beacon signals reside in a limited spectrum of frequencies, and, accordingly, the antenna (e.g., BLOS antenna) is operated for searching for signals within this spectrum. Since, normally, beacon signals are relatively low gain signals, good reception requires alignment of the antenna with the beacon transmitting satellite to maximize gain of the received signal. To accelerate detection of the beacon signals, in some examples, prestored satellites' location data is used for assisting in pointing the antenna in the direction of a beacon transmitting satellite. Information on the position of satellites in space is publicly available, where geostationary satellites have a specific location, and the location of orbiting satellites can be determined based on their known orbit and time.

According to one example, part or all of the satellites' position data can be prestored in data-repository **240** onboard the platform and used during beacon signal positioning. The prestored data can be updated from time to time. According to another example, part or all of the satellites' position data can be obtained in real-time from a third party such as a control station or another platform, upon initiation of the beacon positioning process. According to a further example, beacons position unit **230** is configured to determine the current position of satellites e.g. with the help of satellite position determination unit **403**. An antenna control unit **405** can be configured to pan and tilt the antenna (e.g., BLOS antenna) (e.g. by controlling a pan and tilt assembly) in order to point the antenna in the direction of the given satellite.

According to some examples, if positioning data of beacon transmitting satellites is unavailable or lacking, the beacon position unit can be configured to systematically scan the atmosphere (e.g. with the help of antenna control unit **405**) and search for beacon signal reception. Received signals are analyzed (e.g. with the help of data processing unit **407**) to determine their frequency, and beacon signals are identified as those which reside within the appropriate frequency range.

At block **303**, once a beacon signal is received by the antenna (e.g., BLOS antenna), the frequency of the beacon signal is determined (e.g. with the help of data processing unit **407**) and used for uniquely identifying the respective transmitting satellite.

At block **305**, once the antenna (e.g., BLOS antenna) is pointed in the direction of the beacon transmitting satellite, pan and tilt (pitch and yaw) angles of the antenna to the satellite are determined (e.g. with the help of data processing unit **407**) and a pointing vector from the antenna to the satellite is determined as well. The vector can be stored along with the unique frequency of the beacon transmitting satellite (e.g. in computer data-repository **240** onboard the platform). Once the antenna is locked onto a beacon signal, the respective pitch and yaw angles can be determined directly from the antenna. In some examples, angle of arrival (AoA) of the signal can be calculated, for example by using an antenna array onboard the platform. An INS onboard the platform can be used for determining pitch, yaw, and roll angles of the platform (e.g. Euler angles) relative to Earth (e.g. in ECEF). As the angular position of the antenna relative to the platform is known, platform angles (orientation) can be transformed from platform frame of reference to antenna frame of reference and vice versa, using appropriate transformation matrixes. Notably, the antenna roll angle equals zero.

According to one example, once the pointing vector from antenna to satellite is determined, the pointing vector is transformed to platform frame of reference, e.g., based on platform orientation obtained from INS. According to another example, the pitch and yaw angles of the antenna are first transformed to platform frame of reference and a pointing vector is determined from platform to satellite.

If the platform is moving, its relative movement, from the point of detection of the beacon signal and determination of the pointing vector, is monitored, and the pointing vector can be continuously updated according to the changes in attitude of the platform. For example, beacon position unit **230** can be configured to receive from onboard INS continuous updates of platform attitude and use the updated data for updating the pointing vector to the satellite.

The operations described above with reference to block **301**-**305** are repeated as the antenna (e.g., BLOS antenna) continues to search for at least one additional beacon signal transmitted by a different satellite.

Once at least two pointing vectors to at least two different satellites are available the estimated position of the platform can be determined (block **307**). Position determination can be done by intersecting between the pointing vectors e.g. by implementing methods such as triangulation.

According to one example, the pointing vectors are determined in antenna frame, i.e. extending from antenna to satellite and a position of the antenna is determined using two or more vectors. Then the position of the platform is calculated by transforming the so determined antenna position to platform frame. According to another example, the angles of the pointing vectors are first transformed to platform frame and then the position of the platform is determined in platform frame. Notably, the accuracy of estimation of the platform position is dependent on the quality of the detection of each beacon signal and the accuracy of the determination of the respective pointing vector to the source of the beacon signal, i.e. the respective beacon transmitting satellite.

In case three unique beacon signals from three different satellites are available, two different cross points can be determined, each point obtained by crossing between two pointing vectors, each extending from the antenna (e.g., BLOS antenna) in the direction of a respective satellite. In such cases, the position of the platform can be determined based on the two cross points, e.g. by calculating an average position of two different positions, each calculated by a different pair of pointing vectors. In some examples, an estimator or filter (implemented for example by beacon positioning unit **230**) can be used to calculate an estimate position based on the two or more cross points, using filters which minimize the predicted error, such as least square or other techniques, which are well known in the art.

It is noted that while two different beacon signals and respective vectors are generally sufficient for determination of the platforms' position, the greater the number of unique beacon signals, the more accurate the calculated positioning of the platform. A three-dimensional position of the platform can be determined for example using two pointing vectors, each to a different beacon transmitting satellite and altitude of the platform obtained from an altimeter.

Beacon data can be combined with other data. For example, a pointing vector to a beacon transmitting satellite can be used together with a pointing vector to another structure on the ground, such as a ground control station, that has a known position.

It is to be understood that the system according to the presently disclosed subject matter may be a suitably programmed computer. Likewise, the presently disclosed subject matter contemplates a non-transitory computer program being readable by a computer for executing the method of the presently disclosed subject matter. The presently disclosed subject matter further contemplates a machine-readable memory (transitory and non-transitory) tangibly embodying a program of instructions executable by the machine for executing the method of the presently disclosed subject matter.

It is also to be understood that the presently disclosed subject matter is not limited in its application to the details set forth in the description contained herein or illustrated in the drawings. The presently disclosed subject matter is capable of other embodiments and of being practiced and carried out in various ways. Hence, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting. As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the present presently disclosed subject matter.

Claims:

1. A method of determining position of a mobile platform using satellite beacon signals, the method comprising executing a positioning process:

pointing an antenna onboard the platform for receiving at least two beacon signals, each beacon signal transmitted by a respective satellite;

upon detection of a beacon signal:

determining pitch and yaw angles of the antenna relative to the respective transmitting satellite;

determining a pointing vector from the platform to the respective transmitting satellite; and

calculating an estimated position of the platform using two or more pointing vectors.

2. The method of claim 1, wherein determining a pointing vector from the platform to the respective transmitting satellite further comprises:

determining orientation of the platform;

transforming pitch and yaw angles in antenna frame to platform frame; and

determining the pointing vectors from the platform to the respective transmitting satellite.

3. The method of claim 1, wherein determining a pointing vector from the platform to the respective transmitting satellite further comprises:

determining orientation of the platform;

determining the pointing vectors from the antenna to the respective transmitting satellite;

determining the estimated position of the antenna using two or more pointing vectors; and

transforming pitch and yaw angles in antenna frame to platform frame to thereby obtain the position of the platform.

4. The method of claim 1, wherein the antenna is a BLOS antenna.

5. The method of claim 4 further comprising:

scanning the atmosphere with the antenna to locate the at least two beacon signals.

6. The method of any one of claims 1 to 4 further comprising:

obtaining data indicative of an estimated current position of at least one beacon transmitting satellite; and using the data for pointing the antenna in the direction of the satellite.

7. The method of any one of the preceding further comprising: autonomously initiating the process following determination that one or more conditions are met.

8. The method of claim 7, wherein the conditions include loss of GPS signals for a period longer than a certain length.

9. The method of any one of claims 7 and 8, wherein the conditions include obtaining an indication of suspected GPS signal spoofing or suspected GPS signal blocking.

10. The method of any one of the preceding claims further comprising:

using a GPS positioning unit onboard the platform to determine GPS positioning data; comparing between the GPS positioning data and the estimated position of the platform and validating the GPS positioning data based on the result of the comparison.

11. The method of any one of the preceding claims, further comprising:

repeatedly determining the orientation of the mobile platform; and

updating the pointing vectors and the estimated position of the platform according to changes in the orientation.

12. The method of any one of the preceding claims further comprising:

obtaining altitude of the platform and determining a three-dimensional positioning data of the platform.

13. The method of any one of the preceding claims further comprising:

switching the antenna between receiving beacon signals and communicating.

14. A positioning unit mountable on a mobile platform, the positioning unit being operatively connected to an antenna onboard the mobile platform and comprising a processing circuitry configured to:

generate instructions for causing the antenna to point in a direction of a beacon transmitting satellite to enable receiving a respective beacon signal;

upon detection of a beacon signal:

determine pitch and yaw angles of the antenna relative to the respective transmitting satellite;

determine a respective pointing vector from the platform to a respective beacon transmitting satellite;

upon detection of at least two pointing vectors, each to a different beacon transmitting satellite, calculate an estimated position of the platform using the at least two pointing vectors.

15. The positioning unit of claim 14, wherein the processing circuitry is configured for determining a pointing vector from the platform to the respective transmitting satellite to:

determine orientation of the platform using an inertial navigation system (INS) onboard the platform;

transform pitch and yaw angles in antenna frame to platform frame; and

determine the pointing vectors from the platform to the respective transmitting satellite.

16. The method of claim 14, wherein the processing circuitry is configured for determining a pointing vector from the platform to the respective transmitting satellite to:

determine orientation of the platform using inertial navigation system (INS) onboard the platform;

determine the pointing vectors from the antenna to the respective transmitting satellite;

determine the estimated position of the antenna using two or more pointing vectors; and

transform pitch and yaw angles in antenna frame to platform frame to thereby obtain the position of the platform.

17. The positioning unit of any one of claims 14 to 16, wherein the processing circuitry is further configured to generate instructions for scanning the atmosphere with the antenna to locate at least two beacon signals.

18. The positioning unit of any one of claims 14 to 16, wherein the processing circuitry is further configured to: obtain data indicative of an estimated current position of at least one beacon transmitting satellite; and use the data for pointing the antenna in the direction of the satellite.

19. The positioning unit of any one of claims 14 to 18, wherein the processing circuitry is further configured to autonomously initiate calculation an estimated position of the platform following determination that one or more conditions are met.

20. The positioning unit of claim 19, wherein the conditions include loss of GPS signals for a period longer than a certain length.

21. The positioning unit of claim 19, wherein the conditions include obtaining an indication of suspected GPS signal spoofing or suspected GPS signal blocking.

22. The positioning unit of any one of claims 14 to 20, wherein the processing circuitry is further configured to obtain a GPS positioning data determined by a GPS positioning unit onboard the platform; compare between the GPS positioning data and the estimated position of the platform and validate the GPS positioning data based on the result of the comparison.

23. The positioning unit of any one of claims 14 to 20, wherein the processing circuitry is further configured to repeatedly obtain orientation of the mobile platform; and

update the pointing vectors and the estimated position of the platform according to changes in the orientation.

24. The positioning unit of any one of claims 14 to 23 wherein the platform is a UAV.

25. The positioning unit of any one of claims 14 to 24, wherein the antenna is a beyond line of sight antenna.

26. A positioning system mountable on a mobile platform comprising: a BLOS antenna, an INS and a beacon positioning unit operatively connected to the antenna; the beacon positioning unit comprising a processing circuitry configured to:

generate instructions for causing the antenna to point in a direction of a beacon transmitting satellite to enable receiving a respective beacon signal;

upon detection of a beacon signal:

determine pitch and yaw angles of the antenna relative to the respective transmitting satellite;

determine a respective pointing vector from the platform to a respective beacon transmitting satellite;

upon detection of at least two pointing vectors, each to a different beacon transmitting satellite, calculate an estimated position of the platform using the at least two pointing vectors.

27. The system of claim 24 further comprising a pan and tilt assembly connected to the antenna, wherein the processing circuitry is configured to control the pan and tilt assembly for adjusting pitch and yaw angles of the antenna.

28. The system of any one of claims 24 and 25, wherein the beacon position unit is operatively connected to an inertial navigation system (INS) onboard the mobile platform and wherein the processing circuitry is further configured to:

determine orientation of the platform using the INS;

transform a pointing vector from antenna frame to platform frame; and

determine the respective pointing vector from platform to respective transmitting satellite.

29. The system of any one of claims 24 to 26, wherein the mobile platform is an aircraft.

30. The system of claim 29 wherein the aircraft is a UAV.

31. A computer-readable memory device tangibly embodying a program of instructions executable by the computer for executing the method according to any one of claims 1 to 13.

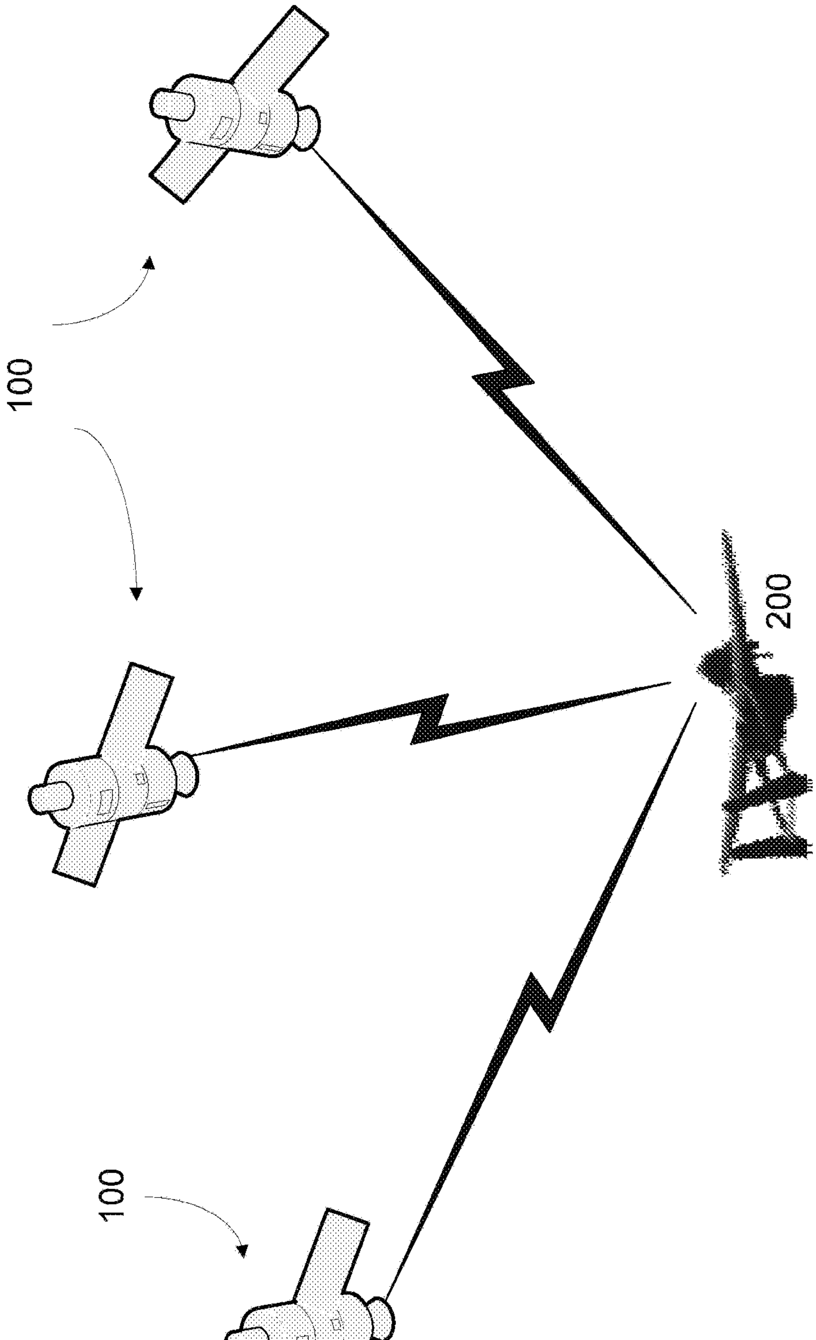
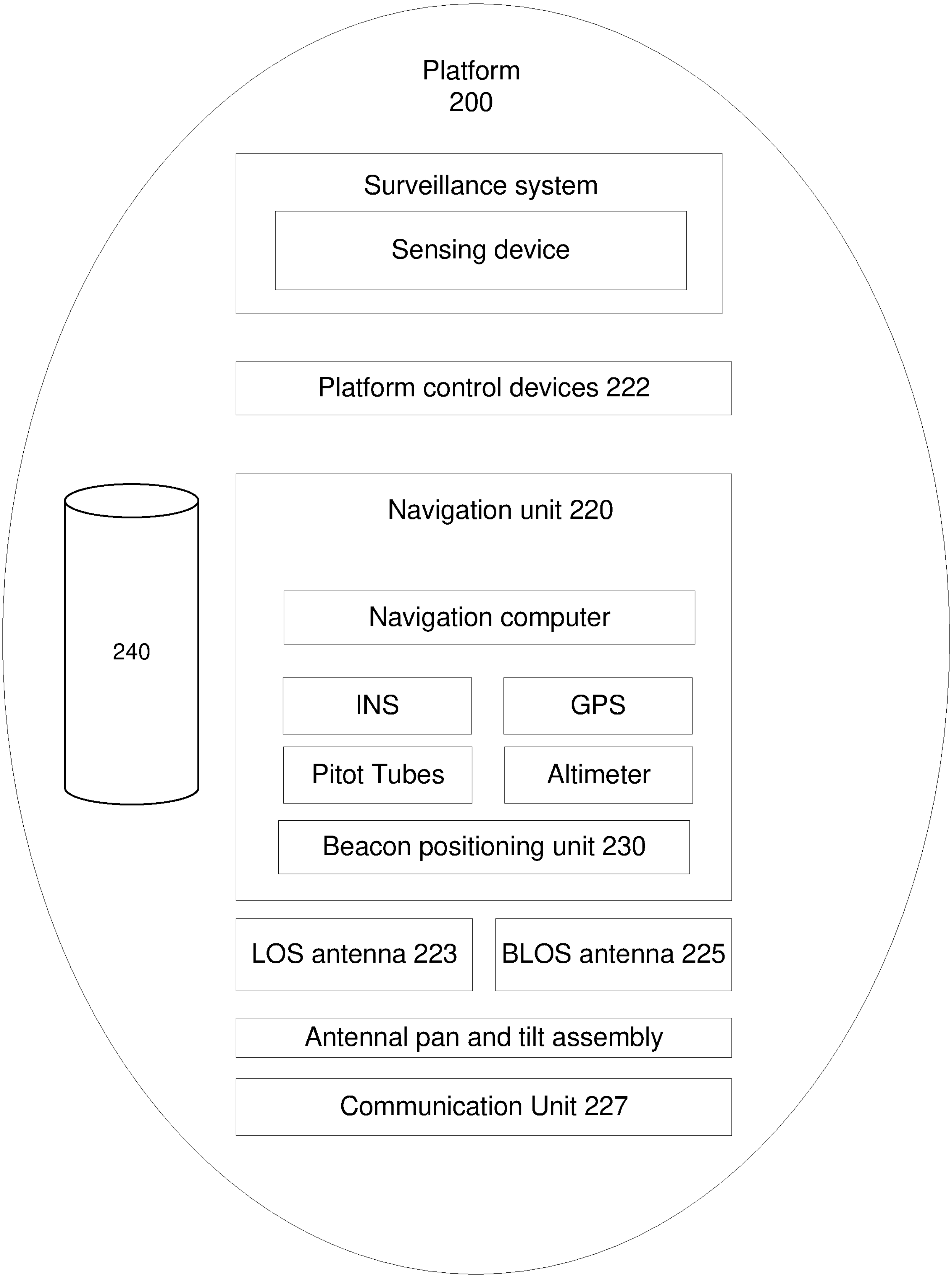


Fig. 1



Platform
200
Surveillance system
Sensing device
Platform control devices 222
240
Navigation unit 220
Navigation computer
INS
GPS
Pitot Tubes
Altimeter
Beacon positioning unit 230
LOS antenna 223
BLOS antenna 225
Antennal pan and tilt assembly
Communication Unit 227

Fig. 2

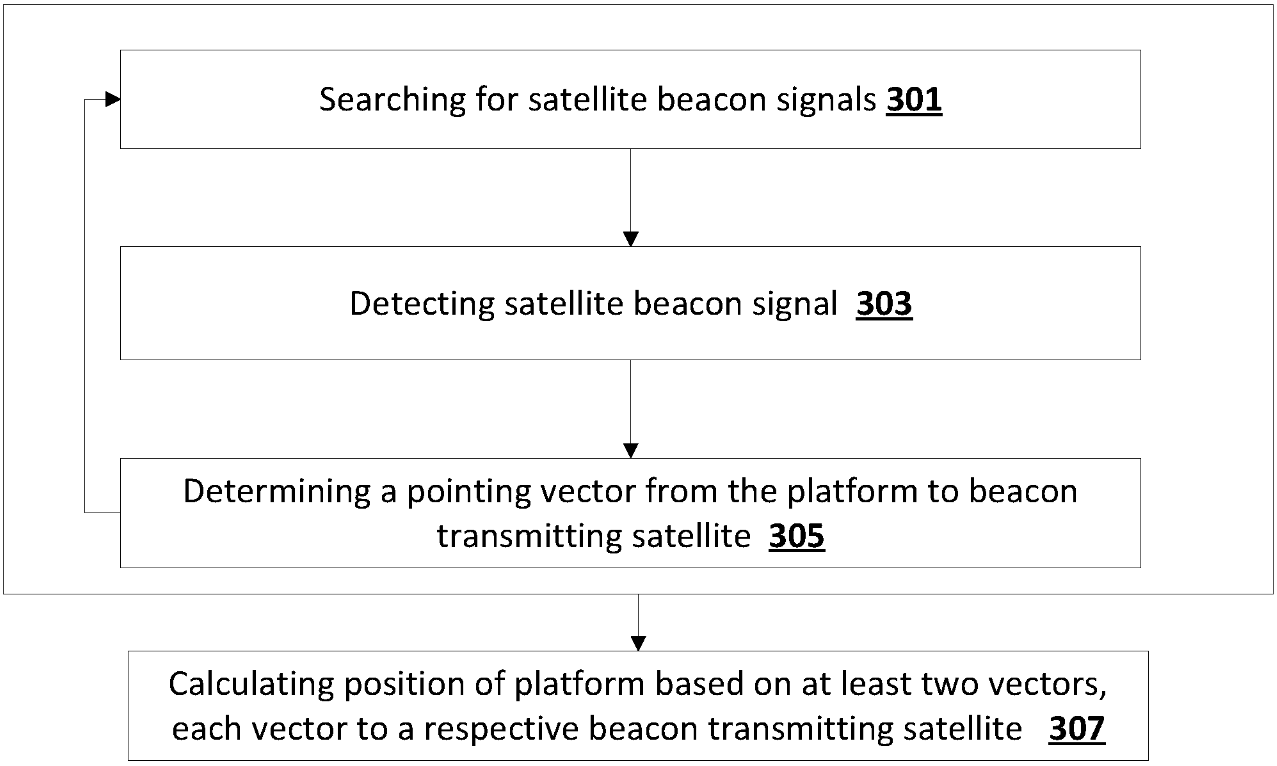

Searching for satellite beacon signals 301
Detecting satellite beacon signal 303
Determining a pointing vector from the platform to beacon transmitting satellite 305
Calculating position of platform based on at least two vectors, each vector to a respective beacon transmitting satellite 307

Fig. 3

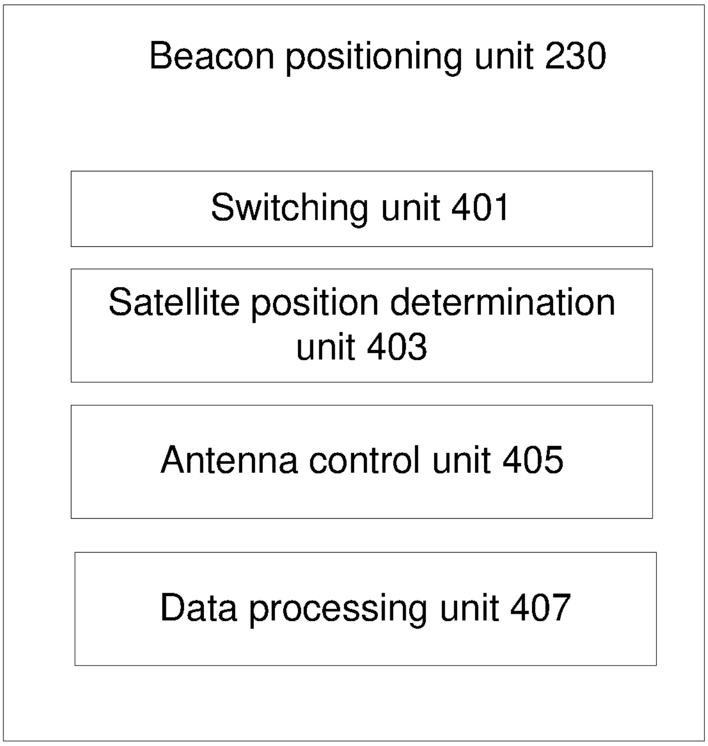

Beacon positioning unit 230
Switching unit 401
Satellite position determination unit 403
Antenna control unit 405
Data processing unit 407

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2021/051085

A. CLASSIFICATION OF SUBJECT MATTER
IPC (20210101) G01S 19/42, G01S 5/02
CPC (20130101) G01S 19/421, G01S 5/02
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)
IPC (20210101) G01S 19/42, G01S 5/02
CPC (20130101) G01S 19/421, G01S 5/02

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)
Databases consulted: Esp@cenet, Orbit, Similari (AI-based)
Search terms used: UAV, antenna, point vector, scan, satellite, beacon, radio, position, navigtaion, BLOS/beyond line of sight

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019346270 A1 AMAZON TECH. INC. [US] 14 Nov 2019 (2019/11/14) The whole document	1-31
A	EP 3654549 A1 THALES SA. [FR]; INSTITUT. NAT. DES. SCIENCES APPLIQUEES DE LYON INSA LYON [FR]; LYON ECOLE CENTRALE [FR]; CENTRE NAT. RECH. SCIENT. [FR]; UNIV. CLAUDE BERNARD LYON [FR] 20 May 2020 (2020/05/20) The whole document	1-31
A	US 2018047295 A1 RICCI FRANSESCO [IT] 15 Feb 2018 (2018/02/15) The whole document	1-31

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"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
28 Dec 2021	28 Dec 2021

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2021/051085

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