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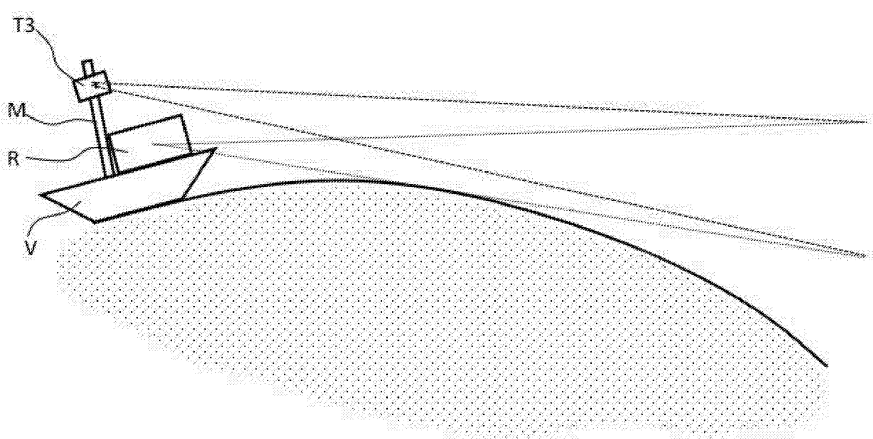
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(54) Title of the Invention: **Radar systems**
 Abstract Title: **Radar system with separate transmitting and receiving apertures**

(57) A radar system suitable for air volume surveillance comprises a transmitter antenna and a receiver antenna, each of the transmitter and receiver antenna apertures being separate to one another and configured to allow the transmitter and receiver to operate simultaneously. The transmitting beam has an angular volume which is relatively small compared with the angular volume of space to be surveyed and the system includes a device to scan the beam over the volume. The aperture of the receiver is larger than the aperture of the antenna such that a receiving beam formed from the receiving antenna is narrower than the transmitting beam. The system is capable of forming multiple receiving beams simultaneously such that collectively they match the angular volume of the transmitting beam and the system includes a device for scanning the receiving beams over the volume. The transmitter is to be positioned higher above the earth's surface than a receiving antenna.

Fig 4A



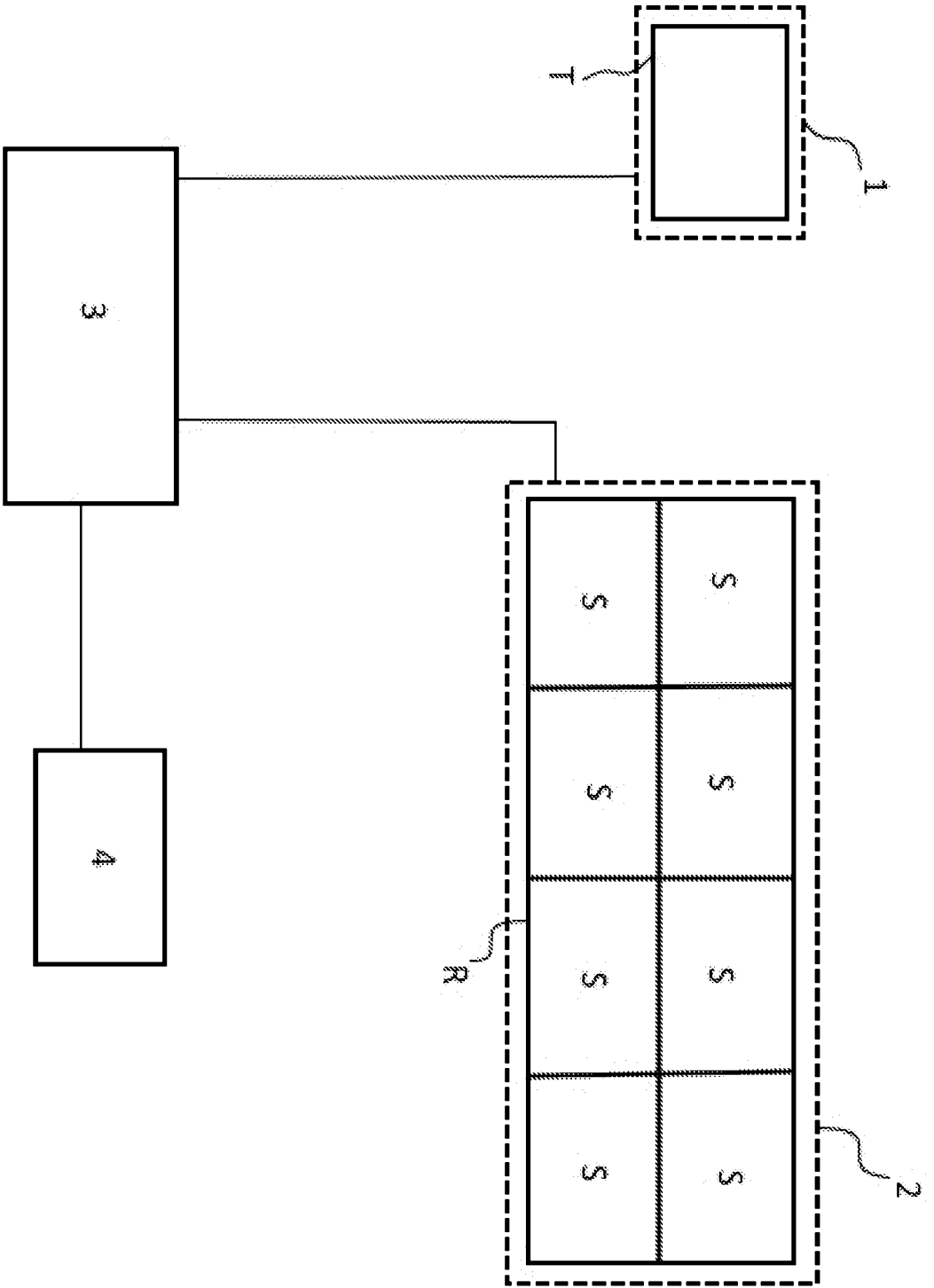


Fig 1

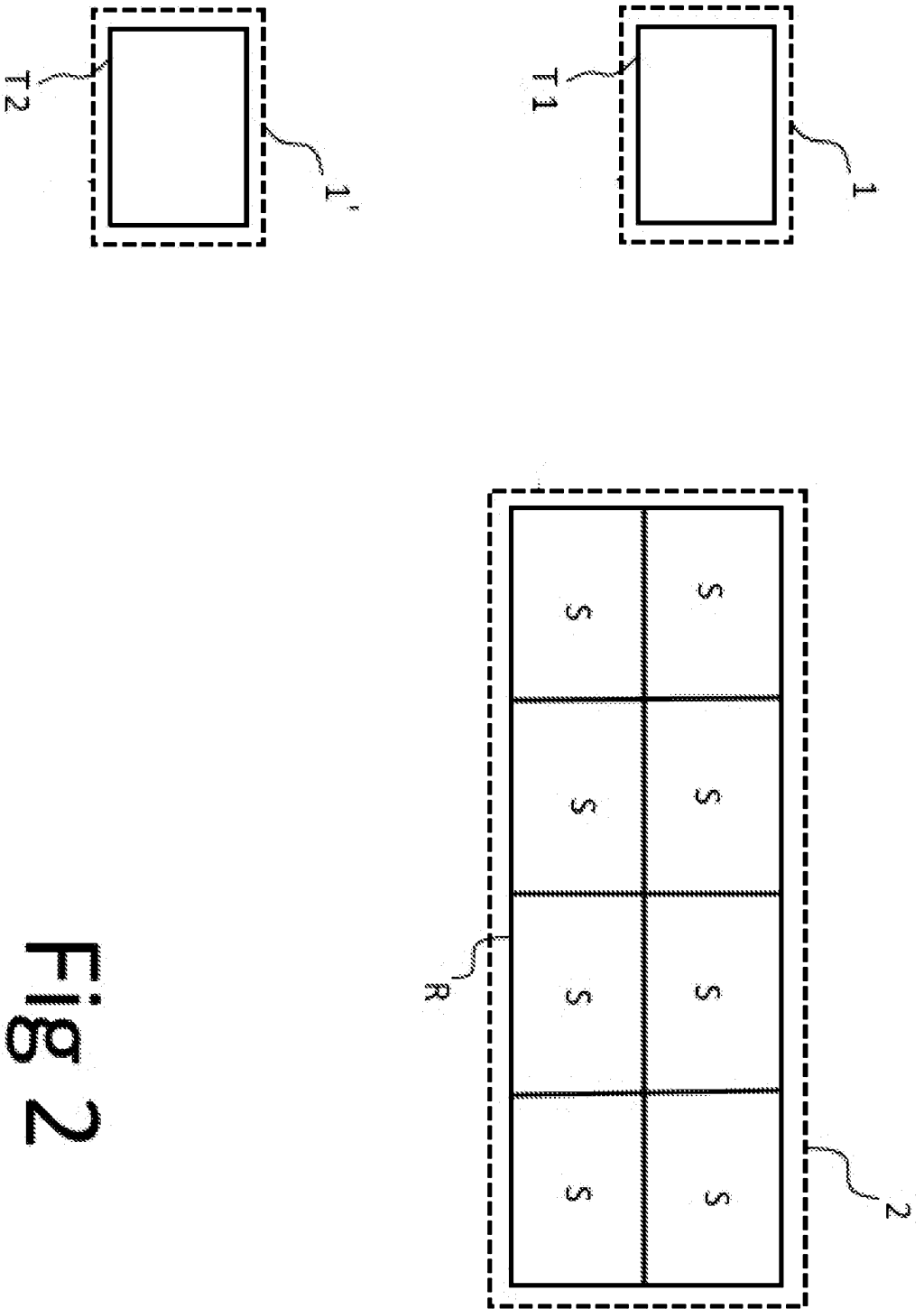


Fig 2

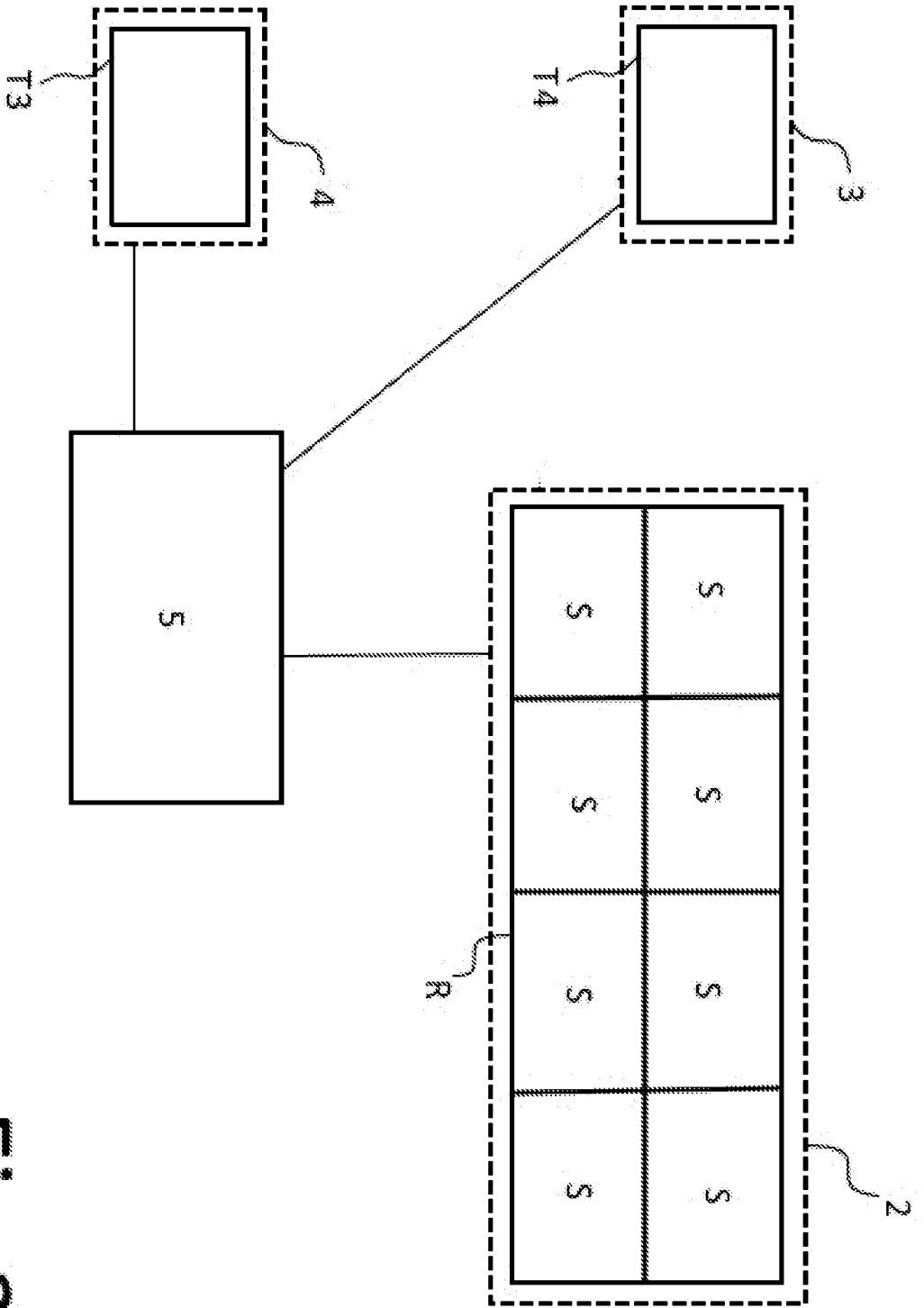


Fig 3

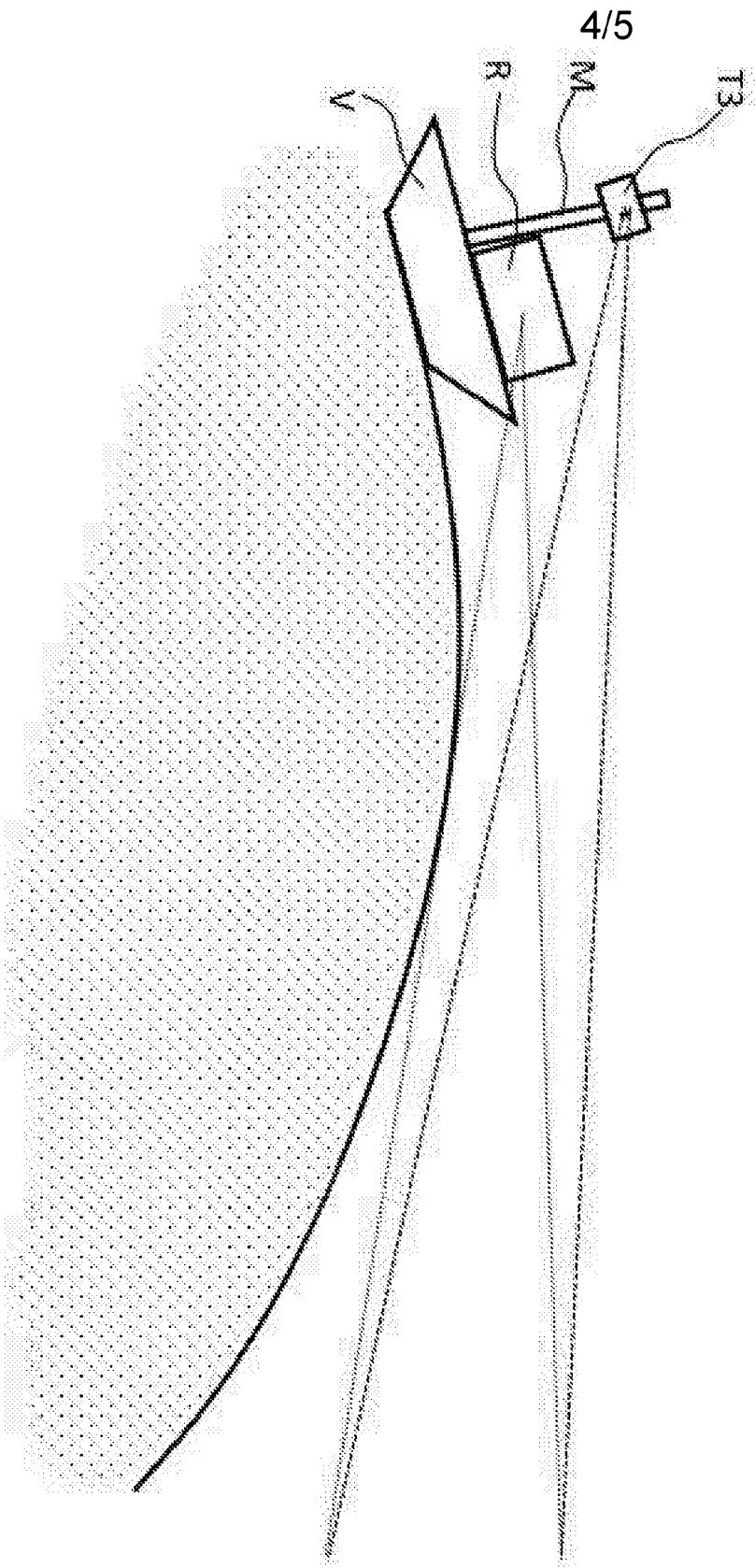


Fig 4A

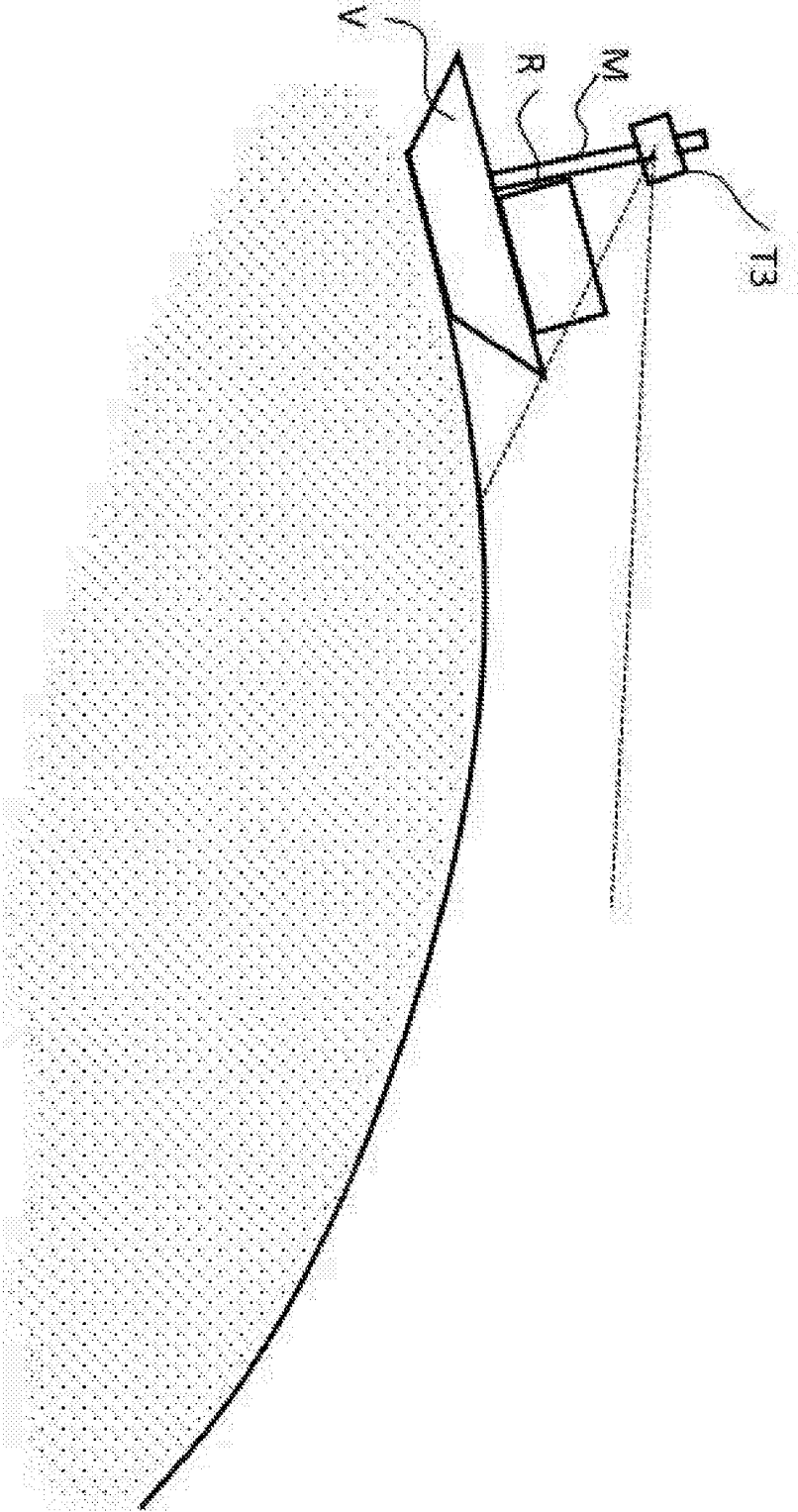


Fig 4B

Radar Systems

The present invention relates to a radar system and methods of operating a radar system.

Most conventional radar systems comprise a co-located transmitter and receiver which share a common antenna and/or reflector (and thus aperture) to transmit and receive. A
5 pulsed signal is transmitted and the time taken for the pulse to travel to the object and back allows the range of the object to be determined.

Such radar systems are used in various applications, for example, target detection and recognition and air search. Known designs for search radar systems fall into two broad classes. Both of these classes use a single shared transmit/receive antenna transmitting
10 and receiving pulsed waveforms.

The first class of search radar systems find use in all domains, namely for use across air, land and sea and typically transmit a single beam of electromagnetic radiation for search which is raster scanned over the area of interest. It is a disadvantage of this class of search radar system that this need to steer the radar beam to all positions in the area
15 to be searched normally restricts the use of this system either to physically small, mechanically scanned antennas, or radars with electronically scanned antennas which can provide the necessary rapid beam steering with a physically large antenna.

The second class of search radar systems use a 'stacked beam' antenna and are normally only found in ground and naval radars. In such known systems, the antenna
20 typically provides several simultaneous receive beams stacked in elevation, with a single broad, often shaped, transmit beam. This design avoids the need for the rapid elevation beam steering required by the first class of radar systems and is better suited to physically large mechanically scanned systems.

The performance of both first and second classes of radars described above is governed
25 by the search radar range equation, which is dependent upon three key factors:

- The total transmitted energy that can be delivered to the target during the search dwell (or 'time on target')

- The total surface area of the receiving antenna (to intercept reflected energy from the target)
- The spatial matching of transmit and receive beam patterns (to avoid energy wastage)

5 The total transmitted energy that can be delivered to the target during the search dwell is the product of the radar system Effective Radiated Power (ERP, the power transmitted and directed using beamforming) and the dwell time.

It is a known artefact of search radar systems that when searching an area of space for targets a large ERP can be achieved by using a larger antenna with a narrower beam,
10 but this necessitates a shorter dwell time if the same area is to be searched in the same overall time. The higher ERP and shorter dwell time compensate (to first order) and thus the total transmitted energy on target remains approximately constant. Thus a high gain transmit beam is not necessarily an advantage in this class of radar for detection purposes.

15 In principle, it is always beneficial to system sensitivity to have the largest possible receiving antenna surface area. However, well-known antenna diffraction theory dictates that a larger receiving antenna will always have a narrower beam (to first order, the spatial coverage of the beam and the antenna area are reciprocally related). It can thus be seen that a larger receiving antenna is not necessarily beneficial, as its narrower
20 beam will become mismatched with the size of the transmitting beam resulting in a loss of useful energy and thus sensitivity (to first order the spatial coverage of the transmitting and receiving beams should be the same to eliminate such losses).

This requirement for spatial matching of the transmit and receive beam patterns can be overcome by forming multiple simultaneous receive beams, which in total cover the
25 same angular region as the transmit antenna. In known systems, this has previously been achieved, for example, by using multiple feed horns on a single reflector antenna. The same result can be achieved by using an electronically scanned antenna with digital beamforming. In such a design, the antenna is sub-divided into multiple sub-arrays each of which is fed to an individual digitizing receiver. The digital outputs of this plurality

of receivers can then be digitally combined in different ways to produce multiple beams simultaneously. Each of these beams has the same beamwidth (dictated by the total size of the antenna) but can be directed in different directions, thus forming a 'fan' of beams which together can cover a larger spatial region than a single beam.

5 These approaches have been used to create area search radars which have the key advantage that they can search a given area more rapidly. This is achieved by using a broad transmit beam (either a fixed 'floodlight' or a broad scanning beam) together with a multi-beam receiving antenna where the multiple beams collectively cover the same spatial region as the transmit beam.

10 These techniques are already well-known in the art and have been variously described using terms such as 'multibeam radar', 'holographic radar' and 'MIMO radar'.

According to the invention there is provided a radar system for air volume surveillance comprising a transmitter having a transmitter antenna; a receiver having a receiver antenna, the transmitter antenna and receiver antenna having respective antenna
15 apertures that are separate and configured to allow both the transmitter and receiver to operate simultaneously; the transmitting aperture providing a transmitting beam with an angular volume which is relatively small compared with the angular volume of space to be surveyed; means to scan the transmitting beam over the angular volume of space to be surveyed; the aperture of the receiver antenna being larger than the aperture of
20 the transmitter antenna such that a receiving beam formed from the receiver antenna is narrower than a transmitting beam from the transmitting antenna; means to form multiple receiving beams simultaneously from the receiving aperture, the multiple receiving beams configured such that collectively they substantially match the angular volume of the transmitting beam; means to scan the multiple receiving beams over the
25 angular volume of space to be surveyed so as to match the scanning of the transmitting beam; and wherein the transmitter antenna is positioned higher above the earth's surface than a receiving antenna.

According to another aspect there is provided a method of operating a radar system for air area surveillance, the radar system comprising a transmitter having a transmitter
30 antenna; a receiver having a receiver antenna, the transmitter antenna and receiver

antenna having respective antenna apertures that are separate and configured to allow both the transmitter and receiver to operate simultaneously; the transmitting aperture providing a transmitting beam with an angular volume which is relatively small compared with the angular volume of space to be surveyed; means to scan the transmitting beam over the angular volume of space to be surveyed; the aperture of the receiver antenna being larger than the aperture of the transmitter antenna such that a receiving beam formed from the receiver antenna is narrower than a transmitting beam from the transmitting antenna; the method comprising forming multiple receiving beams simultaneously from the receiving aperture, the multiple receiving beams configured such that collectively they substantially match the angular volume of the transmitting beam; scanning the multiple receiving beams over the angular volume of space to be surveyed so as to match the scanning of the transmitting beam; and the radar system being operated with the transmitter antenna being higher above the earth's surface than a receiving antenna.

Because the transmitter and receiver have separate apertures, the antenna for each can be of simpler construction compared to conventional radars employing duplexed transmit/receive antennas that share an aperture. This allows lossy duplexing components needed to protect the receiver to be eliminated, which further enhances the sensitivity of the system, increases the power transmitted into free space and improves receive sensitivity. These simplifications have the dual benefit of enhancing radar performance and reducing cost.

Furthermore it is comparatively straightforward to construct a receive-only antenna that can operate over a wide bandwidth.

The use of separate apertures enables operation of the transmitter at a higher duty cycle than would normally be feasible with a conventional time shared transmit/receive antenna. The transmitter may be arranged, when in operation, to transmit a substantially continuous signal which allows higher performance to be achieved.

By way of example, if we consider a conventional radar using a common aperture for transmit/receive with area A and operating with a transmit duty cycle of D_1 and power density of ρ , and compare with the system of the invention having say a transmitting

aperture of area A/N where N is greater than one, the same power density ρ , a duty cycle D_2 , and a receiving aperture of area A . If we use these two systems to survey the same angular area of space in the same time, it can be shown that the performance of the two systems will be the same provided $D_2 = N \times D_1$.

- 5 Because the receiver can operate continuously it is possible to avoid performance penalties associated with the blanking of the receiver during transmit of conventional radar systems using a duplexed antenna.

In conventional radar system employing duplexed antennas, transmit duty cycles of between 5%-33% are commonly employed. In order for the present system to provide
10 equivalent performance, this would require the receiving antenna aperture to be between 3 and 20 times the size of the transmitting antenna aperture. As such it is preferred that the receiving antenna aperture is at least three times the size of the receiving antenna aperture.

Because the aperture of the transmitter is smaller than receiver, the transmitter antenna
15 can be physically smaller and lighter than the receiver antenna. In a number of applications the transmitter antenna may be mounted above (though not necessarily directly above) the receiver antenna. Where this is so, it reduces the top weight of the radar system which significantly reduces the size and cost of the tower/mast required to support the antenna. Where the radar system is carried by a ship or land vehicle, this
20 may also allow a substantially smaller vehicle design to be adopted.

To obtain a very substantial benefit it is favourable that the transmitter aperture (and thus transmitter antenna) is positioned at least 5 m higher above the earth's surface than the receiver aperture (and thus receiver antenna).

In one arrangement there is provided a radar system (e.g. a naval radar system), wherein
25 the transmitter comprises an antenna is physically smaller than the receiver antenna, and in which the transmitter antenna is supported by a tower/and or mast (e.g. of a watercraft (ship, boat or other craft that travels on water)), such that the transmitter antenna and thus transmitter aperture is higher than the receiver antenna.

The receiver antenna may be mounted about the base of the mast/tower though not necessarily supported by the mast/tower.

The receiver may comprise an electronically scanned array antenna.

The transmitter may comprise an electronically scanned array antenna.

- 5 Scanning of the transmitting beam and forming and scanning of the multiple receiving beams simultaneously from the receiving aperture may be carried out using digital beam forming techniques known to those skilled in the art using a suitably programmed beam forming processor.

- 10 The radar system may comprise a first and second transmitter the first and second transmitters arranged to operate at different frequencies; the receiver arranged to be sensitive to both transmitting frequencies of the first and second transmitters. By using two separate transmitters, each can be optimized (e.g. antenna design, power added efficiency) for their specific bands of operation.

The use of different frequencies has a number of advantages. For example it:

- 15 allows the radar to detect frequency-dependent target characteristics, which is a significant aid to target recognition;
- allows the radar to better detect targets whose signature is frequency dependent;
- offers better capabilities to deal with frequency-dependent phenomena such as ducting, multipath and atmospheric attenuation;
- 20 enables the radar system to be employed in a multiple input multiple output (MIMO) configuration, using the two transmitters as separable sources. This allows the synthesis of a much larger receive antenna with commensurate improvements in angular measurement angular accuracy;
- offers improved anti-jamming capabilities.
- 25 The first transmitter may comprise a first transmitting antenna and the second transmitter may comprise a second transmitting antenna. Both the first and second

transmitting antenna may be located, when in use, higher, e.g. at least 5m higher, above the earth's surface than the receiver antenna.

The radar system may comprise a further receiver, the transmitter and the further receiver sharing the transmitting aperture; and wherein the radar system is configured to be switchable between a first mode and second mode; wherein in the first mode the transmitter is arranged, when operating, to transmit a signal with a duty cycle greater than fifty percent, though favourably a substantially continuous signal, and the receiver is arranged to receive a signal from the transmitter reflected from a target; and a second mode in which the transmitter is arranged to transmit a pulsed signal (e.g. with a duty cycle less than 50%) and the further receiver is arranged to receive the signal from the transmitter reflected from the target.

The antenna(s) of the transmitter and further receiver are favourably mounted above the receiver antenna.

In the first mode the combination of the small transmitting aperture and large receiving aperture provides for long range target detection above the radar horizon, whereas in the second mode, the high mounted transmit/receive aperture provides for short range detection out to the radar horizon which is determined by the height of the transmit/receive aperture.

As such the system is favourably adapted when operating in the first mode (e.g. by suitable direction of the transmitting beam), to scan for targets within the radar horizon, and when operating in the second mode, to scan for target beyond the radar horizon.

The radar system may be used as a search radar for use on a wide range of platforms across air, sea, land and space.

The invention will now be described by example with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of radar system comprising separate transmit and receive antennas;

Figure 2 is a schematic diagram of a radar system having two transmit antennas and a single receive antenna; and

Figure 3 is a schematic diagram of a radar system having a transmit/receive antenna and a single receive antenna adapted to switchable between two modes of operation;
5 and

Figures 4A & 4B are schematic diagrams of the radar system similar to Figure 3 but with a single transmitter antenna, mounted on a ship; Figure 4A illustrates operation of the radar system in a first mode for long range surveillance above and beyond the radar horizon and Fig 4B illustrates use in a second mode for short range use to the radar
10 horizon.

With reference to Fig 1 there is shown schematically a radar system for air volume surveillance having a transmitter 1 and receiver 2 and, control and processing means 3. The radar system may be connected to or further comprise a command and control system and/or and display 4, either or both can be of conventional form. The control
15 and processing means 3 and is implemented using digital computing hardware that is suitably programmed by those skilled in the art.

The transmitter 1 comprises an electronically scanned transmit-only array antenna T of area α_1 . The receiver 2 comprises an electronically scanned receiving array antenna R. The receiving antenna has area β where $\alpha < \beta$. The receiving antenna R is comprised
20 from a number N (where $N > 1$) sub-arrays (S), each of an area approximately equal to α_1 . Antennas T and R are physically separate such as to have separate antenna apertures. Antenna T is arranged, when in use, to be physically above (though not necessarily directly above) antenna R.

Purely by way of an example, transmit antenna T could have a square aperture 0.25m
25 x 0.25m operating at 10GHz, which gives rise to a transmitted beam width of approximately 7° ; receiver antenna R could be rectangular, 1m x 4m, subdivided into 64 sub-arrays. The approximate beamwidth of the complete receiver antenna is 1.70° x 0.40° , but the beamwidth of each sub-array is approximately the same as the transmit antenna T.

The transmit antenna T is arranged to operate to provide a substantially continuous wave signal and is typically relatively narrow-band, $< \sim 10\%$ fractional bandwidth, however, it will be appreciated that the bandwidth may differ.

5 The receiver 2 comprises a set of N sub-array receivers, one for each sub-array each sub-array receiver of the set of N sub-array receivers provides a discrete digital output. The outputs from the receivers are processed by the processing means 3 enabling the computation of multiple simultaneous beams on reception at the antenna R. Each beam covers a subset of the space illuminated by the transmitting antenna T, the complete set of beams covering the entirety of the space illuminated by the transmitting antenna T.

10 In use, a continuous wave signal is transmitted from the transmitting antenna T1. The receiving antenna R detects echoes from target(s) illuminated by the transmitting antenna. The outputs from the set of N sub-array receivers of the sub-arrays are combined using techniques known to those skilled in the art to produce a single (relatively narrow) beam using digital beam forming; this process is used to
15 simultaneously produce multiple relatively narrow beams in slightly different directions to produce a spatial fan of narrow beams covering the relatively broad transmit beam.

The steps above provide spatially matched transmit and receive beams, whilst utilising the full area of the receiving antenna R, thereby providing maximum sensitivity.

20 In order to further illustrate the advantages of the invention, consider the following examples:

1. A conventional single-band radar using a transmit/receive antenna of area A, operating at a transmit duty cycle of $1/8$ with a peak power of P per unit area
2. A single-band radar system as described above employing a receive-only array
25 also of area A divided into 8 sub-arrays, each with its associated receiver, plus a single transmit antenna of area $A/8$, transmitting CW with a peak power of P per unit area

It will be appreciated by a person skilled in the art, that these two systems provide approximately the same radar performance for searching the same angular area in the same time, and have similar total power requirements.

5 However, the novel radar system described above, primarily by virtue of its low cost/unit area receive array, may have a system cost of between 25% and 50% of the conventional system.

It will be appreciated that the transmit antenna T operating to provide continuous wave transmission will provide the maximum radar sensitivity; however, the system will still operate if the transmit antenna T is operated at reduced duty cycle. In order for the
10 system to provide comparable performance to conventional solutions using a transmit/receive antenna. The transmitter operates at a duty cycle above 50%.

Figure 2 illustrates an alternative configuration of antenna for a radar system. There is shown a first transmitter 1 comprising an electronically scanned transmit only antenna T1 of area α_1 , and a second transmitter 1' comprising a second electronically scanned
15 transmit only antenna T2 of area α_2 and a receiver 2 having an electronically scanned receive only antenna R of relatively large area β where $\alpha_1 < \beta$ and $\alpha_2 < \beta$. The receiver antenna R is sub-divided into a number N of sub-arrays (S), each of an area approximately equal to the smaller of α_1 , or α_2 (if different). The receiver antenna R is capable of receiving simultaneously any of the frequencies used by the transmitting
20 antennas T1, T2. The antenna T1 T2 are arranged, when in use, to be mounted physically higher, e.g. at least 5 metres higher, than receiving antenna R.

The transmitting antenna T1, T2 are arranged to operate at different widely-spaced frequencies. These could be chosen to ensure that different target or environmental phenomena can be exploited to improve detection. For example, T1 may operate in X-
25 band (~10GHz) and T2 in S-band (~3GHz). X-band provides narrower beam widths and can thus provide more accurate data for target location and tracking than S-band, where the spatial accuracy and resolution is some 3x poorer. However, S-band is much less susceptible to degradation in performance in bad weather, as attenuation in rain is almost an order of magnitude (in dB/km) lower than in X-band. Target characteristics

also tend to differ significantly between bands; this can be valuable both to enhance target detection and to aid target recognition.

The relatively narrowband transmit antenna T1, T2 can be individually optimised to operate at maximum efficiency in a manner that would not be achievable in a dual band
5 transmit/receive antenna.

A further advantage is that this antenna arrangement enables the radar system to be employed in a multiple input multiple output (MIMO) configuration, using the two transmitters T1 and T2 as separable sources. This allows the synthesis of a much larger receive antenna with commensurate improvements in angular measurement accuracy.

10 Another advantage is that it offers considerable anti-jamming capabilities by deploying widely spaced frequencies.

Each transmitting antenna T1, T2 is arranged to illuminate a common (and same angular) area of space each with a substantially continuous wave (CW) signal which is typically relatively narrow-band, $< \sim 10\%$ fractional bandwidth; however, it will be
15 appreciated that the bandwidth may differ. The transmitting antennas T1 and T2 are physically and electronically arranged so as to minimize any coupling to the receiver antenna R. This may be accomplished in a variety of ways depending upon the radar installation. For example, if space permits, they may simply be widely separated; or if a more compact arrangement is required (for example on a ship or aircraft) the some
20 form of shielding, typically employing radar absorbent material, may be employed.

A signal is transmitted from one or more of the transmitting antennas T1, T2. It will be appreciated that if more than one transmit antenna T1, T2 is used, the transmissions are advantageously carried out on different frequencies, each frequency being sufficiently separated from the others to ensure that mutual interference can be
25 controlled and mitigated. Some form of time multiplexing may be used instead but disadvantageously this reduces the mean power (and hence sensitivity) of the radar system.

The receiver 2 comprises a set of N sub-array receivers, one for each sub-array S, each with a discrete digital output. This set of sub-array receivers enables the computation

of multiple simultaneous beams on reception at the antenna R. Each beam covers a subset of the space illuminated by the transmitting antenna(s), the complete set of beams covering the entirety of the space illuminated by the transmitting antenna(s).

5 The receiving antenna R detects echoes from target(s) illuminated by the transmitting antenna(s). The outputs from all the sub-arrays receivers are combined to produce a single (relatively narrow) beam using digital beam forming; this process is simultaneously carried out multiple times in slightly different directions in order to produce a spatial fan of narrow beams covering the relatively broad transmit beam(s).

10 The receiving antenna R is capable of operating over a wide band encompassing all expected transmit frequencies. Digital beamforming is repeated for each transmit frequency thus providing independent outputs for each transmitted frequency.

It will be appreciated that more than two transmit antennas T1, T2 may be used each arranged to transmit at a different frequency band from the others.

15 In an alternative arrangement a single transmitting antenna may be arranged to transmit signals in two frequency bands. This arrangement is less preferred as with two antennas each can be separately optimized to operate at maximum efficiency. Additionally the use of two antennas avoids the major drop in efficiency necessitated by simultaneous multi-frequency operation in a single antenna.

20 Figure 3 illustrates a radar system with a further variant antenna configuration comprising two transmit/receive antennas T3 T4 and a relatively large receive only antenna R.

25 The radar system has a mode selector 5 (e.g. implemented as a function of the radar system controller) that enables the system to be switched between two modes of operation. In a first mode, the system operates as described above wherein the two transmit/receive antennas T3 T4 are employed as transmit only antennas. In a second mode, the transmit/receive antennas T3 T4 are employed as conventional common aperture antennas. In one arrangement of the second mode the receiving antenna is not used. In a variant arrangement of the second mode the receiving antenna is used to augment the receiving function of the transmit/receive antennas T3 T4. The advantage

of this configuration is that the antennas may be disposed to provided substantially different spatial coverage, for example the antennas T3 T4 may be separated in height from the receiver antenna R, e.g. at least 5 meters to extend the radar horizon.

Figures 4A 4B illustrate an implementation of a variant antenna arrangement described in Figure 3 employed as a ship borne airspace surveillance radar.

The radar system comprises a relatively small transmit/receive antenna T3 (though it may have two or more) mounted about the top of the ship's V mast M, and one or more much physically larger receive-only antenna R mounted lower down on the ship's V superstructure or about base of the mast M. The transmit/receive antenna T3 is favourably mounted so as to be 5 metres or higher than the larger receive antenna R. On larger ships the transmit/receive antenna may be 10 metres or higher than the receive antenna. The relatively small size and weight of the transmit/receive antenna T3 minimises mast top weight.

The radar system is able to switch between two modes of operation depending upon function desired. For surveillance above the radar horizon as illustrated in Fig 4A, the radar system operates in a first mode as described in relation to Fig 1 in which the relatively small transmit/receive antenna operates in a transmit only mode to provide a CW signal and the large low-mounted antenna R acts to receive. This mode provides greater sensitivity and range and thus can be used to detect target beyond the radar horizon.

In a second mode the relatively small transmit/receive antenna T3 operates in a conventional duplex transmit/receive fashion with beams directed downwards to provide surveillance out to the radar horizon, a distance which is determined by the height of the transmit/receive antenna. In this mode the larger receiver antenna R is not used; however as the range to the radar horizon is relatively short, the lower sensitivity of the relatively small transmit/receive antenna T3 is still sufficient to provide satisfactory performance. It will be appreciated that the radar system could be similarly implemented on other platforms, e.g. ground vehicle carried radar systems or fixed position radar system.

Claims

1. A radar system for air volume surveillance comprising a transmitter having a transmitter antenna;
a receiver having a receiver antenna, the transmitter antenna and receiver
5 antenna having respective antenna apertures that are separate and configured to allow both the transmitter and receiver to operate simultaneously;
the transmitting aperture providing a transmitting beam with an angular volume which is relatively small compared with the angular volume of space to be surveyed;
10 means to scan the transmitting beam over the angular volume of space to be surveyed;

the aperture of the receiver antenna being larger than the aperture of the transmitter antenna such that a receiving beam formed from the receiver
15 antenna is narrower than a transmitting beam from the transmitting antenna;

means to form multiple receiving beams simultaneously from the receiving aperture, the multiple receiving beams configured such that collectively they substantially match the angular volume of the transmitting beam;
20 means to scan the multiple receiving beams over the angular volume of space to be surveyed so as to match the scanning of the transmitting beam; and

wherein the transmitter antenna is positioned higher above the earth's surface
25 than a receiving antenna.
2. A radar system according to claim 1 wherein the transmitter antenna is
30 positioned at least 5 m higher above the earth's surface than the receiver antenna.

3. A radar system according to claim 1 or 2 comprising a first and second transmitter the first and second transmitters arranged to operate at different frequencies; the receiver arranged to be sensitive to both transmitting frequencies of the first and second transmitters.
- 5 4. A radar system according to claim 3 wherein both the first and second transmitter antenna are positioned higher above the earth's surface than the receiver.
- 10 5. A radar system according to any previous claim comprising a further receiver, the transmitter and the further receiver sharing the transmitting aperture; and wherein the radar system is configured to be switchable between a first mode and second mode; wherein in the first mode the transmitter is arranged, when operating, to transmit a signal and the receiver is arranged to receive the signal from the transmitter reflected from a target; and a second mode in which the transmitter is arranged to transmit a pulsed signal and the further receiver is
15 arranged to receive the signal from the transmitter reflected from the target.
6. A radar system according to claim 5 wherein when the radar system is operating in the first mode the transmitter is arranged to transmit a signal with a duty cycle greater than 50 percent.
- 20 7. A radar system according to claim 5 wherein when the radar system is operating in the first mode the transmitter is arranged to transmit a substantially continuous signal.
- 25 8. A method of operating a radar system for air area surveillance, the radar system comprising a transmitter having a transmitter antenna;
a receiver having a receiver antenna, the transmitter antenna and receiver antenna having respective antenna apertures that are separate and configured to allow both the transmitter and receiver to operate simultaneously;
30 the transmitting aperture providing a transmitting beam with an angular volume which is relatively small compared with the angular volume of space to be surveyed;

means to scan the transmitting beam over the angular volume of space to be surveyed;

5 the aperture of the receiver antenna being larger than the aperture of the transmitter antenna such that a receiving beam formed from the receiver antenna is narrower than a transmitting beam from the transmitting antenna; the method comprising

10 forming multiple receiving beams simultaneously from the receiving aperture, the multiple receiving beams configured such that collectively they substantially match the angular volume of the transmitting beam;

scanning the multiple receiving beams over the angular volume of space to be surveyed so as to match the scanning of the transmitting beam; and

15 the radar system being operated with the transmitter antenna being higher above the earth's surface than a receiving antenna.

20 9. A method of operating a radar system according to claim 8 wherein the radar system is operated with the transmitter antenna at least five meters higher above the earth's surface than a receiving antenna.

25



Application No: GB1812295.2

Examiner: Mr Henry Nevell

Claims searched: 1-9

Date of search: 24 January 2019

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 2, 5-9	US2016/139254 A1 (WITTENBERG) See particularly paragraphs 14 and 46
X	1, 3, 4-8	EP2857857 A1 (HONEYWELL) See figures 1a, 4 and paragraphs 36 and 55-57
X	1, 5-8	US2015/070208 A1 (GOTO) See figures 1, 3 and paragraphs 12, 16-19, 25 and 26

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

G01S; H01Q

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, Patent Fulltext

International Classification:

Subclass	Subgroup	Valid From
G01S	0013/48	01/01/2006
G01S	0013/00	01/01/2006