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(71) Applicant: BAE SYSTEMS PLC [GB/GB]; 6 Carlton Gardens, London SW1Y 5AD (GB).

Inventors: MITCHELL, Kevin, Gerald; BAE SYSTEMS, Warton Aerodrome, Warton, Preston Lancashire PR4 1AX (GB). MILLER, David, Alexander;

BAE SYSTEMS, Warton Aerodrome, Warton, Preston
Lancashire PR4 1AX (GB).

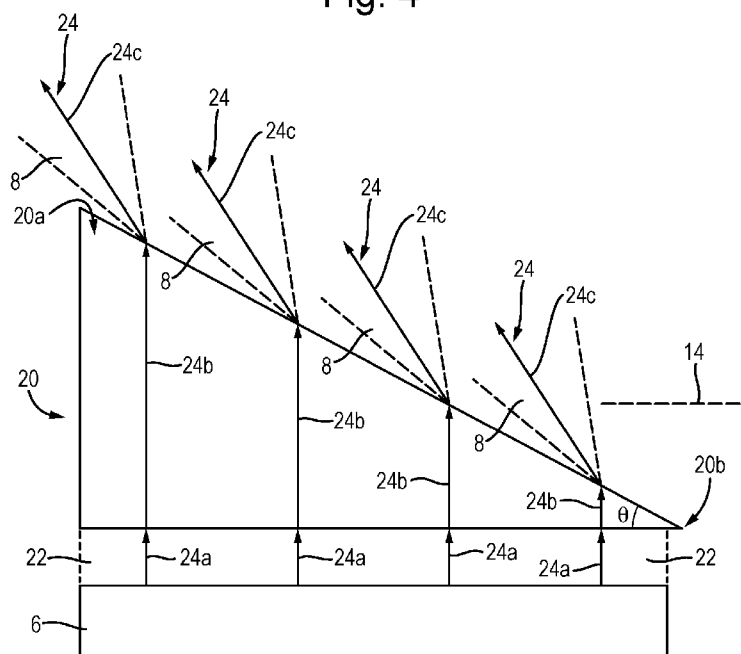
(74) Agent: BAE SYSTEMS PLC, GROUP IP DEPT; PO
Box 87, Farnborough Aerospace Centre, Farnborough
Hampshire GU14 6YU (GB).

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(54) Title: ANTENNA ASSEMBLY

Fig. 4



(57) Abstract: An antenna assembly, for example for use on an aircraft, comprising: an antenna having a field of view; and a device coupled to the antenna and configured to impart a phase delay to a beam of the antenna so as to change the orientation of the field of view of the antenna relative to the antenna. The device may comprise a metamaterial. A permittivity and/or a permeability of the device may vary (e.g. linearly) across the structure of the device.

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ANTENNA ASSEMBLY

FIELD OF INVENTION

The present invention relates to antenna assemblies.

5

BACKGROUND

Many aircraft include antenna systems. Such antenna systems may be used, for example, for communication, navigation, electronic warfare, sensing purposes, threat detection, and target detection and tracking purposes.

10 The field of view of an antenna mounted to the surface of the aircraft tends to be limited. Also, it tends to be desirable for an aircraft antenna to be able to “see” along or below at least part of a plane spanned by a roll axis and a pitch axis of the aircraft (i.e. the azimuth plane). Typically, when the aircraft is in flight, this plane spanned by the roll and pitch axes of the aircraft aligns with the
15 horizon.

In the case of commercial aircraft, it is common to mount a satellite communications antenna on the upper surface of the fuselage, or atop the fin. This tends to provide for good communication with overhead satellites. To allow the satellite communications antenna to operate near the azimuth plane, the
20 installation in which the satellite communications antenna is located typically protrudes above the surface of the vehicle. Thus, a drag penalty is imposed on the aircraft.

In the case of Low Observable (LO) aircraft, most of these types of aircraft are “flat” in shape, meaning their vertical extent is small in comparison to
25 their dimensions in the horizontal plane. This shape of LO aircraft advantageously tends to provide for reduced radar signature, but means that there is little space available to mount antennas other than on the upper and lower surfaces of the LO aircraft. This tends to mean that antennas are typically directed either upwards or downwards, making operation in the azimuth plane
30 difficult.

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To further illustrate this point, Figure 1 is a schematic illustration (not to scale) showing a side-view cross-section of part of an aircraft (for example an LO aircraft) 2 comprising an uppermost external surface 4 of the aircraft, and an antenna 6.

5 In this example, the antenna 6 is mounted to the external skin of the aircraft such that the upper surface of the antenna 6 conforms to the upper external surface 4 of the aircraft. Thus, the upper external surface 4 of the aircraft and the upper surface of the antenna 6 form a substantially smooth, contiguous surface. This smooth surface, with no protrusion therefrom,
10 advantageously tends to reduce or eliminate a drag penalty of the antenna 6 and/or preserve LO properties of the aircraft.

 The field of view of the antenna 6 is indicated in Figure 1 by reference numerals 8 and is bounded by dashed lines. In this example, the field of view 8 of the antenna 6 covers a volume of airspace within an angle 10 (e.g. 60°) from
15 a normal 12 to the upper surface of the antenna 6. However, the field of view 8 of the surface mounted antenna 6 tends to be limited, and also is directed upwards. It tends to be desirable for an aircraft antenna 6 to be able to “see” along or below the azimuth plane 14.

 One solution to the problem of providing that the azimuth plane 14 is
20 within the field of view 8 of the antenna 6 is shown in Figure 2.

 Figure 2 is a schematic illustration (not to scale) showing a side-view cross section of part of an aircraft 2 in which the antenna 6 is mounted within a cavity 16. The cavity 16 is recessed in the upper external surface 4 of the aircraft.

25 In this example, the antenna 6 is arranged in the cavity 16 (e.g. vertically) such that the field of view 8 of the antenna 6 covers the azimuth plane 14.

 However, the cavity 16 and the antenna 6 arranged in the cavity 16 tends to drastically increase drag on the aircraft, as well as tending to increase installation size and/or increase the radar cross section of the aircraft.

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SUMMARY OF INVENTION

The present inventors have realised that it would be beneficial to provide an antenna assembly having an improved field of view, for example, a field of view that additionally covers the azimuth plane which may be spanned by a roll
5 axis and a pitch axis of an aircraft on which the antenna assembly is located.

The present inventors have realised that it would be beneficial to provide an antenna assembly having a reduced drag penalty.

The present inventors have realised that it would be beneficial to provide an antenna assembly that maintains the LO properties of an aircraft. The
10 present inventors have realised that it would be beneficial to provide an antenna assembly that overcomes the difficulties posed by LO aircraft having relatively flat shapes.

In a first aspect, the present invention provides an antenna assembly comprising an antenna having a field of view, and a device coupled to the
15 antenna and configured to impart a phase delay to a beam of the antenna so as to change the orientation of the field of view of the antenna relative to the antenna.

The phase delay imparted by the device to the beam may vary (e.g. substantially linearly) across a structure of the device.

20 The antenna assembly may be comprised in at least part of a vehicle. An exposed surface of the antenna assembly may be conformal with an external surface of the at least part of the vehicle.

The beam of the antenna may comprise electromagnetic signals transmitted and/or received by the antenna.

25 The device may comprise a metamaterial. The metamaterial may comprise a plurality of repeated elements. A periodicity of the repeated elements may be less than or equal to $\lambda/10$, where λ is a wavelength of electromagnetic signals transmitted and/or received by the antenna. The periodicity of the metamaterial may vary (e.g. linearly) across the structure of
30 the device. Metamaterial properties of the metamaterial vary across the structure of the device. A design of the metamaterial elements may vary across the structure of the device.

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A permittivity of the device may vary (e.g. linearly) across the structure of the device. A permeability of the device may vary (e.g. linearly) across the structure of the device. A thickness of the device may vary (e.g. linearly) across the structure of the device. A density of the device may vary (e.g. linearly)

5 across the structure of the device.

The antenna may be a scannable antenna. The antenna may comprise a first portion configured to transmit electromagnetic signals, and a second portion configured to receive electromagnetic signals. The antenna assembly may further comprise means configured to impose a phase distribution on one or both of a beam transmitted by the antenna and a beam received by the antenna. This may provide that the beam transmitted by the antenna and the beam received by the antenna are substantially parallel.

The antenna and the device may be spaced apart such that there is a gap disposed between the antenna and the device.

15 In a further aspect, the present invention provides at least part of a vehicle comprising an antenna assembly, the antenna assembly being in accordance with any preceding aspect.

An external surface of the antenna assembly may be conformal with an external surface of the vehicle. An external surface of the antenna assembly may be contiguous with an external surface of the vehicle.

20 The antenna may be located at or proximate to an external surface of the vehicle. The antenna may be substantially parallel with an external surface of the vehicle.

The vehicle may be an aircraft. The device may orientate the field of view of the antenna such that at least part of a plane spanned by a roll axis and a pitch axis of the aircraft is within the orientated field of view. The aircraft may be a low observable aircraft. The low observable aircraft may have its surfaces and/or edges oriented at a limited number of directions. The antenna may have at least one surface and/or at least one edges oriented at one or the limited number of directions.

30 In a further aspect, the present invention provides a method comprising providing an antenna having a field of view, and coupling a device to the

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antenna thereby to impart a phase delay to a beam of the antenna and thereby to change the orientation of the field of view of the antenna relative to the antenna.

5 BRIEF DESCRIPTION OF FIGURES

Figure 1 is a schematic illustration (not to scale) showing a part of an aircraft;

Figure 2 is a schematic illustration (not to scale) showing a part of an aircraft;

10 Figure 3 is a schematic illustration (not to scale) showing a side-view cross-section of part of an aircraft in which an embodiment of an antenna assembly is implemented;

Figure 4 is a schematic illustration (not to scale) showing further details and operation of the antenna assembly; and

15 Figure 5 is a schematic illustration (not to scale) showing further details and operation of a further antenna assembly.

DESCRIPTION

In the Figures, like reference numerals refer to like elements.

20 Figure 3 is a schematic illustration (not to scale) showing a side-view cross-section of part of an aircraft 2 in which an embodiment of an antenna assembly 18 is implemented.

The part of the aircraft 2 comprises an uppermost external surface 4 of the aircraft and an installed antenna assembly 18. The antenna assembly 18
25 comprises an antenna 6, and a device configured to improve the field of view (FOV) of the antenna 6 which is hereinafter referred to as “the device” and is indicated in the Figures by the reference numeral 20. In this embodiment, the device 20 is a radome that acts to improve the FOV of the antenna 6 as described in more detail later below.

30 The aircraft may be a “Low Observable” (LO) aircraft, i.e. an aircraft that is relatively difficult to detect using radar systems. The LO aircraft may employ a

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variety of stealth technologies to reduce the aircraft's reflection and emission of electromagnetic radiation such as radar signals and infrared radiation. For example, the principle of planform alignment may be used in the design of the shape of the aircraft. This provides that there are a relatively small number of
5 different orientations of the surfaces of the aircraft structure compared to the number of different surface orientations in aircraft that are not LO aircraft. For example, on an LO aircraft, the leading edges of the aircraft may have the same orientation as the trailing edges of the aircraft. Also, other structures, such as air intake bypass doors and re-fuelling apertures, may use the same angles as the
10 aircraft leading/trailing edges. An effect of planform alignment is that only radar radiation (emitted by a radar antenna) that is incident onto the LO aircraft at a small number of specific angles (i.e. normal to the angles of orientation of the surfaces of the LO aircraft) is reflected back towards the transmitting radar antenna, whereas radar radiation that is incident onto the LO aircraft at angles
15 other than those specific angles tends to be reflected away from the transmitting radar antenna. This is in contrast to aircraft that are not LO aircraft. Such non-LO aircraft would typically reflect incident radar radiation in many directions so that that aircraft is detectable at many angles.

In this embodiment, the device 20 is disposed between the antenna 6
20 and the external surface of the aircraft.

An upper surface of the device 20 substantially conforms to the upper external surface 4 of the aircraft. Thus, the upper external surface 4 of the aircraft and the upper surface of the device 20 form a substantially smooth, contiguous surface. This smooth surface, with no protrusion therefrom,
25 advantageously tends to reduce or eliminate additional drag on the aircraft by the antenna assembly 18 and/or preserve LO properties of the aircraft.

The antenna 6 is positioned facing and proximate to a lower surface of the device 20. The lower surface of the device 20 is opposite to the upper surface of the antenna 6.

30 Figure 4 is a schematic illustration (not to scale) showing further details and operation of the antenna assembly 18.

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In this embodiment, the antenna 6 and the device 20 are spaced apart such that there is an air gap 22 between the lower surface of the device 20 and the upper surface of the antenna 6. In some embodiments, this air gap 22 is replaced by a solid material such as a plastic that is substantially transparent to
5 electromagnetic waves at the frequency of operation of the installed antenna 6. In other embodiments, the antenna 6 and the device 20 are not spaced apart, i.e. the antenna 6 and the device 20 are directly attached together.

In this embodiment, the device 20 is substantially wedge shaped. In other words, the shape of the device 20 is substantially that of a triangular
10 prism.

The device 20 comprises a relatively thick first end 20a, and a relatively thin second end 20b opposite to the first end 20a. The device 20 tapers inwards from its first end 20a to its second end 20b. The device 20 reduces in thickness (e.g. linearly) from its first end 20a to its second end 20b. The device 20 tapers
15 to nothing at its second end 20b.

In this embodiment, the device 20 is made of a material that allows electromagnetic signals to propagate through it. Examples of appropriate materials include, but are not limited to, ceramic powder embedded in a resin material, metamaterials, glass reinforced plastics (for example, cyanate ester,
20 polyimide, polybutadiene or epoxy resin, along with Kevlar(TM), E-glass, D-glass, polyethylene, or quartz reinforcement), high density polyethylene, polypropylene, PEEK, polyurethane foam, and slip cast fused silica.

In this embodiment, the permittivity and/or permeability of the device 20 (with respect to the electromagnetic waves at the frequency of operation of the
25 installed antenna 6) varies between its first end 20a and its second end 20b. In particular, the permittivity and/or permeability of the device 20 decreases (e.g. linearly) from its first end 20a to its second end 20b. Thus, at its first end 20a, the device 20 has a relatively higher permittivity and/or permeability while, at its second end 20b, the device 20 has a relatively lower permittivity and/or
30 permeability. This advantageously tends to allow for a reduction in the vertical space occupied by the device 20, and thereby the antenna assembly 18. Thus,

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installation of the antenna assembly 18 onto the aircraft (for example LO aircraft) tends to be facilitated.

The device 20 may be made using any appropriate process, for example, using Additive Manufacturing to build the device 20 designed using an
5 electromagnetic computation program.

In this embodiment, the antenna 6 is an active electronically scanned antenna that is configured to be operated as a phased array to allow steering of transmitted/received electromagnetic beams.

In operation, the antenna 6 is controlled to transmit and/or receive
10 electromagnetic signals. By way of example, signals transmitted by the antenna 6 are indicated in Figure 4 by arrows and the reference numerals 24. Signals received by the antenna may follow the same or similar paths as the transmitted signals 24 in the opposite direction. The path of the transmitted signals 24 comprises a first portion 24a through the air gap 22 and onto the lower surface
15 of the device 20. The transmitted signals 24 then follow a second path portion 24b, as indicated in Figure 4 by arrows and the reference numerals 24b, during which they propagate through the device 20 to the upper surface of the device 20. The transmitted signals 24 then exit the device 20 at the upper surface of the device 20 and travel away from the aircraft along a third path portion 24c.

20 In this embodiment, the antenna 6 is controlled to steer the transmitted signals 24 in such a way that the transmitted signals 24c emitted from the device 20 are substantially parallel to each other, and preferably very highly parallel. In some embodiments, an additional phase taper and/or phase differential is implemented in conjunction with the device 20 to provide that the
25 transmitted rays 24 from the antenna assembly 18 are very highly parallel.

In this embodiment, different transmitted signals 24 travel through different thicknesses of the device 20. In particular, electromagnetic signals transmitted from regions of the antenna 6 closer to the second end 20b of the device 20 travel a shorter distance through the device 20, between the lower
30 and upper surfaces of the device 20, compared to signals 24 transmitted from

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regions of the antenna 6 closer to the first end 20a. Also, the device 20 has a greater permittivity and/or permeability at its first end 20a than at its second end 20b

As a result of at least the angle θ of the wedge-shaped device 20 and/or
5 the material from which the device 20 is fabricated, the device 20 bends or changes the direction of the beam or signals 24 emanating from the antenna 6. In the example shown in Figure 4, the rays 24a transmitted by the antenna 6 travel, in parallel directions, normal to the antenna 6. As these rays 24a enter the device 20, they tend not to be refracted since they enter the device 20
10 normal to the lower surface of the device 20. However, the rays tend to be slowed down by the device 24 according to the material characteristics of the device 20, i.e. rays 24b travelling through the device 20 tend to be slower than those outside the device 20. The wavelength of the rays also tends to be reduced by the device 20 at the same time to maintain a constant frequency. As
15 the rays leave the device 20, they are refracted according to Snell's Law as it applies to microwaves. That is, upon leaving a material of higher permittivity or permeability and entering a medium having lower permittivity or permeability, the rays 24 tend to be refracted further away from the normal to the interface than the corresponding angle at which they approach the interface. Thus, the
20 path of the rays 24 transmitted by the antenna 6 is bent by the device 20.

Thus, in effect, the device 20 re-orientates the field of view 8 of the antenna 6. Preferably, the device 20 is configured (for example, by selecting suitable angle θ and device material) to provide that the field of view 8 of the antenna 6 includes the azimuth plane 14 spanned by a roll axis and a pitch axis
25 of the aircraft.

In the above embodiments, the device 20 is a wedge-shaped device having tapered thickness. However, in other embodiments, the device 20 is not wedge shaped. For example, in some embodiments, the device 20 has substantially uniform thickness.

30 Figure 5 is a schematic illustration (not to scale) showing a further embodiment of the antenna assembly 18.

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In this embodiment, the device 20 is fabricated from a metamaterial. The metamaterial device 20 may be designed and fabricated to have any desired dimensions and physical properties. For example, the metamaterial device 20 may be designed and fabricated to have substantially uniform thickness.

5 A metamaterial may be regarded as a material engineered to have particular predetermined electromagnetic properties that tend not to occur naturally. Properties of metamaterials typically derive from the design of the structure of the metamaterial. Advantageously, it tends to be possible to design a metamaterial such that its physical properties (such as, its structure, shape,
10 geometry, size, orientation, and arrangement) provide desired electromagnetic properties.

In this embodiment, the metamaterial comprises multiple different materials, such as composite materials, metals, or plastics. The different materials are arranged in repeating patterns or elements. The periodicity of the
15 metamaterial (i.e. the distance between adjacent repeated elements) is smaller than the wavelength of the electromagnetic signals being influenced by the metamaterial. For example, the periodicity of the metamaterial may be less than or equal to $\lambda/10$, where λ is the wavelength of the signals being transmitted and/or received by the antenna 6.

20 In this embodiment, the metamaterial is such that the phase delay (with respect to radio signals passing through the metamaterial) of the metamaterial device 20 varies between its first end 20a and its second end 20b. This may be achieved in any appropriate way, for example, the periodicity of the metamaterial device 20 may vary between its first end 20a and its second end
25 20b, metamaterial properties of the metamaterial device 20 may vary between its first end 20a and its second end 20b, the design of the metamaterial elements may vary between its first end 20a and its second end 20, or a combination of these factors. In this embodiment, the metamaterial device 20 is configured to include a phase taper such that the phase delay of the
30 metamaterial device 20 decreases (e.g. linearly) from its first end 20a to its second end 20b. Thus, at its first end 20a, the phase delay of the metamaterial

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device 20 is relatively high while, at its second end 20b, the phase delay of the metamaterial device 20 is relatively low. Thus, propagation of electromagnetic waves through the metamaterial device 20 tends to be slower at and proximate to the first end 20a of the device 20 compared to at and proximate to the second end 20b. In other embodiments, the metamaterial device 20 may be configured such that the phase delay of the metamaterial device 20 increases (e.g. linearly) from its first end 20a to its second end 20b. In other embodiments, the metamaterial device 20 may be configured such that the phase delay of the metamaterial device 20 varies in a different way between its first end 20a to its second end 20b.

In this embodiment, different rays 24 transmitted from or received by the antenna 6 travel through different regions of the metamaterial device 20 having different phase delays. For example, rays 24 transmitted from the antenna 6 closer to the second end 20b of the metamaterial device 20 travel through a medium having a lower refractive index than that of the medium through which rays 24 transmitted from the antenna 6 closer to the first end 20a of the metamaterial device 20 travel. This advantageously tends to “bend” the paths travelled by the rays 24 transmitted from the antenna 6. Thus, in effect, the metamaterial device 20 bends or rotates the field of view 8 of the antenna 6. Preferably, the metamaterial device 20 is configured such that the field of view 8 of the antenna assembly 18 includes the azimuth plane 14.

Advantageously, the above described metamaterial device tends to occupy less volume on the aircraft than the above described wedge-shaped device.

Advantageously, the above described antenna assemblies tend to allow for the antenna to be positioned close to the external surface of the aircraft. Also, the above described antenna assemblies tend to allow for the antenna to be positioned substantially parallel to the external surface of the aircraft, and preferably highly parallel with that surface. Thus, the antenna may be planform aligned with the aircraft surfaces and edges. Also, the antenna assembly may be conformal with the aircraft outer surface. Thus the above described apparatuses and methods tend not to significantly detrimentally affect the radar

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cross section of the aircraft. In other words, the above described antenna assemblies advantageously tends to preserve the LO properties of the aircraft.

Furthermore, the above described system and method tend provide an improved field of view. For example, electromagnetic signals can be transmitted
5 and/or received within the azimuth plane.

Conventionally, in some aircraft and other vehicles, an antenna is located in blisters that protrude from external surfaces of the vehicle. Locating the antenna in an external blister allows the antenna to “see” along the horizon. The above described system and method advantageously tends to provide an
10 antenna assembly that conforms to the external surface of the aircraft, and that can see along the horizon. Thus, the use of external blisters may be avoided. This advantageously tends to reduce drag experienced by the vehicle.

In the above embodiments, the antenna assembly is implemented on board an aircraft, for example a LO aircraft. However, in other embodiments,
15 the antenna assembly is not on board an aircraft or a LO aircraft. For example, in other embodiments, the antenna assembly may be implemented on a different type of aircraft (e.g. a non-LO aircraft), a land-based vehicle, a building, or a water-based vehicle.

In the above embodiments, the antenna assembly is positioned on the
20 aircraft at an upper external surface of the aircraft. However, in other embodiments, the antenna assembly is positioned differently on the vehicle or other entity. For example, in some embodiments, the antenna assembly is located at or proximate to a lower surface of an aircraft.

In the above embodiments, the antenna assembly conforms to an
25 external surface of the aircraft. In other words, the external surface of the device substantially follows an outer mould line (OML) of the aircraft. However, in other embodiments the antenna assembly does not conform to the external surface of the aircraft. For example, in some embodiments, at least part of the antenna assembly protrudes beyond the external surface of the aircraft skin. Also, in
30 some embodiments, the antenna assembly may be located in a cavity or other

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structure recessed in the aircraft, and may be entirely below a level of the external surface of the aircraft skin.

In the above embodiments, the antenna is an active electronically scanned antenna that is configured to be operated as a phased array. However,
5 in other embodiments, the antenna is a different type of antenna.

In the above embodiments, the antenna assembly comprises a single device for improving the antenna FOV. However, in other embodiments the antenna assembly comprises multiple such devices. For example, in some embodiments, multiple devices may be disposed side-by-side across a surface
10 of a common antenna. Also for example, in some embodiments, one or more devices may be positioned on top of another such device such that transmitted and/or received rays pass through one device, and then subsequently through one or more different devices.

In some embodiments, the antenna comprises multiple sections which
15 operate at different respective frequencies or frequency bands. Also, in some embodiments, the antenna is configured to be both a transmitter and a receiver. For example, in some embodiments, the antenna may comprise a transmitter portion configured to transmit electromagnetic signals having a first frequency, and a different receiver portion configured to receive electromagnetic signals
20 having a second, different frequency. In such case, the impact of the device 20 on the transmit and receive beams will tend to be different, for example, because a given structure will tend to bend the path of rays having shorter wavelength more than those having longer wavelength. It may be desirable for the transmit and receive beams of an antenna assembly to be parallel. One
25 option to provide for parallel transmit and receive beams is to impose an additional phase distribution, for example by means of a phase taper, on one or both of the transmitted and receive beams. This additional phase distribution may be applied, for example, at the surface of the antenna. This additional phase distribution may be configured to cancel the difference in propagation
30 characteristics through the device attributable to the different transmit and receive frequency bands used. Advantageously, by fabricating the device from a metamaterial, the use of an additional phase distribution may be avoided as

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the metamaterial can be configured to provide for the desired cancellation of propagation characteristics, in addition to orienting the beam as desired.

In some embodiments the antenna is only a receiver of electromagnetic signals. Also, in some embodiments, the antenna is only a transmitter of
5 electromagnetic signals.

In the above embodiments, the antenna assembly comprises a single antenna. However, in other embodiments the antenna assembly comprises multiple antennas which may, for example, transmit and/or receive signals through a common device.

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CLAIMS

1. An antenna assembly comprising:
an antenna having a field of view; and
a device coupled to the antenna and configured to impart a phase delay
5 to a beam of the antenna so as to change the orientation of the field of view of
the antenna relative to the antenna.
2. An antenna assembly according to claim 1, wherein a phase delay
imparted by the device to the beam varies substantially linearly across a
10 structure of the device.
3. An antenna assembly according to claim 1, wherein the antenna
assembly is comprised in at least part of a vehicle, and an exposed surface of
the antenna assembly is conformal with an external surface of the at least part
15 of the vehicle.
4. An antenna assembly according to any of claims 1 to 3, wherein the
beam of the antenna comprises electromagnetic signals transmitted and/or
received by the antenna.
20
5. An antenna assembly according to any of claims 1 to 4, wherein the
device comprises a metamaterial.
6. An antenna assembly according to claim 5, wherein the metamaterial
25 comprises a plurality of repeated elements, and a periodicity of the repeated
elements is less than or equal to $\lambda/10$, where λ is a wavelength of
electromagnetic signals transmitted and/or received by the antenna.
7. An antenna assembly according to any of claims 1 to 6, wherein a
30 permittivity and/or a permeability of the device varies across the structure of the
device.

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8. An antenna assembly according to any of claims 1 to 7, wherein a thickness of the device varies across the structure of the device.
9. An antenna assembly according to any of claims 1 to 8, wherein a
5 density of the device varies across the structure of the device.
10. An antenna assembly according to any of claims 1 to 9, wherein the antenna is a scannable antenna.
- 10 11. An antenna assembly according to any of claims 1 to 10, wherein the antenna comprises a first portion configured to transmit electromagnetic signals, and a second portion configured to receive electromagnetic signals.
12. An antenna assembly according to claim 11, further comprising means
15 configured to impose a phase distribution on one or both of a beam transmitted by the antenna and a beam received by the antenna, thereby to provide that the beam transmitted by the antenna and the beam received by the antenna are substantially parallel.
- 20 13. An antenna assembly according to any of claims 1 to 12, wherein the antenna and the device are spaced apart such that there is a gap disposed between the antenna and the device.
14. At least part of a vehicle comprising an antenna assembly, the antenna
25 assembly being in accordance with any of claims 1 to 13.
15. At least part of vehicle according to claim 14, wherein an external surface of the antenna assembly conforms to an external surface of the vehicle.
- 30 16. At least part of vehicle according to claim 14 or 15, wherein the antenna is proximate to an external surface of the vehicle.

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17. At least part of vehicle according to any of claims 14 to 16, wherein the antenna is substantially parallel with an external surface of the vehicle.

18. At least part of vehicle according to any of claims 14 to 17, wherein the
5 vehicle is an aircraft.

19. At least part of vehicle according to claim 18, wherein the device orients the field of view of the antenna such that at least part of a plane spanned by a roll axis and a pitch axis of the aircraft is within the oriented field of view.
10

20. At least part of vehicle according to claim 18 or 19, wherein the aircraft is a low observable aircraft

21. At least part of vehicle according to claim 20, wherein the low observable
15 aircraft has its surfaces and/or edges oriented at a limited number of directions.

22. At least part of vehicle according to claim 21, wherein the antenna has at least one surface and/or at least one edges oriented at one or the limited number of directions.
20

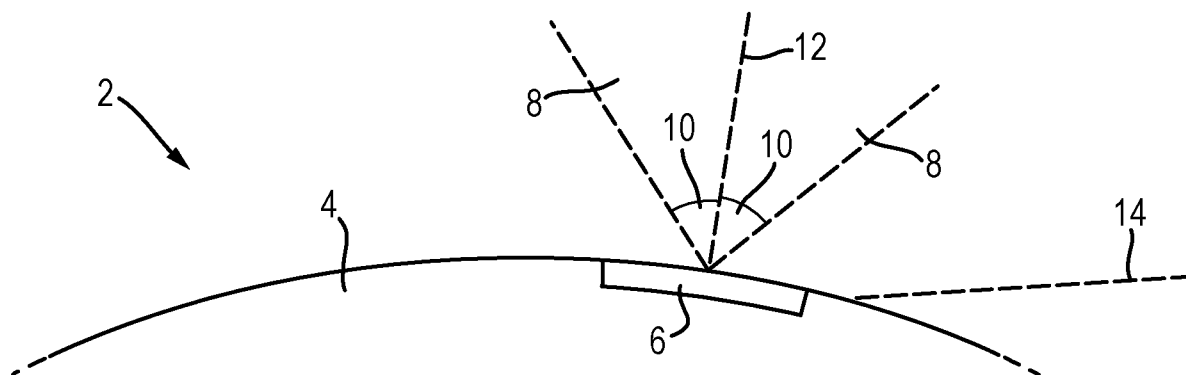
23. A method comprising:
providing an antenna having a field of view; and
coupling a device to the antenna thereby to impart a phase delay to a beam of the antenna and thereby to change the orientation of the field of view of
25 the antenna relative to the antenna.

24. An antenna assembly substantially as described herein with reference to the accompanying Figures.

30 25. A vehicle substantially as described herein with reference to the accompanying Figures.

Fig. 1

Prior Art

**Fig. 2**

Prior Art

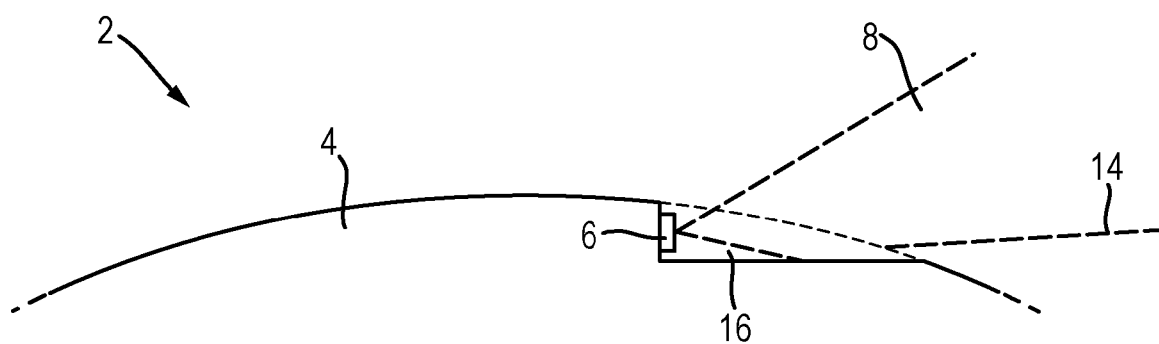


Fig. 3

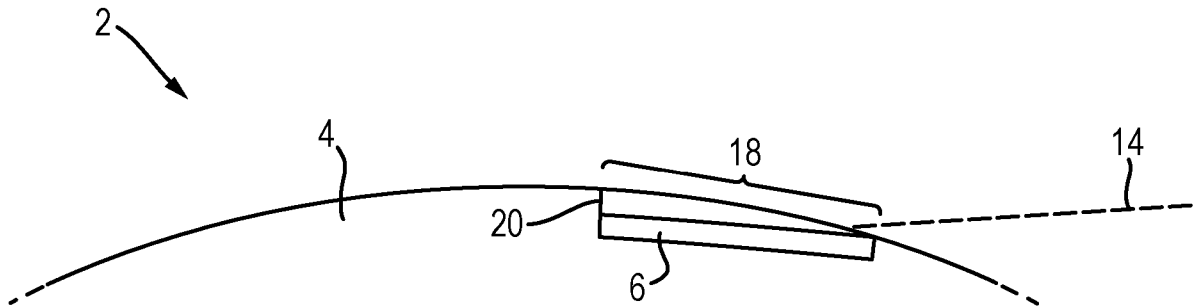


Fig. 4

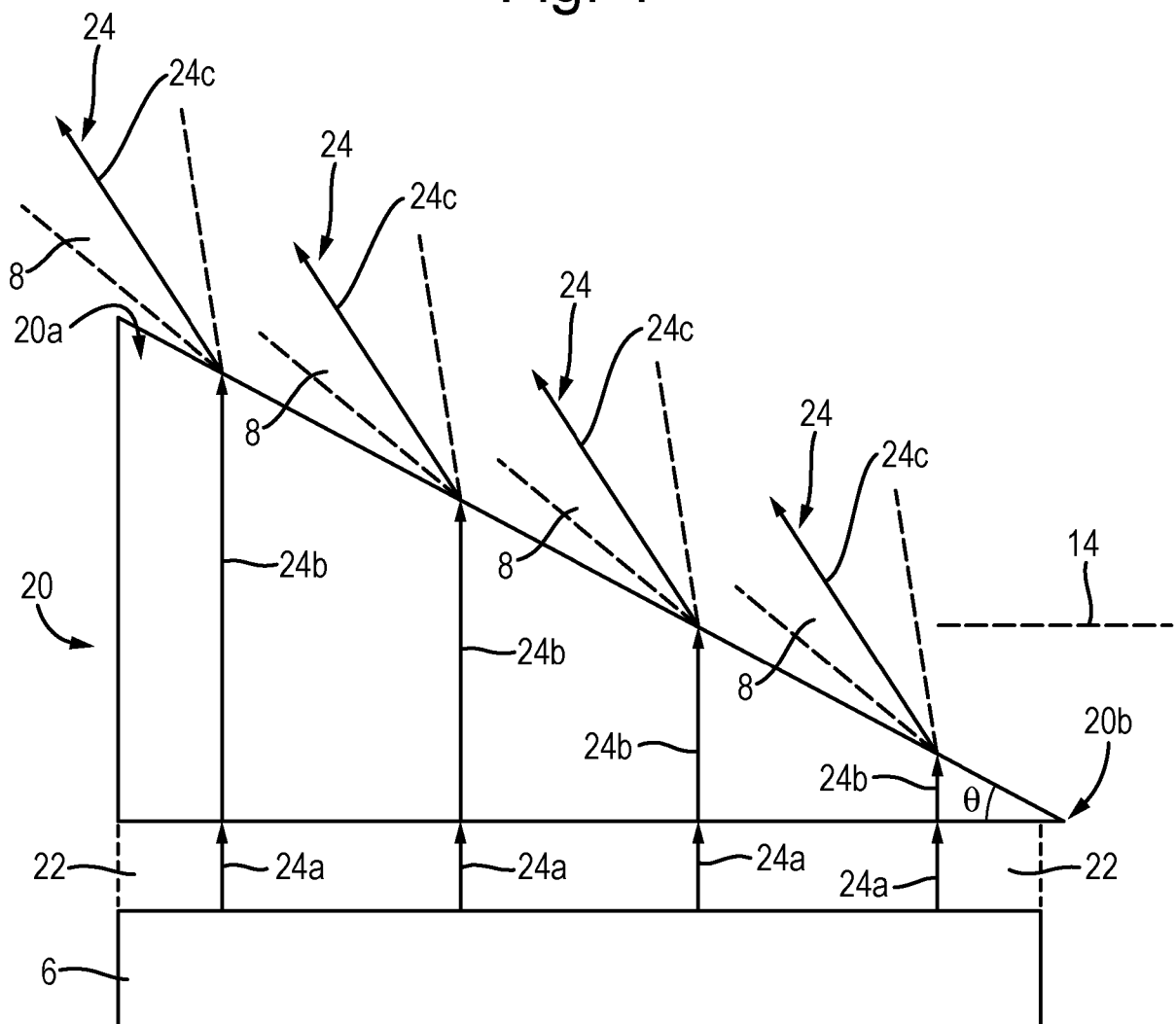
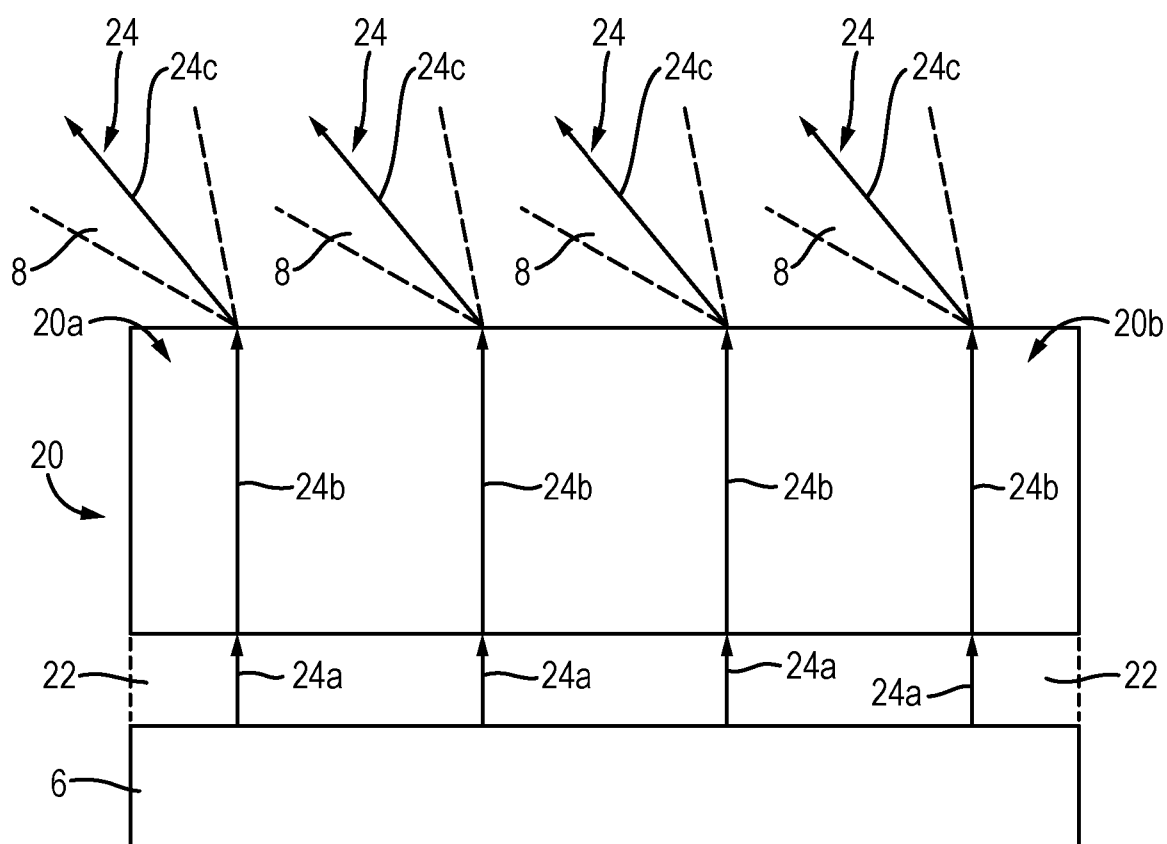


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/053252

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q1/28 H01Q15/00 H01Q19/06 H01Q21/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/285327 A1 (PASCHEN DEAN ALAN [US] ET AL) 13 December 2007 (2007-12-13)	1-4,7-22
Y	paragraph [0035] - paragraph [0054]; figures 1-5	5,6
Y	----- US 7 570 432 B1 (YONAK SERDAR H [US]) 4 August 2009 (2009-08-04) column 7, line 47 - column 8, line 50; figures 5A-5D	5,6
A	----- US 2005/264449 A1 (STRICKLAND PETER C [CA]) 1 December 2005 (2005-12-01) paragraph [0019] - paragraph [0027]; figures 1,2	1-23



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 January 2018

Date of mailing of the international search report

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Degraeve, Alexis

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2017/053252

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007285327 A1	13-12-2007	US 8068053 B1	29-11-2011
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		US 2006082516 A1	20-04-2006
		WO 2005119839 A2	15-12-2005
