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(54) **A RADOME ARRANGEMENT FOR A RADAR ANTENNA SYSTEM AND A METHOD FOR ITS MANUFACTURING**

(57) A radome arrangement (100) with variable permittivity for radar signals is disclosed. The arrangement comprises: a first radome wall (no) having a first artificial dielectric layer structure (111) with a first anisotropic permittivity for the radar signals; a second radome wall (120) having a second artificial dielectric layer structure (121) with a second anisotropic permittivity for the radar signals; and a support structure (200) configured to hold the first radome wall (110) and the second radome wall (120) as a combined radome structure (250), wherein the support structure (200) is further configured to move the first radome wall (110) relative to the second radome wall (120) to vary the permittivity of the combined radome structure (250) for the radar signals.

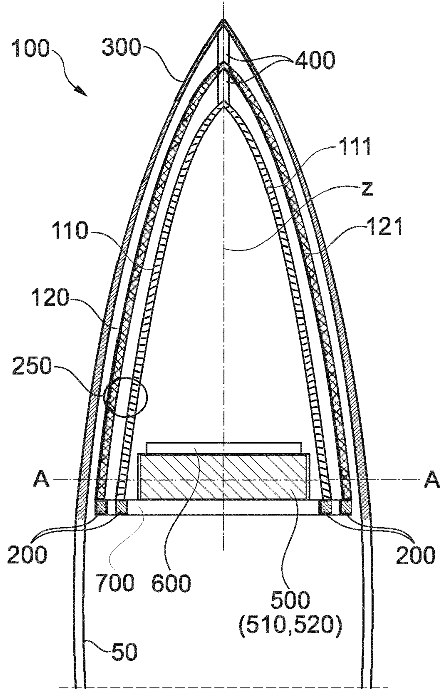

Fig. 1

EP 4 518 028 A1

Description

[0001] The present invention relates to a radome arrangement with variable permittivity for radar signals, a method for manufacturing the radome arrangement with variable permittivity for radar signals, and, in particular, to a tunable radome design.

BACKGROUND

[0002] There is an on-going effort for future applications to hinder high frequency radar detectability or to make it more difficult. This relates especially to radome-enclosed radar system, wherein the camouflage shall at the same time satisfy structural, environmental, and electrical and high-frequency requirements.

[0003] The methods used for the radome design is uniquely challenging because the radome materials and the radome wall construction affect the whole radome performance. Among the challenges to improve the radome design are for example to increase radio frequency, RF, transparency, low RF-observability, frequency selective surfaces, reduced weight, and improved structural efficiency.

[0004] One possible radome design is an electromagnetically active distribution of different materials inside the random structure, which can allow RF-radiation to pass only in certain frequency ranges and block other frequency ranges as well. However, this radome design protects mainly the internal components such as the antennas and, in case of a flying application, has an aerodynamic function.

[0005] Therefore, there is a demand for overcoming at least some of these limitations and to provide new designs for radome arrangements that change the RF radiation properties at least partially so that an antenna can still operate as desired, while it is undetectable by adversary parties.

SUMMARY OF THE INVENTION

[0006] At least some of the problems as described before are overcome by a radome arrangement according to claim 1 or a method for manufacturing a radome arrangement according to claim 13. The dependent claims refer to further advantageous realizations of the subject matters defined in the independent claims.

[0007] The present invention relates to a radome arrangement with variable permittivity for radar signals. The arrangement comprises: a first radome wall, a second radome wall, and a support structure. The first radome wall comprises a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals. The second radome wall comprises a second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals. The support structure is configured to hold the first radome wall and the second radome wall as a combined radome structure. The support structure is further configured to move the first radome wall relative to the second radome wall to vary a permittivity of the combined radome structure for the radar signals.

[0008] Optionally, the support structure is configured to move the first radome wall and the second radome wall in a predetermined distance. The value of predetermined distance may be selected with regard the permittivity of the radar signals. In other embodiments, the distance between the radome walls (e.g., the distance between the first radome and the second radome wall, and the distance between the second radome wall and possibly third radome wall or more walls) may be the same or not. In other embodiments, the support structure can move the first radome wall relative to the second radome wall to increase or decrease the distance between the first radome wall and the second radome wall (e.g., by axial movements of a circular symmetric dome).

[0009] Optionally, the radome arrangement further comprises an outer radome wall configured to enclose the first radome wall and the second radome wall and to provide environmental protection. According to embodiments, the outer radome wall can be part of the second radome wall if the first radome wall is formed inside the second radome wall. The outer radome wall may cover all inner radome walls (the first radome wall, the second radome wall, the third radome wall etc.). The outer radome wall may be configured to surround the inner radome walls completely and protect radiating antenna elements (e.g., a radar antenna system) from an external environment, such as erosion, rain, lightning strike, aerodynamic loads. The outer radome wall may also be robust against mechanical impact and may have high rain erosion resistance.

[0010] The outer radome wall may comprise a dielectric material having a positive refractive index. The outer radome wall may also comprise an artificial dielectric layer structure with positive refractive index or a different artificial dielectric layer structure with a negative refractive index. The outer radome wall and the inner radome walls may have a concentric arrangement. The radome arrangement may have a curved surface, a cylindrical shape, a spherical shape or a hemispherical shape or other shapes having an axial symmetry.

[0011] Optionally, the first artificial dielectric layer structure of the first radome wall comprises a first pattern with electrical performance extending in an axial direction and in an angular direction. Optionally, the second artificial dielectric layer structure of the second radome wall comprises a second pattern with electrical performance extending in the axial direction and in the angular direction. The first pattern with electrical performance and/or the second pattern with electrical performance may be formed by a plurality of metallic elements or other materials with electrical performance e.g., carbon, carbon-based materials, electrically conductive polymers, other compositions, or a combination thereof. In the following description these arrangements are sometimes named as metallic pattern. The term "electrical performance" refers to a characterization of materials in term of electrical parameters such as resistance, capacitance, inductance and can be tested by electrical measurements.

[0012] Optionally, the first pattern and/or the second pattern are characterized by at least one of the following:

- the first pattern and/or the second pattern are periodic with a same or different periodicity in one or both directions of the combined radome structure,
- the first pattern and/or the second pattern comprise inhomogeneities along one or both directions of the combined radome structure,
- the first pattern and/or the second pattern are homogeneous in one or both directions of the combined radome structure,
- the first pattern and/or the second pattern comprise different or variable gaps between the metallic elements in one or both directions to the combined radome structure,
- the metallic elements forming the first pattern and/or the second pattern comprise different or variable sizes or shapes in one or both directions to the combined radome structure.

[0013] Optionally, the elements forming the first pattern and/or forming the second pattern are separated by dielectric material. Optionally, the elements forming the first pattern and/or forming the second pattern have at least one of the following forms: polygon forms, rectangular forms, quadratic form, circular forms, oval forms.

[0014] Optionally, the first pattern form one more layers in or on the first radome wall. Optionally, the second pattern form one more layers in or on the second radome wall. For example, patterns may be formed as metallization on both surfaces of the respective walls or may be embedded as a layer stack inside the respective walls. The wall material holding the metallic structures may be a dielectric material so that the radome walls form a metamaterial.

[0015] Optionally, the radome arrangement further comprises a controller configured to control the support structure to rotate or to move (e.g., in the axial direction) the first radome wall and/or the second radome wall independently of each other. For example, the controller may be configured to control the support structure to move the first radome wall and/or the second radome wall clockwise or anti-clockwise. For example, by rotating the inner radome walls relative to the second radome wall, it is possible to provide window portions and blocking (e.g., masking) portions of the radar signals. For example, the window portion can allow specific permittivity to specific areas of the radome arrangement to be transparent to the electromagnetic radiation. For example, the blocking portion can prevent specific permittivity to specific areas of the radome arrangement to be non-transparent to the electromagnetic radiation. Additionally or alternatively, the first radome wall and/or the second radome wall can be rotated together.

[0016] In accordance with these rotations at least one of the following is achieved:

- the permittivity of the combined radome structure is adjusted to pass the radar signals in controllable regions (e.g., only there),
- the permittivity of the combined radome structure is adjusted to block the radar signals from other controllable regions (e.g., only there),
- the permittivity of the combined radome structure is adjusted to pass the radar signals in controllable frequency ranges,
- the permittivity of the combined radome structure is adjusted to block the radar signals in other controllable frequency ranges.

[0017] Therefore, the radome wall(s) may have an inner surface and an outer surface with variable permittivity with respect to frequencies and/or directions of radar signals. Furthermore, the radome wall(s) with the artificial dielectric layer structure may have a frequency selective surface. The frequency selective surface can be for example a layer or a coating applied to the inner surface and/or to the outer surface of the radome wall. For example, the frequency selective surface of the radome wall can either transmit or reflect electromagnetic waves. In other embodiments, the material of the frequency selective surface can be arranged on the inner surface of the radome wall, mixed with the composite of the radome wall or embedded within the radome wall.

[0018] Therefore, the combined radome structure may be configured to pass the radar signals in predetermined frequency ranges, after the support structure moves the first radome wall and the second radome wall to the predefined position. The combined radome structure may also be configured to reject or block the radar signals in different predetermined frequency ranges, after the support structure moved the first radome wall and the second radome wall to another or the same predefined position.

[0019] Optionally, the radome arrangement comprises a network of inner radome walls having multiple inner radome walls enclosed by the outer radome wall, wherein first radome wall and the second radome wall as defined before can be any two inner radome walls within the network of inner radome walls. Thus, the radome arrangement can comprise more than two radome walls. For example, a third radome wall, a fourth first radome wall, a fifth first radome, etc. may be formed together the first and second radome walls.

[0020] According to embodiments, the random wall(s) can be a compact (e.g., monolithically) comprising a single type of artificial dielectric material. Furthermore, the radome wall(s) can also have multilayer wall construction (e.g., sandwich structure), wherein the multilayer wall construction comprises at least three layers, which differ in the dielectric constant. For example, the multilayer wall construction may have an odd number of high-density layers and an even number of low-density layers, wherein the dielectric constant of the high-density layer is less than the dielectric constant of the low-density layer.

[0021] Embodiments relate further to a tunable radar system with a radome arrangement as defined before and an array of radar antenna elements located inside the combined radome structure.

[0022] Optionally, the tunable radar system further comprises a mounting structure configured to rotatably support the array of radar antenna elements. The mounting structure and the support structure may be controllable to move the first radome wall and/or the second radome wall simultaneously together with a rotation of the array of radar antenna elements. For example, the controller of the radome arrangement may be in communication with a respective controller of mounting structure to ensure the combined radome structure allows a transmission of the radar signals in the current viewing direction of the array of radar antenna elements. For example, the moving caused by support structure can follow the rotation of the radar antenna elements. In addition, the mounting structure can provide rotations about multiple rotation axes (e.g., by motor-rotatable rings). For example, the mounting structure may comprise a gimbal or multiple rotatable rings to allow independent rotations about all three rotational axes.

[0023] Optionally, the array of radar antenna elements comprises at least one of the following:

- transmitting antennas configured to transmit the radar signals through the radome arrangement;
- receiving antennas configured to receive the radar signals through the radome arrangement;
- an antenna aperture adapted to perform both receive function and transmit function of the radar signals as synthetic aperture.

[0024] Further embodiments relate a method for manufacturing a radome arrangement with variable permittivity for radar signals. The method comprises at least one of the following steps:

- providing a first radome wall having a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals;
- providing a second radome wall having a second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals;
- providing a support structure configured to hold the first radome wall and the second radome wall as a combined radome structure and to move the first radome wall relative to the second radome wall to vary the permittivity of the combined radome structure for the radar signals.

[0025] In addition, further embodiments relate to a method of controlling the support structure, or a method to operate the radome arrangement to vary a permittivity of the radome for RF signals. These methods may also be implemented in software or as a computer program product. Embodiments of the present invention can, in particular, be implemented by software or a software module in the control unit. Therefore, embodiment relate also to a computer program having a program code for performing the method(s), when the computer program is executed on a processor. In addition, embodiments may also relate to computer-readable storage device having a software that is stored thereon and is designed to operate the controller to control the support structure as claimed in claim, when the computer program is executed on a processor.

[0026] When compared to conventional systems, embodiments of the present radome arrangement provide the following advantages. The disclosed radome arrangement is able to vary the permittivity of the combined radome structure for the radar signals or other RF signals by moving at least one inner radome wall relative to at least one other radome wall. Therefore, embodiments of the present invention can particularly be used for such radome-enclosed radar systems that can be tuned by rotating or axially moving the radome walls.

[0027] In particular, concentrically mounted radome walls are made possible to optimize the high frequency function of the tunable radome-enclosed radar systems. The high frequency band radar may be particularly important for example in long-range target monitoring, airborne early warning, or anti-stealth detection.

[0028] This provides the advantages that the embodiments of the radome arrangement can be for use on flight vehicles (e.g., aircraft, missiles), surface vehicles and fixed ground installations. For example, the radome arrangement according to an embodiment is mounted on the top of an aircraft.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Some embodiments of the present invention will be described in the following by way of examples only, and with respect to the accompanying figures, in which:

Fig. 1 shows a schematic arrangement of a tunable radome arrangement according to an embodiment;

Fig. 2 shows a cross-sectional view of the tunable radome arrangement according to an embodiment;

Fig. 3 shows a schematic view of the first radome wall having an artificial dielectric layer structure and the second radome wall having a second artificial dielectric layer structure, and the distance between the first radome wall and the second radome wall according to another embodiment;

Fig. 4 shows a cross-sectional view of the radome wall having an artificial dielectric layer structure according to an embodiment;

Fig. 5 shows a flow diagram of a method for manufacturing a tunable radome with artificial dielectric layer structure.

DETAILED DESCRIPTION

[0030] Various examples will now be described more fully with reference to the accompanying drawings in which some examples are illustrated.

[0031] Accordingly, while examples are capable of various modifications and alternative forms, the illustrative examples in the figures will herein be described in detail. It should be understood, however, that there is no intent to limit examples to the particular forms disclosed, but on the contrary, examples are to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure. Like numbers refer to like or similar elements throughout the description of the figures.

[0032] It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.).

[0033] The terminology used herein is for the purpose of describing illustrative examples only and is not intended to be limiting. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes" and/or "including," when used herein, specify the presence of stated features, steps, operations, elements and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components and/or groups thereof.

[0034] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which examples belong. It will be further understood that terms, e.g., those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0035] Fig. 1 shows a schematic arrangement of a tunable radome arrangement 100 with variable permittivity for radar signals according to an embodiment, and further shows a cutting plane line of the radome arrangement 100 defined as view A-A.

[0036] The radome arrangement 100 comprises a first radome wall no having a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals. The radome arrangement 100 further comprises a second radome wall 120 having a second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals. The radome arrangement 100 further comprises a support structure 200 configured to hold the first radome wall 110 and the second radome wall 120 as a combined radome structure 250. The support structure 200 is further configured to move the first radome wall 110 relative to the second radome wall 120 to vary the permittivity of the combined radome structure 250 for the radar signals.

[0037] It is understood that the number of the radome walls in not limited to two, the radome arrangement 100 can have more than two inner radome walls (e.g., a third radome wall 130, a fourth radome wall 140 ...). The inner radome walls may be arranged on top of each other.

[0038] The artificial dielectric layer structure of the first radome wall 110 and the second radome wall 120 can be for example a metamaterial. For example, the metamaterial can be a composite material that exhibits a negative index of refraction. The advantage of using metamaterials for the artificial dielectric layer structure is that the combined radome structure 250 is transparent to frequencies in the high frequency band.

[0039] As the electromagnetic wave (e.g., radar signals) propagates through a conventional radome wall a loss or a reduction in signal strength may occur. Part of the signal loss may occur as a reflection at the air/conventional radome wall interface. Other part of the signal loss may occur from dissipation within the dielectric layers of the radome wall. The reflected electromagnetic wave on the inner surface of the radome wall may bounce between the opposite sides of the radome walls. For example, the radome arrangement 100 according to the embodiments may be made up of artificial dielectric layer structures (e.g., metamaterials) that may minimally degrade the electrical performance of the enclosed radome arrangement 100, and may reduce the signal loss or increase the signal strength.

[0040] For example, the first artificial dielectric layer structure of the first radome wall 110 may comprise a first pattern 111 extending in an axial direction, z and in an angular direction, a, and the second artificial dielectric layer structure of the second radome wall 120 may comprise a second pattern 121 extending in the axial direction, z, and in the angular direction, a. The patterns 111, 121 may be formed by a plurality of metallic elements and/or can be other materials with electrical performance.

[0041] For example, the plurality of metallic elements of the artificial dielectric layer structure may be a dielectric resonator (e.g., metal plates), wherein the dielectric resonator is a metamaterial. For example, the tuning of the dielectric resonators (e.g., metamaterial) can be achieved by applying an electric field of different strengths.

[0042] The radome arrangement 100 may further comprise an outer radome wall 300. The outer radome wall 300 may be configured to enclose the first radome wall 110 and the second radome wall 120, or other inner radome walls (130, 140, 150 ...) and protect the inner componets of the radome arrangement 100 from an external environment. For example, the outer radome wall 300 and/or the inner radome walls (110, 120, 130, ...) are held with bearings 400. For example, the bearings 400 are structural members of the radome arrangement 100 and may be rotational bearings.

[0043] The radome arrangement 100 may further comprises an array of radar antenna elements 500 located inside the combined radome structure 250.

[0044] The tunable radar system 100 may further comprise a mounting structure 700 coupled to the array of radar antenna elements 500 and to the combined radome structure 250. The mounting structure 700 may be configured to rotate simultaneously together the array of radar antenna elements 500 with the combined radome structure 250. Likewise, the support structure 200 may be configured to rotate simultaneously together the first radome wall 110 and/or the second radome wall 120 with a rotation of the array of radar antenna elements 500 caused by the mounting structure 700.

[0045] In embodiments, the mounting structure 700 can be placed on rails, skids, rollers, hydraulic jacks or other moving or rotating mechanisms like motor-rotatable rings. The support structure 200 can be configured to initiate a movement of the first and/or the second radome wall 110, 120 at the same time as the mounting structure 700 moves or rotates the array of radar antenna elements 500 or with a predefined delayed.

[0046] The array of radar antenna elements 500 may comprise transmitting antennas 510 for transmitting radar signals through the radome arrangement 100, receiving antennas 520 for receiving radar signals through the radome arrangement 100, and an antenna aperture 600. The antenna aperture 600 may be adapted to perform the receive function and the transmit function at high frequency band.

[0047] For example, the array of radar antenna elements 500 can be located at the base center of the radome arrangement 100. In other embodiments, the array of radar antenna elements 500 may be asymmetrically located at the base of the radome arrangement 100. For example, the radome arrangement 100 may be mounted on the top of an aircraft 50.

[0048] **Fig. 2** shows a section view of the tunable radome arrangement 100 according to an embodiment, which is defined as view A-A on **Fig. 1.**

[0049] The second radome wall 120 with the second artificial dielectric layer structure can superimpose on the first radome wall 110 with the first artificial dielectric layer structure. Likewise, the outer radome wall 300 can also superimpose on the second radome wall 120 and on the first radome wall 110.

[0050] It is understood that the radome walls did not provide the high-frequency function on their own, separately from each other. At least two superimposed inner radome walls have together artificial dielectric layer function and the properties of the array of radar antenna elements 500 or the e-scan radar system can be adjusted by moving (e.g., rotating) the inner radome walls (e.g., first radome wall 110, second radome wall 120, third radome wall 130, ...) relative to each other. Therefore, at one inner radome wall may be placed on another inner radome wall and held by bearings 400.

[0051] The rotation of the first radome no wall and/or the second radome wall 120 can influence the properties (e.g., permittivity) of the radome arrangement 100 positively or negatively.

[0052] It is understood that the number of the radome walls in not limited to two, the radome arrangement 100 can have multiple number of inner radome walls arranged on top of each other (e.g., a network of inner radome walls).

[0053] A conventional radome-enclosed radar system can have a range of $\pm$60 degree, with the high performance generated at 60 degree. In contrast, the superimposed radome walls of the radome arrangement 100 having a negative refractive index of a metamaterial as artificial dielectric layer structure with metallic pattern (111, 121, ...) can generate such an artificial dielectric layer structure that extremely increase the swivel angle of the tunable radome-enclosed radar system with such a geometry as shown on **Fig. 2.**

[0054] The radome arrangement 100 having radome walls (110, 120, 130, ...) that rotate relative to each other may influence the tunable radome-enclosed radar system and the e-scan radar (500, 510, 520) characteristics, and it may improve the radiating properties by increasing the swivel angles.

[0055] In one embodiment, the support structure 200 may actuate (e.g., move) only one radome wall (e.g., first radome wall 110) to a predefined position. The second radome wall 120 or the other radome walls (130, 140, ...) remain stationary while the first radome wall 110 is rotated to a new position. Then as a next step, the support structure 200 may move another radome wall (e.g., the second radome wall 120) to a predefined position. Therefore, the first radome wall 110 or the other radome walls (130, 140, ...) remain stationary while the second radome wall 120 is rotated to a new position.

[0056] In other embodiments, the support structure 200 may move the inner radome walls simultaneously, therefore all the inner radome walls may be rotated with a predefined degree to a predefined position.

[0057] Therefore, at a certain position rearranged radome walls it is provided a predefined bandpass performance. Meanwhile, at the same position of the radome walls, it is provided a predefined band reject performance.

[0058] **Fig. 3** shows a schematic view of the first radome wall 110 having an artificial dielectric layer structure with the first pattern 110 and the second radome wall 120 having a second artificial dielectric layer structure with the second pattern 121, and the distance d between the first radome wall 110 and the second radome wall 120 according to another embodiment.

[0059] For example, the first pattern 111 can be a first partly metallized pattern. The second pattern 121 can also be a second partly metallized pattern. The first partly metallized pattern may be different from the second partly metallized pattern.

[0060] The support structure 200 may be configured to hold in a distance d the first radome wall 110 and the second radome wall 120. The distance itself could be also part of the RF functionality as the space is filled with air or a medium with dedicated RF performance e.g.

[0061] **Fig. 4** shows a cross-sectional view of a radome wall having an artificial dielectric layer structure according to an embodiment.

[0062] At a specific radome arrangement 100, the permittivity for radar signals is completely blocked (e.g., shielding effect), and at the same time at a different position, the permittivity for radar signals is unblocked (area of regard). For example, the radome arrangement 100 may have low radio frequency observability.

[0063] The support structure 200 can be configured to hold the combined radome structure 250 in a predefined position. In addition, the combined radome structure 250 can be configured to pass the radar signals in predetermined frequency ranges 102 and/or controllable regions 101, after the support structure 200 moved the first radome wall 110 and the second radome wall 120 to the predefined position. Likewise, the combined radome structure 250 can be configured to reject the radar signal in other controllable regions 103 and/or predetermined frequency ranges 104, after the support structure 200 moved the first radome wall 110 and the second radome wall 120 to the predefined position.

[0064] For example, a controller may be configured to control the support structure 200 to rotate or to move the first radome wall 110 and the second radome wall 120 independently of each other, or to rotate together the first radome wall 110 and the second radome wall 120.

[0065] For example, the array of radar antenna elements 500 (e.g., with the e-scan radar) can remain undetected from a pre-determined direction while at the same time can still continue to scan the surrounding from another pre-determined direction.

[0066] For example, the radome arrangement 100 can be suitable for vehicular radome-enclosed radar systems, airborne radome-enclosed radar systems, or terrestrial radome-enclosed radar systems, wherein the e-scan radar system 500 is a key component of the tunable radome-enclosed radar system.

[0067] In addition, the tunable radome-enclosed radar system may find applications in technology areas that include, but are not limited to, satellite navigation and communications, telecommunications, and avionics.

[0068] For example, the radome arrangement 100 may provide one or more bandpass performances at a predefined frequency range 102. For example, the radome arrangement 100 may also provide one or more band reject performances at another predefined frequency range 104.

[0069] Therefore, the radome arrangement 100 is either reflect or transmit electromagnetic waves with one or more predefined frequency ranges 102, 104. The radome arrangement 100 may be configured to provide multiple bandpass and multiple band reject frequency selective performance.

[0070] **Fig. 5** shows a flow diagram of a method for manufacturing a tunable radome arrangement 100 with variable permittivity for radar signals. The method comprises the steps of:

- providing Sno a first radome wall no having a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals;
- providing S120 a second radome wall 120 having a second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals; and
- providing S130 a support structure 200 configured to hold the first radome wall 110 and the second radome wall 120 as a combined radome structure 250, wherein the support structure 200 is further configured to move the first radome wall 110 relative to the second radome wall 120 to vary the permittivity of the combined radome structure 200 for the radar signals.

[0071] In comparison to conventional systems, embodiments provide the following advantages:

- increase the antenna gain;
- reduce the maximum transmission loss;
- reduce the loss and distortion of the radiation pattern;
- reduce the beamwidth;
- reduce the antenna sidelobe-level degradation;
- minimizing the effects of sidelobe degradation;
- minimizing the boresight error;
- minimizing the boresight error slope.

[0072] This advantageous effect can be achieved by building the tunable radome arrangement 100 having rotatable inner radome walls (110, 120, 130, ...) with metallic patterns (111, 121, 131, ...) having electrical performances and providing window portions and blocking portions of the radar signals at controllable frequency ranges (102, 104, 106...) and/or controllable regions (101, 103, 105, ...) to improve the performance of the tunable radome-enclosed radar system.

[0073] In addition, the radome arrangement 100 may comprise a network of inner radome walls having multiple inner radome walls enclosed by the outer radome wall 300. The first radome wall 110 and the second radome wall 120 are any two inner radome walls within the network of inner radome walls.

[0074] The description and drawings merely illustrate the principles of the disclosure. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the disclosure and are included within its scope.

[0075] Furthermore, while each embodiment may stand on its own as a separate example, it is to be noted that in other embodiments the defined features can be combined differently, i.e. a particular feature described in one embodiment may also be realized in other embodiments. Such combinations are covered by the disclosure herein, unless it is stated that a specific combination is not intended.

List of reference signs

[0076]

100	radome arrangement
101, 103	controllable regions
102, 104	controllable frequency ranges
110	first radome wall
111	first pattern
120	second radome wall
121	second pattern
200	support structure
250	combined radome structure
300	outer radome wall
400	bearings
50	aircraft
500	array of radar antenna elements (e-scan radar system)
510	transmitting antennas (e.g., e-scan radar)
520	receiving antennas (e.g., e-scan radar)
600	antenna aperture
700	mounting structure
a	angular direction
d	distance
z	axial direction

Claims

1. A radome arrangement (100) with variable permittivity for radar signals, the arrangement comprising:

a first radome wall (110) having a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals;
a second radome wall (120) having a second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals; and
a support structure (200) configured to hold the first radome wall (110) and the second radome wall (120) as a combined radome structure (250),
wherein the support structure (200) is further configured to move the first radome wall (110) relative to the second radome wall (120) to vary a permittivity of the combined radome structure (250) for the radar signals.

2. The radome arrangement (100) according to claim 1, wherein the support structure (200) is configured to hold the first radome wall (110) and the second radome wall (120) in a predetermined distance (d).

3. The radome arrangement (100) according to claim 1 or claim 2, further comprising an outer radome wall (300) configured to enclose the first radome wall (110) and the second radome wall (120) and to provide environmental protection.

4. The radome arrangement (100) according to one of the preceding claims,
wherein

the first artificial dielectric layer structure of the first radome wall (110) comprises a first pattern (111) with electrical performance extending in an axial direction (z) and in an angular direction (a), and
the second artificial dielectric layer structure of the second radome wall (120) comprises a second pattern (121) with electrical performance extending in the axial direction (z) and in the angular direction (a),
wherein the patterns (111, 121) with electrical performances are formed by a plurality of metallic elements.

5. The radome arrangement (100) according to claim 4, wherein the metallic elements forming the first pattern (111) and/or the second pattern (121) are separated by dielectric material and have at least one of the following forms: polygon forms, rectangular forms, quadratic form, circular forms, oval forms.

6. The radome arrangement (100) according to claim 4 or claim 5, wherein at least one of the first pattern (111) and the second pattern (121) are **characterized by** at least one of the following:

- the first pattern (111) and the second pattern (121) are periodic with a same or different periodicity in one or both directions to the combined radome structure (250),
- the first pattern (111) and the second pattern (121) comprise inhomogeneities along one or both directions of combined radome structure (250),
- the first pattern (111) and the second pattern (121) are homogeneous in one or both directions to the combined radome structure (250),

- the first pattern (111) and the second pattern (121) comprise different or variable gaps between the metallic elements in one or both directions to the combined radome structure (250),
- the metallic elements forming the first pattern (111) and the second pattern (121) comprise different or variable sizes or shapes in one or both directions to the combined radome structure (250).

7. The radome arrangement (100) according to any of claims 4 to 6, wherein

the first pattern (111) form one more layers in or on the first radome wall (no), and/or
the second pattern (121) form one more layers in or on the second radome wall (120).

8. The radome arrangement (100) according to one of the preceding claims, further comprising a controller configured to control the support structure (200) to rotate or to move the first radome wall (110) and the second radome wall (120) independently of each other, or to rotate together the first radome wall (110) and the second radome wall (120) to achieve at least one of the following:

- to adjust the permittivity of the combined radome structure (250) to pass the radar signals in controllable regions (101),
- to adjust the permittivity of the combined radome structure (250) to block the radar signals from other controllable regions (103),
- to adjust the permittivity of the combined radome structure (250) to pass the radar signals in controllable frequency ranges (102),
- to adjust the permittivity of the combined radome structure (250) to block the radar signals in other controllable frequency ranges (104).

9. The radome arrangement (100) according to one of the preceding claims further comprising a network of inner radome walls having multiple inner radome walls enclosed by the outer radome wall (300), wherein first radome wall (110) and the second radome wall (120) are any two inner radome walls within the network of inner radome walls.

10. A tunable radar system including:

a radome arrangement (100) according to any of the claims 1 to 9; and
an array of radar antenna elements (500) located inside the combined radome structure (250).

11. The tunable radar system according to claim 10 further comprising:

a mounting structure (700) configured to rotatably support the array of radar antenna elements (500),
wherein the mounting structure (700) and the support structure (200) are controllable to move at least one of the first radome wall (110) and the second radome wall (120) simultaneously together with a rotation of the array of radar antenna elements (500).

12. The tunable radar system according to claim 10, wherein the array of radar antenna elements (500) comprising at least one of the following:

- transmitting antennas (510) configured to transmit the radar signals through the radome arrangement;
- receiving antennas (520) configured to receive the radar signals through the radome arrangement;
- an antenna aperture (600) adapted to perform both receive function and transmit function of the radar signals as synthetic aperture.

13. A method for manufacturing a radome arrangement (100) with variable permittivity for radar signals, the method comprising at least one of the following steps:

- providing (S110) a first radome wall (110) having a first artificial dielectric layer structure (111) with a first anisotropic permittivity for the radar signals;
- providing (S120) a second radome wall (120) having a second artificial dielectric layer structure (121) with a second anisotropic permittivity for the radar signals; and
- providing (S130) a support structure (200) configured to hold the first radome wall (110) and the second radome wall (120) as a combined radome structure (250) and to move the first radome wall (110) relative to the second radome wall (120) to vary the permittivity of the combined radome structure (250) for the radar signals.

14. A computer-readable storage device having a software that is stored thereon and is designed to operate the controller to control the support structure (200) as claimed in claim 8, when the computer program is executed on a processor.

Amended claims in accordance with Rule 137(2) EPC.

1. A radome arrangement (100) with variable permittivity for radar signals, the arrangement comprising:

a first radome wall (110) having a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals;
a second radome wall (120) having a second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals;
a support structure (200) configured to hold the first radome wall (110) and the second radome wall (120) as a combined radome structure (250); and
a network of inner radome walls having multiple inner radome walls,
wherein the support structure (200) is further configured to move the first radome wall (110) relative to the second radome wall (120) to vary a permittivity of the combined radome structure (250) for the radar signals,
wherein the first radome wall (110) and the second radome wall (120) are any two inner radome walls within the network of inner radome walls.

2. The radome arrangement (100) according to claim 1, wherein the support structure (200) is configured to hold the first radome wall (110) and the second radome wall (120) in a predetermined distance (d).

3. The radome arrangement (100) according to claim 1 or claim 2, further comprising an outer radome wall (300) configured to enclose the first radome wall (110) and the second radome wall (120) and to provide environmental protection.

4. The radome arrangement (100) according to one of the preceding claims, wherein

the first artificial dielectric layer structure of the first radome wall (110) comprises a first pattern (111) with electrical performance extending in an axial direction (z) and in an angular direction (a), and
the second artificial dielectric layer structure of the second radome wall (120) comprises a second pattern (121) with electrical performance extending in the axial direction (z) and in the angular direction (a),
wherein the patterns (111, 121) with electrical performances are formed by a plurality of metallic elements.

5. The radome arrangement (100) according to claim 4, wherein the metallic elements forming the first pattern (111) and/or the second pattern (121) are separated by dielectric material and have at least one of the following forms: polygon forms, rectangular forms, quadratic form, circular forms, oval forms.

6. The radome arrangement (100) according to claim 4 or claim 5, wherein at least one of the first pattern (111) and the second pattern (121) are **characterized by** at least one of the following:

- the first pattern (111) and the second pattern (121) are periodic with a same or different periodicity in one or both directions to the combined radome structure (250),
- the first pattern (111) and the second pattern (121) comprise inhomogeneities along one or both directions of combined radome structure (250),
- the first pattern (111) and the second pattern (121) are homogeneous in one or both directions to the combined radome structure (250),
- the first pattern (111) and the second pattern (121) comprise different or variable gaps between the metallic elements in one or both directions to the combined radome structure (250),
- the metallic elements forming the first pattern (111) and the second pattern (121) comprise different or variable sizes or shapes in one or both directions to the combined radome structure (250).

7. The radome arrangement (100) according to any of claims 4 to 6, wherein

the first pattern (111) form one more layers in or on the first radome wall (110), and/or
the second pattern (121) form one more layers in or on the second radome wall (120).

8. The radome arrangement (100) according to one of the preceding claims, further comprising a controller configured to control the support structure (200) to rotate or to move the first radome wall (110) and the second radome wall (120) independently of each other, or to rotate together the first radome wall (110) and the second radome wall (120) to achieve at least one of the following:

- to adjust the permittivity of the combined radome structure (250) to pass the radar signals in controllable regions (101),
- to adjust the permittivity of the combined radome structure (250) to block the radar signals from other controllable regions (103),
- to adjust the permittivity of the combined radome structure (250) to pass the radar signals in controllable frequency ranges (102),
- to adjust the permittivity of the combined radome structure (250) to block the radar signals in other controllable frequency ranges (104).

9. The radome arrangement (100) according to one of the preceding claims, wherein the network of inner radome walls having multiple inner radome walls are enclosed by the outer radome wall (300).

10. A tunable radar system including:

a radome arrangement (100) according to any of the claims 1 to 9; and
an array of radar antenna elements (500) located inside the combined radome structure (250).

11. The tunable radar system according to claim 10 further comprising:

a mounting structure (700) configured to rotatably support the array of radar antenna elements (500),
wherein the mounting structure (700) and the support structure (200) are controllable to move at least one of the first radome wall (110) and the second radome wall (120) simultaneously together with a rotation of the array of radar antenna elements (500).

12. The tunable radar system according to claim 10, wherein the array of radar antenna elements (500) comprising at least one of the following:

- transmitting antennas (510) configured to transmit the radar signals through the radome arrangement;
- receiving antennas (520) configured to receive the radar signals through the radome arrangement;
- an antenna aperture (600) adapted to perform both receive function and transmit function of the radar signals as synthetic aperture.

13. A method for manufacturing a radome arrangement (100) with variable permittivity for radar signals, the method comprising at least one of the following steps:

- providing (Sno) a first radome wall (110) having a first artificial dielectric layer structure (111) with a first anisotropic permittivity for the radar signals;
- providing (S120) a second radome wall (120) having a second artificial dielectric layer structure (121) with a second anisotropic permittivity for the radar signals; and
- providing (S130) a support structure (200) configured to hold the first radome wall (110) and the second radome wall (120) as a combined radome structure (250) and to move the first radome wall (110) relative to the second radome wall (120) to vary the permittivity of the combined radome structure (250) for the radar signals,
- providing a network of inner radome walls having multiple inner radome walls,

wherein the first radome wall (110) and the second radome wall (120) are any two inner radome walls within the network of inner radome walls.

14. A computer-readable storage device having a software that is stored thereon and is designed to operate the controller to control the support structure (200) as claimed in claim 8, when the computer program is executed on a processor.

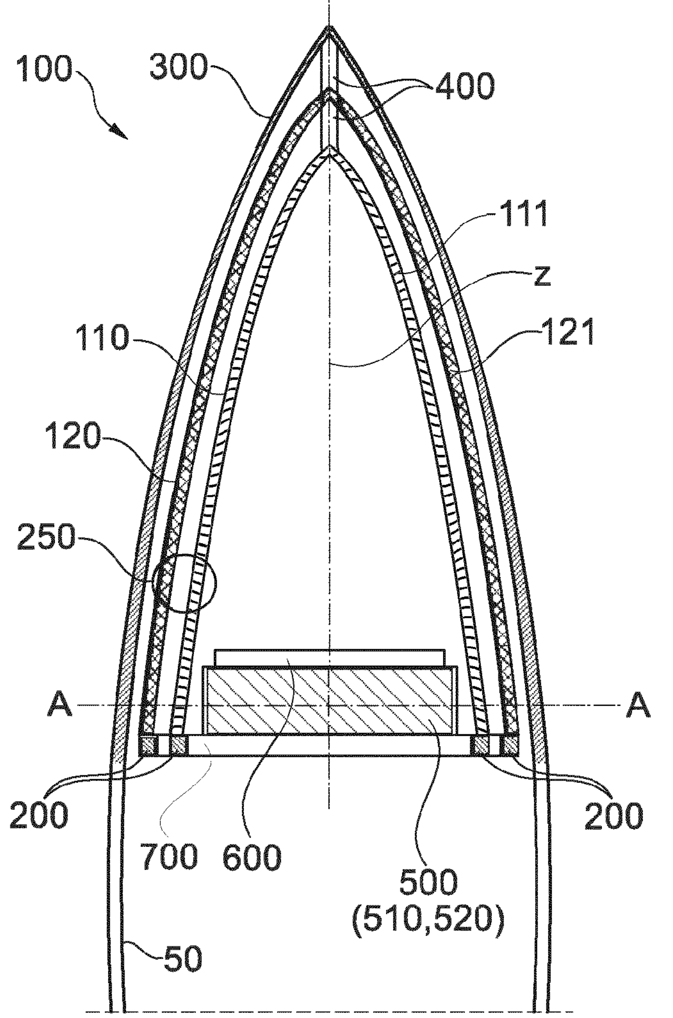
100
300
400
111
z
121
110
120
250
A
A
200
200
700
600
500
(510,520)
50

Fig. 1

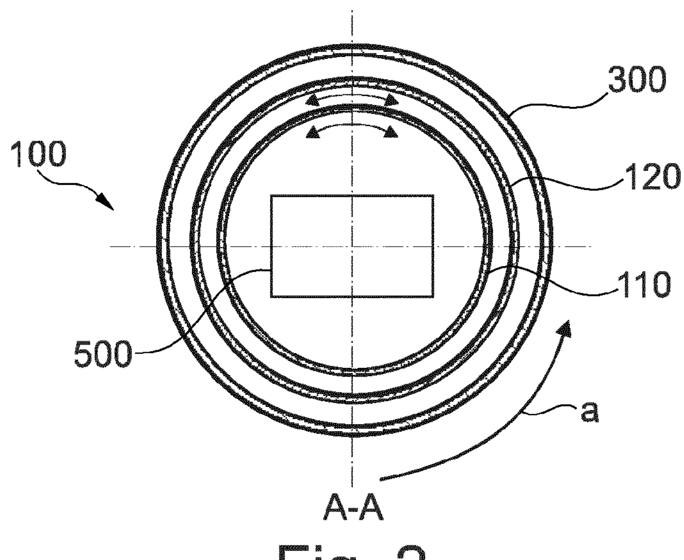
300
100
120
110
500
a
A-A

Fig. 2

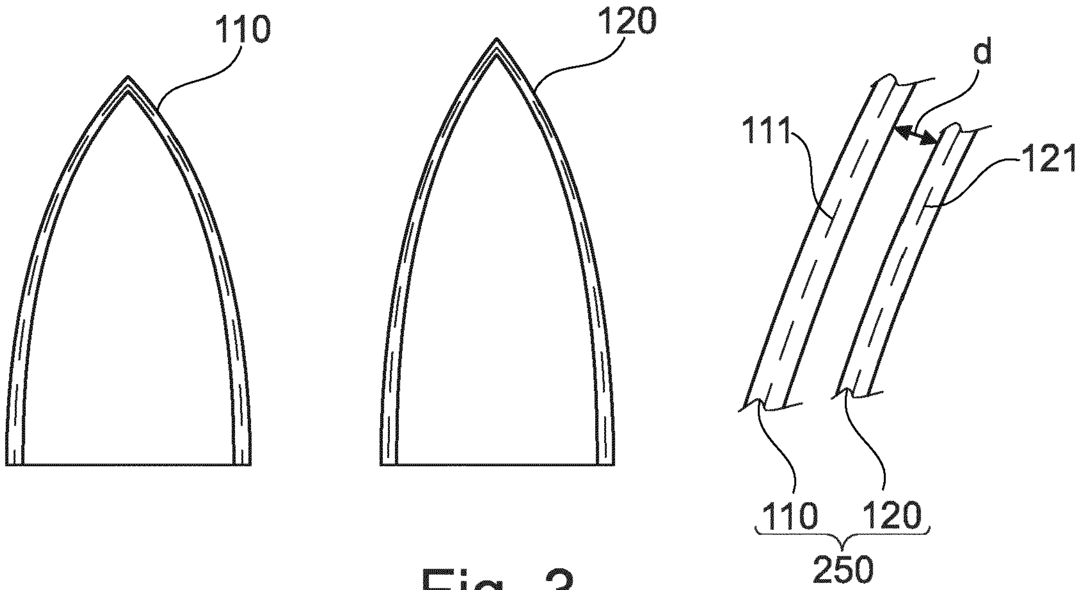

Fig. 3

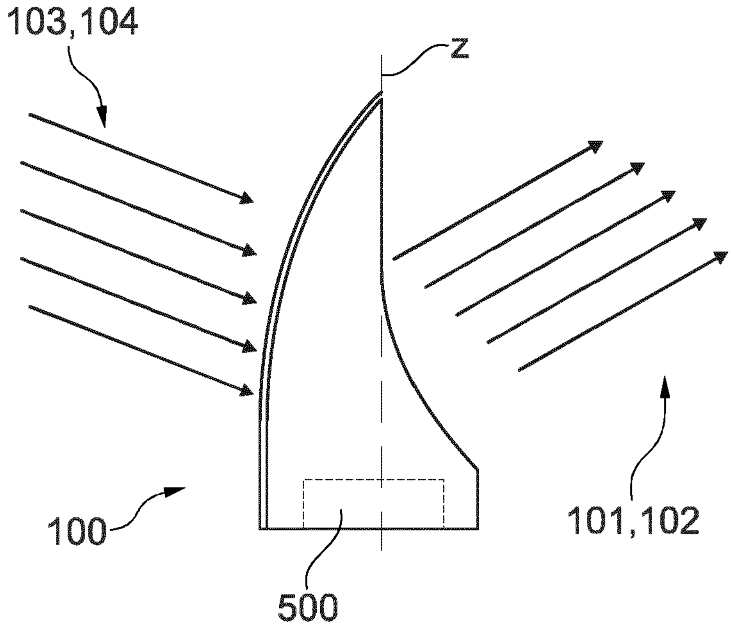

Fig. 4

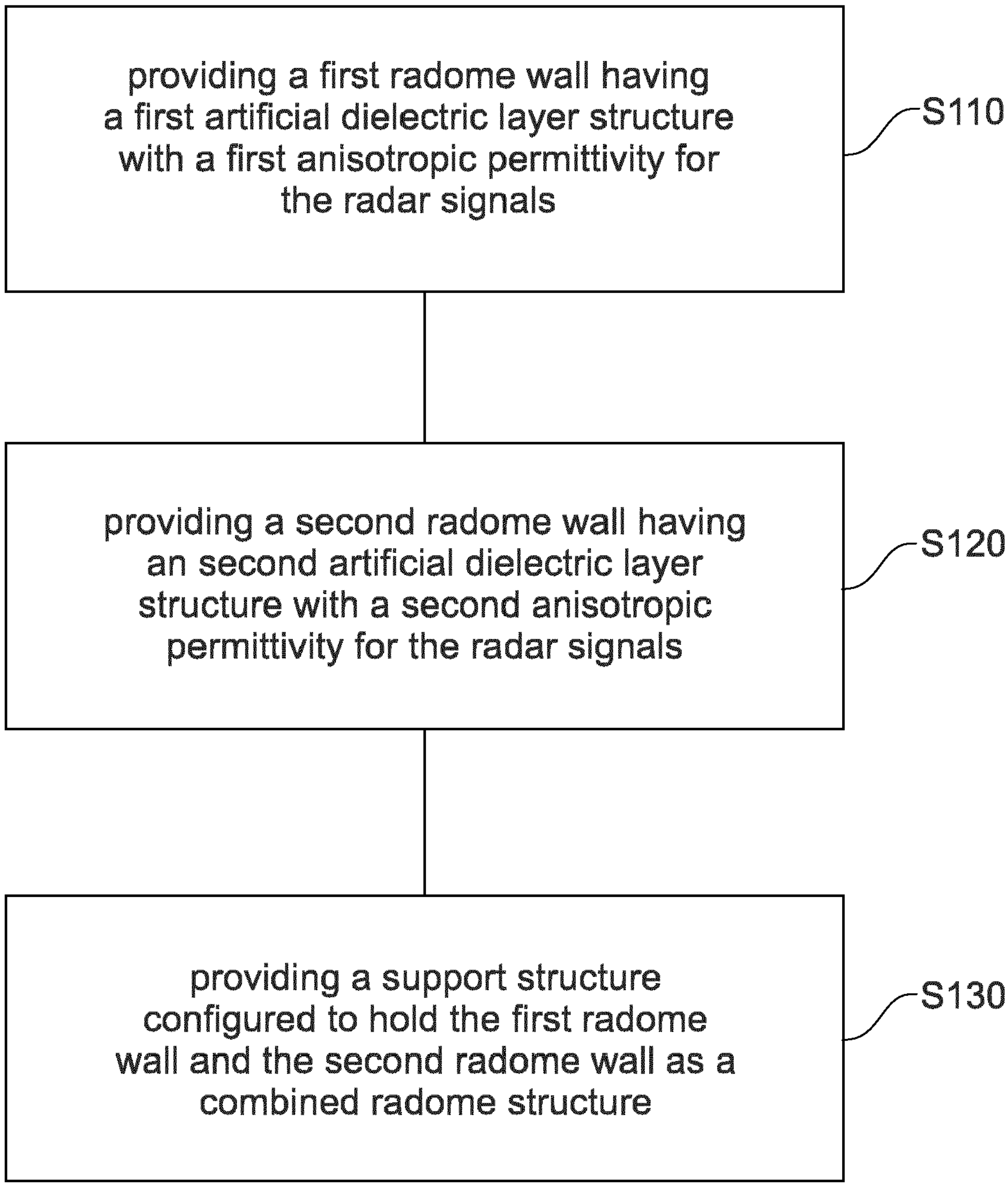
providing a first radome wall having a first artificial dielectric layer structure with a first anisotropic permittivity for the radar signals
S110
providing a second radome wall having an second artificial dielectric layer structure with a second anisotropic permittivity for the radar signals
S120
providing a support structure configured to hold the first radome wall and the second radome wall as a combined radome structure
S130

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 23 19 4542

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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document	T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document

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