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Description

The invention relates to a method for detecting the residence of at least one object in an air space and/or at least one property of the object.

The monitoring of an air space to capture intruding objects and for detecting other object properties such as, for example, a direction of motion of objects, is essential both for civil aviation safety as well as for military and security applications. The most well known type of air space monitoring is an air space monitoring using active radar devices, which emit radar radiation into the air space and detect reflected radar signals. Active radar systems, however, have many disadvantages. For example, an active radar system with long range requires large quantities of energy, which means active radar devices with long ranges have poor mobility and are complicated to set up. In addition, particularly when they are used for securing an air space, for example in object protection, securing a border or protecting military encampments, it is a disadvantage that an active radar system is easy to locate and therefore particularly vulnerable to attack.

An alternative means of air space monitoring involves the use of passive detection devices. Thus, in document EP 0 608 732 B1 a sensor device is disclosed which captures radio reception connections from multiple satellites and which, by comparison of the radio connections affected by a potential attacker with the unaffected radio reception connections, detects any intrusion into the air space. In the case of so-called passive radars, the types of interference affecting received signals are also evaluated in detail, in order to infer a flight trajectory and/or the nature and/or size of the object. In addition, research is taking place into passive radar systems that use other signal sources such as the transmission signal from mobile phones.

Document US 2013/050024 A1 discloses a system with passive detection devices which evaluate radio signals from satellites.

The paper by Howland P. F.: "Target tracking using television-based bistatic radar"; IEEE Proceedings: Radar, Sonar and Navigation; Institution of Electrical Engineers, GB, Vol. 146, No. 3, 03 June 1999 (1999-06-03), pages 166-174, describes the use of a television broadcasting station as an illuminator for a bistatic radar.

Document US 2009/121940 A1 describes a system for the determination of position information.

A disadvantage of the various passive radar systems, however, is that these systems cannot be used to capture the entire air space and/or that certain movement patterns of objects are poorly detected. In particular, passive detection devices that evaluate radio signals from satellites, have a low detection accuracy in the detection of objects with low altitude and/or a small elevation angle.

The object of the invention is therefore to specify a method for object detection which is improved compared to the above, in particular with regard to the detection accuracy throughout the observed air space.

This object is achieved according to the invention by a method of the above-mentioned type, comprising the following steps:

- receiving at least one satellite radio signal, emitted by a satellite, by means of at least one first reception device and of at least one terrestrial radio signal, emitted by a terrestrial transmitter, by means of at least one second reception device,

- ascertaining a first piece of interference information, describing interference with the satellite radio signal by the object, and a second piece of interference information, describing interference with the terrestrial radio signal by the object, by means of a signal processing device, and

- ascertaining whether the object is in the air space and/or the property of the object by means of joint evaluation of the first and second pieces of interference information by the signal processing device.

It is thereby proposed in accordance with the invention in order to detect the residence of an object in an air space or for ascertaining the properties thereof, to use radio signals from different sources with very different geometric arrangement. The radio signals evaluated are both those radiated onto the object from a high altitude, scattered by the object and then detected, as well as radio signals that are radiated onto the object from the ground, reflected there and then detected. At the same time, signals from multiple satellites and/or multiple terrestrial stations can be advantageously detected. For this purpose, the reception device used advantageously has at least one antenna for receiving satellite radio signals and at least one antenna for receiving terrestrial radio signals. Preferably, however, a plurality of antennas are provided to detect signals from multiple directions and/or signals in different frequency bands. Alternatively or additionally, antennas that rotate about a given axis can also be used, in order to perform time-shifted detection of signals from different directions.

As properties of the object, in particular information about the location of the object and the relative speed of the object relative to the receiver are used. In addition, information about the nature and/or size of the object can be obtained from the backscattering characteristic of the object. This uses the fact that an original transmission signal from the satellite or the terrestrial transmitter is known or is received in addition to the signal scattered at the object or can be at least partially reconstructed from the signal scattered at the object, for example by means of error correction in digital satellite radio and/or terrestrial radio signals. An intrusion of an object into the air space can thus be detected, in particular, by the fact that a sudden change occurs in the signal due to the interference by the object. By evaluating which of the received signals are subject to interference, initial position information about the object can also be obtained. For example, a satellite radio signal is particularly strongly perturbed when the object is located in the region between the satellite and the reception device.

In particular, it is possible that the first and/or the second piece of interference information is/are ascertained on the basis of a Doppler shift in at least one frequency band of the satellite radio signal or of the terrestrial radio signal on account of a scatter at the object. The Doppler shift of the received signal is determined as a function of a motion of the object relative to the source of the corresponding signal, thus the satellite or the terrestrial transmitter, and as a function of a motion of the object relative to the first or the second receiver. A Doppler shift can be ascertained in the case of a known original signal, or a known carrier frequency of the original signal, for example, by using a phase-locked loop with a very narrow bandwidth of the loop filter. The frequency of an oscillator of the control loop then does not follow the modulation of the received signal, but only a frequency shift of the carrier signal, such as is generated by a scattering object. Alternatively, the phase angle of the scattered satellite radio signal, respectively of the scattered terrestrial radio signal, with respect to a signal with the frequency of the non-scattered signal can be determined. The temporal change of the phase angle between the signal at the original frequency and the Doppler-shifted scattered signal enables the Doppler shift to be determined. After digitization of the satellite radio signal or of the terrestrial radio signal, a change in the phase angle can also be determined from the fact that the received scattered signal is Fourier transformed, wherein with a discrete Fourier transform the frequencies of the transformation are chosen in such a way that the original frequency of the satellite radio signal or the terrestrial radio signal coincides with a frequency of the transform. If such a transformation is carried out for multiple temporally spaced blocks, the Fourier transform determines a relative phase shift between the blocks, which can be evaluated as described above.

In the method according to the invention the position of the satellite and/or the terrestrial transmitter is advantageously known. The Doppler shift ascertained is dependent on the speed of the change in distance between the object and the satellite or terrestrial transmitter and on the speed of the change in distance between the object and the reception device, and thus on the position of the object, the speed of motion and the direction of motion. In the case of reception by multiple satellite radio signals and/or multiple terrestrial radio signals it is therefore possible to determine, from the Doppler shift of the various signals alone, both the position and the speed of the object.

Alternatively or in addition, the propagation time of the satellite radio signal and/or the terrestrial radio signal can be evaluated. If the satellite radio signal or the terrestrial radio signal is reflected at an object that is spaced apart from a connecting line between the satellite or terrestrial transmitter and the associated receiver, then the reflected signal travels a longer distance and thus also has a longer signal propagation delay than a directly received signal. In this case the satellite radio signal and/or the terrestrial radio signal can comprise in particular a signal component received directly from the satellite or from the terrestrial transmitter and a signal component scattered at the object, wherein the first and/or the second piece of interference information is/are determined on the basis of a propagation time difference between the directly received and the scattered signal. This is possible in particular due to a correlation between the directly received and the scattered signal component. Before the correlation, Doppler shifts of the scattered signal can in particular be compensated.

A propagation time difference can also be determined, in particular, without taking into account a directly received signal if a unique piece of time information is assigned to the satellite radio signal or the terrestrial radio signal. For example, navigation satellites transmit a unique time encoding, which uniquely defines a transmission time of the signal. By a comparison of the coded transmission time with the reception time or with the transmission time of other received signals that are received at the same time, a propagation time difference can also be determined. A determination of a propagation time difference without a directly received signal component is particularly advantageous if the terrestrial transmitter or the satellite is positioned in such a way that no signal can be received directly by the reception device.

In addition or as an alternative to Doppler shifts and propagation time differences it is also possible to evaluate the phase, the amplitude and/or the polarization of the satellite radio signal or terrestrial radio signal and, in particular, to compare them with the phase, amplitude and/or polarization of a signal not scattered by the object, to determine the first or the second piece of interference information. In particular, by means of an amplitude comparison it can also be detected when the satellite radio signal or the terrestrial radio signal is exclusively attenuated by an object which has penetrated the air space. This means in particular that objects which have a low reflectivity for the radio signals used can also be detected.

In the method according to the invention the presence of an object in the air space can also be detected if a presence of the object in the air space is determined solely from the first and/or solely from the second piece of interference information. This exploits in accordance with the invention the fact that flying objects with high altitude and/or a large elevation angle tend to interfere with satellite radio signals more strongly than terrestrial radio signals and flying objects with a low flight altitude and/or a low elevation angle tend to interfere with terrestrial radio signals more strongly than satellite radio signals. The first piece of interference information and the second piece of interference information thus have different sensitivities with respect to different areas of the air space in which the object is located, and with regard to different directions of motion or motion patterns of the object that has intruded into the air space.

Alternatively it can be provided to detect a presence of an object in the air space only if a presence of the object in the air space is determined from both the first and the second piece of interference information. Particularly advantageously, a first warning level can also be provided if only one of the pieces of interference information indicates a presence of the object in the air space and a second level, if this is indicated by both pieces of interference information.

It is possible that at least one property of the object is determined exclusively from the first piece of interference information and at least one additional property of the object is determined exclusively from the second piece of interference information. It is possible, for example, to determine a vertical object speed exclusively from the first piece of interference information, i.e. by evaluation of the satellite radio signal, and a horizontal speed of the object exclusively from the second piece of interference information, i.e. by evaluation of the terrestrial radio signal. Depending on the specific satellite or satellites and terrestrial transmitters used, different properties of objects can be advantageously determined from the first or the second piece of interference information.

As a terrestrial transmitter, in particular, a radio transmitter or a transmitter associated with a mobile radio network can be used. Alternatively or in addition, the use of radio transmitters which are associated with wireless networks or something similar would also be possible. When multiple terrestrial transmitters are used in the method according to the invention, terrestrial transmitters can also be used that are assigned different tasks, such as one or more radio broadcast transmitters and at the same time, one or more transmitters associated with a wireless network.

In particular, a satellite associated with a position determination system, a communications satellite or a radio broadcasting satellite can be used as a satellite. Navigation satellites can belong, in particular, to the GPS or the Galileo system. An advantage of the use of a signal of a satellite assigned to a positioning system is that these signals typically comprise or encode an explicit piece of time information, which can be used to determine propagation time differences particularly easily. When receiving satellite radio signals from multiple satellites, signals from satellites with different purposes can also be received, such as one or more signals from radio broadcasting satellites and one or more signals from communication satellites.

It is particularly advantageous if the terrestrial transmitters and/or the satellite transmit useful information digitally. In the case of a digital signal transmission, even at relatively low signal-to-noise ratios an original signal can be reconstructed completely, which in particular facilitates the separation between a directly received signal component and a signal component scattered by the object. The detection of frequency shifts, phase shifts and amplitude changes is also improved when digital signals are used.

In order to ascertain the most accurate and unambiguous information in particular about the location and the direction of motion and speed of an object it is advantageous to take into account as many pieces of interference information as possible, each of which is assigned to a received satellite radio signal or terrestrial radio signal. This can be achieved if the satellite radio signals from multiple satellites and/or the terrestrial radio signals of multiple terrestrial transmitters are received and evaluated. Alternatively or additionally, to obtain additional pieces of interference information a plurality of reception devices can be used for the same signal. It is therefore particularly advantageous if a plurality of first and/or second reception apparatuses are used that are arranged at physical intervals. The distance between the reception apparatuses can be, for example, greater than 10 m, greater than 100 m or greater than 1 km. Through the use of multiple devices that are physically spaced apart, in particular a plurality of propagation time differences between signals that are scattered and not scattered at the object, or a plurality of Doppler shifts due to the object, can be determined and evaluated.

The invention also relates to a detection device for detecting the residence of at least one object in an air space and/or at least one additional property of the object. In this regard, the detection device comprises at least one first reception device for receiving at least one satellite radio signal emitted by a satellite and at least one second reception device for receiving a terrestrial radio signal emitted by a terrestrial transmitter, as well as a signal processing device. The signal processing device is used to ascertain a first piece of interference information, which describes an interference of the satellite radio signal due to the object, and a second piece of interference information which describes an interference of the terrestrial radio signal due to the object, and to ascertain whether the object is in the air space and/or the property of the object by means of joint evaluation of the first and second piece of interference information.

The signal processing device can be designed to determine the first and/or the second piece of interference information on the basis of a Doppler shift in at least one frequency band of the satellite radio signal or of the terrestrial radio signal on account of a scatter at the object.

The terrestrial transmitter can be, in particular, a radio transmitter or a transmitter associated with a mobile radio network. The satellite can be a satellite associated with a position determination system, a communications satellite or a radio broadcasting satellite.

The reception device according to the invention can be extended further in accordance with the features disclosed in relation to the method according to the invention.

Additional advantages and details of the invention are obtained from the exemplary embodiments described below, and on the basis of the drawings. These show:

Fig. 1 a schematic drawing of the monitoring of an air space by an exemplary embodiment of the detection device according to the invention,

Fig. 2 a schematic drawing of the detection of an object intruding into the air space by an exemplary embodiment of the method according to the invention,

Fig. 3 a schematic drawing of a flow diagram of an exemplary embodiment of a method according to the invention, and

Fig. 4 a schematic drawing of an exemplary embodiment of a detection device according to the invention.

Fig. 1 shows a schematic drawing of the monitoring of an air space by a detection device 1 for detecting the residence of at least one object in the air space and for ascertaining further properties of the object. The detection device 1 has a plurality of reception devices, wherein a plurality of first reception devices are used for receiving the satellite radio signals from the satellites 3, 2, 30 and a plurality of second reception devices are used for receiving the terrestrial transmitters 4, 5, 6, 7. Two of the satellites are television satellites 30, one of the satellites is a communications satellite 2 and two of the satellites are satellites 3 which are associated with a position determination system, in particular, a GPS system. The terrestrial transmitter 4 is associated with a wireless computer network, the terrestrial transmitter 5 is a mobile radio base station, the terrestrial transmitter 6 is a television transmitter and the terrestrial transmitter 7 is a radio transmitter.

If an object 8, for example an aircraft, penetrates the air space and, in particular, enters one of the monitoring areas 9, 10, then the object 8 interferes with at least parts of the satellite radio signals from the satellites 3, 2, 30 and/or the terrestrial radio signals from the terrestrial transmitters 4, 5, 6, 7. Such an interference takes place, in particular, due to a scattering of the satellite radio signal or the terrestrial radio signal. In addition, however, a reduction in the signal amplitude can also be observed due to a shadowing of the corresponding satellite or terrestrial transmitter. Because the reception device 1 receives the satellite radio signals and the terrestrial radio signals, shadowing of the signal can be detected by amplitude changes and reflections of the signal at the objects 8 by the evaluation of additional signal properties. Reflections of one or more satellite radio signals or terrestrial radio signals at one of the objects 8 are detected by separating the reflected signal component from a directly received signal component and evaluating a frequency shift and/or a propagation time of the reflected signal component. If a satellite radio signal or a terrestrial radio signal is reflected at one of the objects 8, the received signal travels a longer distance on the route from the satellite 3, 2, 30 or the terrestrial channel 4, 5, 6, 7 to the corresponding reception device than in the case of a direct transmission. This leads to a longer signal propagation time, wherein a rotation ellipse on which the object 8 is located can be determined from the propagation time difference. In addition, by means of the detection device 1 a Doppler shift in the frequency of the scattered satellite radio signal or the terrestrial radio signal is determined, which depends on the rate of change of the distance of the object 8 to the transmitter, i.e. the satellite 3, 2, 30 or the terrestrial transmitter 4, 5, 6, 7, as well as on the rate of change of the distance to the respective reception device. From the Doppler shift in the frequency of the respective signal, in particular a speed of movement of the object can be determined, but from a comparison of multiple Doppler shifts of multiple signals an object location can also be determined. Since in the monitoring areas 9, 10 multiple satellite radio signals and/or terrestrial radio signals can be scattered at each of the objects 8, from the respective propagation time differences and/or Doppler shifts of the signals both the position of the object 8 as well as its direction of motion and speed can be determined.

The monitoring area 9 marks the area in which the objects 8 can be detected particularly well on the basis of a first piece of interference information, which describes an interference of satellite radio signals. The monitoring area 9 extends essentially in a conical shape above the detection device 1 or the reception devices of the detection device 1. By contrast, objects in the monitoring area 10 can be detected particularly easily by a second piece of interference information, which is ascertained from an interference of at least one terrestrial radio signal. The monitoring area 10 is roughly toroidal in shape and extends radially around the detection device 1 or the reception devices of the detection device 1. In order to detect any intrusion into the observed air space, the presence of the object 8 in the air space is detected as soon as the first piece of interference information alone or the second piece of interference information alone indicates a presence of the object 8 in the air space. In other words, both objects 8 in the monitoring area 10 as well as objects 8 in the monitoring area 9 are reliably detected.

While the monitoring areas 9 and 10 are shown schematically in Fig. 1 as separate areas, of course objects 8 in the monitoring area 9 nevertheless also interfere with terrestrial radio signals and objects 8 in the monitoring area 10 interfere with satellite radio signals. This means that for a single object 8, information about object properties can be obtained both from interference information of the satellite radio signals as well as interference information of the terrestrial radio signals. In the detection device 1 this is exploited in order to apply both types of interference information for the determination of properties of the object 8, in particular the position and the speed of the object 8.

It is thus possible that individual pieces of interference information of a single satellite radio signal or a single terrestrial radio signal indicate that this radio signal is not perturbed. If during the determination of the interference information, for example, a propagation-time difference is examined and the object 8 is located on the connecting line between a satellite and the reception device, then no change in the signal propagation time is determined. The interference information therefore shows that no interference is present. However, since the detection device 1 detects the satellite radio signals of a plurality of satellites 3, 2, 30 and a plurality of terrestrial radio signals from terrestrial transmitters 4, 5, 6, 7, when an object 8 is resident in the monitoring areas 9, 10 a piece of interference information is always determined for at least one of the satellite radio signals or the terrestrial radio signals, which indicates interference of the corresponding signal. Objects 8 in the monitoring area 9 and 10 are thus reliably detected.

Figure 2 shows a schematic drawing of the reception of a satellite radio signal 12, 13 and a terrestrial radio signal 15, 16 in a method for detecting the residence of at least one object 8 in an air space and the properties of the object 8. In this case a detection device is used, which comprises two first reception devices 17, 19 for receiving satellite radio signals from the satellite 3 and two second reception devices 18, 20 for receiving the terrestrial radio signal of the terrestrial transmitter 6, as well as a signal processing device 21 connected to the reception devices 17, 18, 19, 20 via a communication network 11. The two first and second reception devices 17, 18, 19, 20 are spaced apart by the distance 22, for example, one kilometre.

The satellite radio signal 12 emitted by the satellite 3 is scattered by the object 8. As a result the scattered satellite radio signal 13 is generated, wherein the scattering object 8 can be considered as a point source for the scattered satellite radio signal 13. The scattered satellite radio signal 13 is received by the first two reception devices 17 and 19. In order to maintain clarity of presentation, the direct reception by the first two receivers 17, 19 of the satellite radio signal 12 emitted by the satellite 3 is not shown. Accordingly, the terrestrial signal 15 emitted by the terrestrial transmitter 6 is scattered by the object 8 and the scattered terrestrial signal 16 is received by the two second reception devices 18, 20.

The determination of respectively assigned pieces of interference information is described in the following with reference to Figure 3. Due to the use of multiple first and second reception devices 17, 18, 19, 20 the number of received signals is multiplied, as is therefore the number of pieces of interference information. In the case shown in Figure 2, for example, on the basis of two signal sources, namely the terrestrial transmitter 6 and the satellite 3, four reception signals and thus also four pieces of interference information are available. Since a single piece of interference information can detect, in particular, a propagation time difference and a Doppler shift, as many as eight parameters are therefore available that describe the object 8, which makes possible, for example, an unequivocal identification of the position and speed of the object.

Figure 3 shows an exemplary embodiment of a method for detecting the residence of at least one object in an air space and a plurality of properties of the object. In step S1 a satellite radio signal emitted by a satellite is received by a first reception device. In steps S2 and S3 a first piece of interference information is ascertained from this signal. The first piece of interference information comprises information about a possible propagation time change of the received signal due to a scattering at the object, which is determined in step S2, and pieces of information about a possible change in frequency of the received signal on account of a Doppler shift caused by scattering at the object, which are determined in step S3.

In step S2 a propagation time difference between a signal component received directly from the satellite and the signal component scattered at an object is detected. This makes use of the fact that in the case of a digital signal transmission by the satellite, even for a reception signal strongly affected by interference the original transmission signal from the satellite can be reconstructed completely. In this way, the signal component scattered at the object, despite a typically far smaller amplitude than the directly received signal, can be sufficiently separated from the directly received signal component to determine a propagation time difference. The propagation time difference between the signal components is determined by a correlation of the directly received signal component and the signal component scattered at the object.

Alternatively, in step S2 if the satellite radio signal contains an explicit or implicit time coding, as is standard, in particular, in satellites of a satellite positioning system, it would be possible to determine the propagation time difference directly by evaluating the time information encoded in the scattered signal. This process may involve, in particular, using an internal time reference of the detection device, which is synchronized using time information of one or more directly received satellite signals.

In step S3 a frequency shift of the scattered signal component due to a Doppler shift is ascertained. The identified Doppler shift in this case depends on the rate of change of the distance from the object to the satellite whose signal is received and to the reception device by means of which the signal is received. To determine the frequency shift, a block-wise discrete Fourier transform of the signal is used, wherein the frequencies of the discrete Fourier transform are selected so that one of the transformation frequencies coincides with the carrier frequency with which the corresponding satellite sends the received signal. If signals are sent on multiple carrier frequencies via one satellite, the frequency bands can first be separated and a frequency shift can be determined either for one or more of these frequency bands. The discrete Fourier transform is performed in such a way that a phase shift is determined for at least the carrier frequency of the satellite radio signal. The change in the phase shift between the Fourier transformations of temporally spaced blocks of the satellite radio signal corresponds to a frequency shift in the satellite radio signal.

The steps S1 to S3 can be repeated for multiple satellite radio signals from multiple satellites. In addition, the steps S1 to S3 can also be repeated for a plurality of first reception devices which, in particular, are physically spaced apart. This is shown in Figure 3 by the points shown next to step S3.

In step S4 by means of a second receiver, a terrestrial radio signal emitted by a television terrestrial is received. For this terrestrial radio signal, in steps S5 and S6 a second piece of interference information is determined. In step S5, as described in relation to step S2, a propagation time difference between a directly received signal component and a signal component scattered at the object is determined. In step S6, as described in relation to step S3, a frequency shift of the terrestrial radio signal due to the scattering at the object is determined. The steps S4 to S6 can be repeated for a plurality of terrestrial radio signals received from a plurality of terrestrial transmitters, and when using a plurality of second reception devices, for each of the second reception devices. This is shown by the dots shown in Figure 3 by the side of step S6.

The first and second pieces of interference information determined in steps S2, S3, S5 and S6 as well as the other determined pieces of interference information, which are provided when using additional first and/or second reception devices or in the evaluation of signals from other satellites and/or terrestrial transmitters, are evaluated by the signal processing device in step S7 in order to determine firstly whether an object is located in the monitored air space, and if this is the case, what properties does this object have, in particular, at which position is it located, and with what speed is it moving in which direction. In the signal processing device the relative positions of the terrestrial transmitters whose terrestrial radio signals are evaluated are stored, along with those of the satellites whose satellite radio signals are evaluated. If geostationary satellites are not used in the method, then the specification of the satellite position can also be time-dependent. In addition, position corrections can be transmitted, in particular by satellites as part of their satellite radio signal, which signals are evaluated by the signal processing device. In step S7 therefore, multiple pieces of interference information are available which describe the respective interference components of a satellite radio signal or a terrestrial radio signal, as well as the geometrical arrangement of the individual reception devices and the satellites and terrestrial transmitters used. From this information it is determined in step S7 whether an object is in fact located in the air space being monitored. This information is output as a set of multi-level warning information in step S8. If it is ascertained from only one of the pieces of interference information that an object is located in the air space being monitored, then a first warning level is issued. If at least according to a first piece of interference information and according to a second piece of interference information it is ascertained in each case that an object is in the air space being monitored, then a second warning level is issued.

In addition to the mere presence of an object in the monitored air space, the position of the object in the three-dimensional space is output as a first property of the object in step S9. The position of the object is determined here by evaluation of at least one first and one second piece of interference information, that is, depending on at least one received satellite signal and at least one of terrestrial radio signal. In this case, the position is ascertained from the propagation time differences determined in step S3 and S6. Each of the propagation time differences defines a rotation ellipse, for which it is known that the object is located on it. By intersecting the rotation ellipses, the position of the object can be restricted to two possible positions in almost all cases. If in addition to the two propagation time differences determined in steps S3 and S6 no further propagation time differences are determined, then the remaining ambiguity can be eliminated by taking into account the Doppler shifts ascertained in step S2 and S5, or at least by taking account of the respective propagation time differences for two consecutive monitoring periods. If multiple satellites or multiple terrestrial transmitters or multiple first or second reception devices are used, then the position of the object can be uniquely determined solely from the propagation time differences at a time of detection.

In step S10 and S11, speeds in a flat surface parallel to the surface of the earth and perpendicular thereto are provided as additional properties of the object. For this purpose, the frequency shifts calculated in step S2 and S5 are additionally evaluated. If both multiple satellite radio signals and multiple terrestrial radio signals are evaluated, it is possible in particular for the speed parallel to the surface of the earth's surface output in step S10 to be calculated solely by consideration of first pieces of interference information, thus the information ascertained in steps S2 and S3, and for the speed in the vertical direction output in step S11 to be calculated solely as a function of the second pieces of interference information output in step S5 and S6.

Figure 4 shows a schematic drawing of the structure of a detection device, with which the method explained above can be carried out. The detection apparatus 1 here comprises a first detection device 17 with a first antenna 23 and a first signal pre-processing device 24, and a second detection device 18 with a second reception antenna 25 and a second signal pre-processing device 26. The first antenna 23 is used to receive a satellite radio signal and the second antenna 25 is used to receive a terrestrial radio signal. The signal pre-processing device 24 and 26 amplify the signals received by the antennas 23 or 25 and perform an analogue-to-digital conversion of the signals.

The digitized signals are transferred to the signal processing device 21. The signal processing device 21 is designed as a programmable computing device, wherein the signal processing is carried out by three separate program modules. By means of the program modules 27 and 28, as explained in relation to the steps S2, S3, S5 and S6 in Figure 3, a first and a second piece of interference information are determined. The determination of the interference information is carried out in the program module 27 for the satellite radio signal and in the program module 28 for the terrestrial radio signal. The satellite radio signal and the terrestrial radio signal are processed separately to determine the interference information, since the values calculated depend exclusively on the individual received signal.

The pieces of interference information determined in the program modules 27 and 28 are fed to the evaluation module 29, which as explained in relation to steps S7 to S11 in Figure 3, ascertains on the one hand whether an object is present in the monitored air space and on the other hand, determines properties of the object. Depending on the data determined by the evaluation module 29, a display device 14 is then controlled to give a user an overview of the monitored air space. In addition, under certain conditions, such as the appearance of an unknown object in a certain part of the air space with a certain speed and direction, further warning signals can be triggered.

List of reference numerals

1	detection device
2	satellite
3	satellite
4	terrestrial transmitter
5	terrestrial transmitter
6	terrestrial transmitter
7	terrestrial transmitter
8	object
9	monitoring area
10	monitoring area
11	communication network
12	satellite radio signal
13	satellite radio signal
14	display device
15	terrestrial signal
16	terrestrial signal
17	reception device
18	reception device
19	reception device
20	reception device
21	signal processing device
22	distance
23	antenna
24	signal pre-processing device
25	reception antenna
26	signal pre-processing device
27	program module
28	program module
29	evaluation module
30	satellite
S1 - S11	step

Patentkrav

1. Fremgangsmåde til konstatering af i det mindste et objekts (8) ophold i et luftrum og/eller i det mindste en egenskab ved objektet (8), omfattende trinene:
- i det mindste en første modtageindretnings (17, 19) modtagelse af i det mindste et satellitradiosignal (12), der er udstrålet af en satellit (2, 3, 30), og i det mindste en anden modtageindretnings (18, 20) modtagelse af i det mindste et terrestrisk radiosignal (15), der er udstrålet af en terrestrisk sender (4, 5, 6, 7),
- en signalbearbejdningsindretnings (21) bestemmelse af en første støjinformation, der beskriver en forstyrrelse af satellitradiosignalet (12, 13) på grund af objektet (8), og af en anden støjinformation, der beskriver en forstyrrelse af det terrestriske radiosignal (15, 16) på grund af objektet (8), og
- bestemmelse af, om objektet (8) befinder sig i luftrummet, og/eller af objektets (8) egenskab ved hjælp af signalbearbejdningsindretningens (21) fælles evaluering af den første og den anden støjinformation.

2. Fremgangsmåde ifølge krav 1,
kendetegnet ved,
at den første og/eller den anden støjinformation bestemmes i afhængighed af en dopplerforskydning af i det mindste et frekvensbånd i henholdsvis satellitradiosignalet (12, 13) og det terrestrisk radiosignal (15, 16) på grund af en spredning på objektet (8).

3. Fremgangsmåde ifølge krav 1 eller 2,
kendetegnet ved,
at satellitradiosignalet (12, 13) og/eller det terrestriske radiosignal (15, 16) omfatter en direkte fra henholdsvis satellitten (2, 3, 30) og fra den terrestriske sender (4, 5, 6, 7) modtaget signalandel (12, 15) og en på objektet (8) spredt signalandel (13, 16), hvorved den første og/eller den anden støjinformation bestemmes i afhængighed af en løbetidsforskel mellem det direkte modtagne (12, 15) og det spredte signal (13,

16).

4. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at der som terrestrisk sender (4, 5, 6, 7) anvendes en radiosender eller en sender, der er tilordnet til et mobilradionet.

5. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at der som satellit (2, 3, 30) anvendes en til et positionsbestemmelsessystem tilordnet satellit, en kommunikationssatellit eller en radiosatellit.

6. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at den terrestriske sender (4, 5, 6, 7) og/eller satellitten (2, 3, 30) overfører nytteinformationer digitalt.

7. Fremgangsmåde ifølge et af de foregående krav, kendetegnet ved, at der benyttes flere første og/eller anden modtageanordninger (17, 18, 19, 20), der har en rumlig afstand fra hinanden.

8. Detekteringsindretning til konstatering af i det mindste et objekts (8) ophold i et luftrum og/eller af i det mindste en yderligere egenskab ved objektet (8), kendetegnet ved, at detekteringsindretningen (1) har i det mindste en første modtageindretning (17, 19) til modtagelse af i det mindste et satellitradiosignal (12), der er udstrålet af en satellit (2, 3, 30), og i det mindste en anden modtageindretning (18, 20) til modtagelse af i det mindste et terrestrisk radiosignal (15), der er udstrålet af en terrestrisk sender (4, 5, 6, 7), samt en signalbearbejdningsindretning (21), hvor signalbearbejdningsindretningen (21) tjener til bestemmelse af en første støjinformation, der beskriver en forstyrrelse af satellitradiosignalet (12, 13) på grund af objektet (8), og af

en anden støjinformation, der beskriver en forstyrrelse af det terrestriske radiosignal (15, 16) på grund af objektet (8), samt til bestemmelse af, om objektet (8) befinder sig i luftrummet, og/eller af objektets (8) egenskab ved hjælp af fælles evaluering af den første og den anden støjinformation.

9. Detekteringsindretning ifølge krav 8,
kendetegnet ved,
at signalbearbejdningsindretningen (21) er udformet til bestemmelse af den første og/eller den anden støjinformation i afhængighed af en dopplerforskydning af i det mindste et frekvensbånd i henholdsvis satellitradiosignalet (12, 13) og det terrestriske radiosignal (15, 16) på grund af en spredning på objektet (8).

10. Detekteringsindretning ifølge krav 8 eller 9,
kendetegnet ved,
at den terrestriske sender (4, 5, 6, 7) er en radiosender eller en sender, der er tilordnet til et mobilradionet.

11. Detekteringsindretning ifølge et af kravene 8 til 10,
kendetegnet ved,
at satellitten (2, 3, 30) er en satellit, der er tilordnet til et positionsbestemmelsessystem, en kommunikationssatellit eller en radiosatellit.

FIG. 1

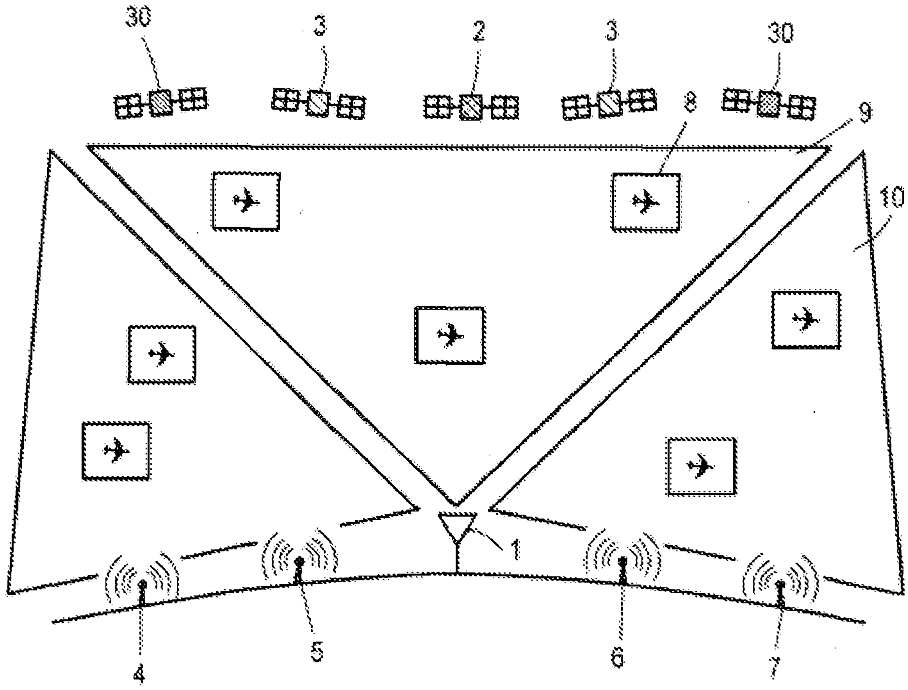

FIG. 2

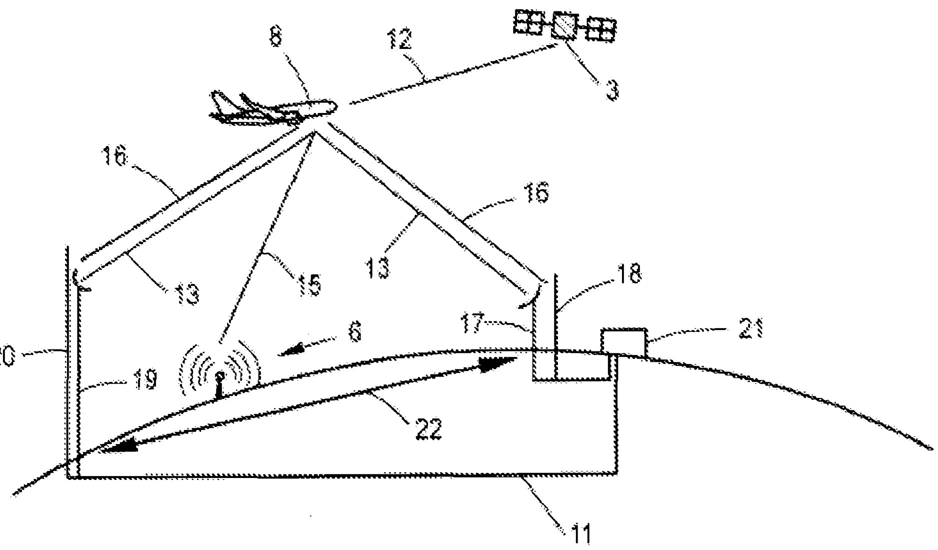

FIG. 3

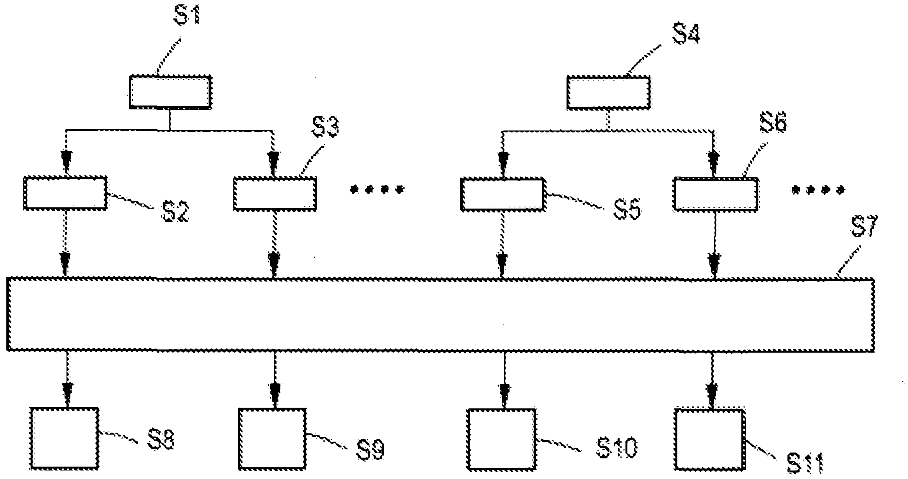

FIG. 4