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(72) Inventors:
• **GIMENO MARTIN, Alejandro**
82024 Taufkirchen (DE)
• **ZIEGLER, Volker**
82024 Taufkirchen (DE)

(74) Representative: **LKGLOBAL**
Lorenz & Kopf Patentanwalt
Attorney at Law PartG mbB
Brienner Straße 11
80333 München (DE)

(71) Applicant: **Airbus SAS**
31707 Blagnac (FR)

(54) **ANTENNA WITH A RADIATION FORMING ELEMENT AND AIRCRAFT COMPRISING SUCH ANTENNA**

(57) An antenna system (10) and an aircraft (100) comprising such an antenna system (10) is provided. The antenna system (10) comprises an antenna (11), a housing (12), and a beamforming material (13). The housing (12) at least partially enclosed the antenna (11) and comprises a cutout portion (14) that is covered by the beamforming material (13). The antenna (11) is oriented inside the housing (12) such that it radiates electromagnetic waves (15) towards the cutout portion (14) and an inner

surface of the beamforming material (13). The beamforming material (13) is configured to receive the electromagnetic waves (15) emitted by the antenna (11) and to modify them such that a desired radiation pattern (16) is generated outside the housing (12) and emitted by the outer surface (23) of the beamforming material (13). The fuselage (20) of the aircraft (100) corresponds to the housing (12) of the antenna system (10).

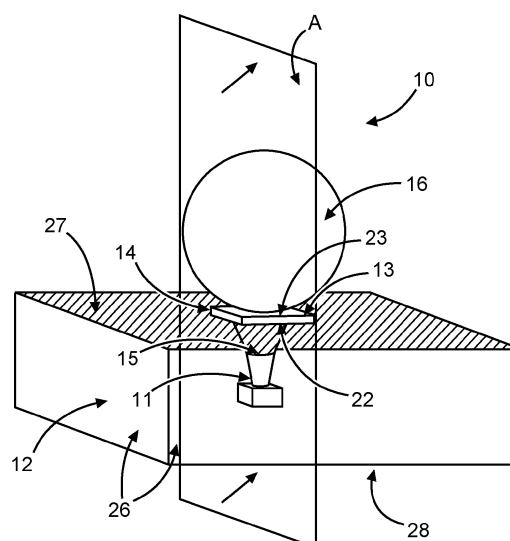


Fig. 1

Description

TECHNICAL FIELD

[0001] The description relates to antennas in general and more particular to antennas for aircrafts which do not protrude from the fuselage of the aircraft. Furthermore, the description relates to an aircraft with such an antenna.

TECHNICAL BACKGROUND

[0002] Modern aircrafts are oftentimes equipped with different types of antennas, such as for radar or communication applications, wherein each antenna must have a particular transmission characteristic, i.e., generate a particular signal pattern specific for the intended purpose. Usually, aircraft antennas therefore are placed on an outer surface of a fuselage structure, in order not to disturb the signal by the fuselage and to enable the antenna to radiate in the desired pattern and receive signals from the environment of the aircraft. Also, antennas on aircrafts usually must be protected from detrimental influences of the environment, e.g., by radomes. Since such an antenna together with the respective radome is placed outside the fuselage structure of the aircraft, the antenna systems introduce additional drag to the aircraft, which needs to be kept as low as possible. This is particularly interesting for reducing the energy consumption of the aircraft but also for improving the aerodynamic properties and therefore the flight dynamics.

DESCRIPTION

[0003] It is an objective to reduce drag of aircraft, in particular to provide an antenna, in particular for aircrafts, with reduced drag while still generating the desired signal pattern.

[0004] This objective is solved by the subject matter of the independent claims. Further embodiments are described in the dependent claims as well as in the following description.

[0005] According to a first aspect, an antenna system is provided. The antenna system comprises an antenna, a housing, and a beamforming material. The housing at least partially encloses the antenna and comprises a cutout portion. The antenna is oriented inside the housing such that the antenna radiates electromagnetic waves towards the cutout portion and an inner surface of the beamforming material. The cutout portion of the housing is covered by the beamforming material and the beamforming material is configured to receive the electromagnetic waves emitted by the antenna and to modify these electromagnetic waves such that a desired radiation pattern is generated outside the housing and emitted by an outer surface of the beamforming material.

[0006] The antenna can be any kind of antenna, such as radar antennas or communications antennas. In air-

craft applications in particular, such antennas oftentimes have to be mounted outside the aircraft on the fuselage, in order to generate a desired radiation pattern. However, mounting the antenna outside the aircraft produces certain protrusions or projections on the fuselage of the aircraft, which introduces additional drag forces on the aircraft.

[0007] In order to avoid these adverse effects, in the presently described antenna system, the antenna is placed inside a regular housing, but not in such a way that the radiating portion of the antenna is placed on top of the housing or is protruding from the housing. Rather, the antenna does not protrude in any way from the outside of the housing. The housing therefore (at least partially) encloses the antenna. For example, the housing may be any three-dimensional structure having an inner empty space in which the antenna is placed and a corresponding number of walls surrounding the empty space.

[0008] The cutout portion of the housing is a region on one side of the housing, at which one of the walls of the housing is cut open, so that an opening or aperture from the inside to the outside of the housing is formed. In other words, the cutout portion is a hole or a recess in an outer wall of the housing. This hole may have any suitable shape, such as rectangular or circular. However, other shapes are conceivable, too. Each antenna has a certain radiation direction or radiation directions. For example, the antenna may be a horn antenna and the horn may comprise an opening from which the antenna radiates electromagnetic waves. However, the antenna may be any kind of antenna.

[0009] The antenna is placed inside the housing in such a way as to radiate towards the cutout portion or hole. Therefore, the radiation of the antenna in principle can leave the housing through the cutout portion. However, because the antenna is set back from the cutout portion, the regular radiation pattern of the antenna, that would be created if the radiating portion of the antenna, e.g., the horn of a horn antenna, would be protruding from the housing, is distorted by the housing.

[0010] Therefore, in order to achieve a certain desired radiation pattern of the antenna system outside the housing, e.g., an azimuthal or spherical radiation distribution or any other kind of desired energy distribution, a beamforming material at least partially or entirely covers the cutout portion, i.e., the beamforming material closes the cutout portion or hole and complements the housing. Since the beamforming material closes the cutout portion and the antenna radiates towards the cutout portion, electromagnetic waves of the antenna impinge on the inner surface of the beamforming material.

[0011] The beamforming material in general is a passive material that transforms or modifies electromagnetic waves passing through it in a certain way. Therefore, the beamforming material transforms radiation impinging on the inner surface and emits the transformed radiation at its outer surface. Such effects can, e.g., be achieved by

certain internal reflection and transmission properties of the beamforming material. The beamforming material may be chosen specific to the desired pattern and to the frequency band of the used antenna. In particular, the beamforming material may be a metamaterial as described further below. However, other materials achieving the desired radiation pattern may also be used. The beamforming material may in particular comprise a plate like structure that can replace part of the housing.

[0012] Although the disclosed antenna system is described with reference to aircrafts, it should be understood that the antenna system may also be used for other applications. In particular, the antenna system may also be used in automotive applications or in other vehicles like submarine vessels and/or watercraft. However, the antenna system is not limited to vehicle applications.

[0013] The disclosed principle in general allows for advantageous aerodynamic properties but also for a clean design. In particular, in vehicle applications such as in aircrafts, the housing of the antenna system may not be a distinct housing but may also be, e.g., the fuselage of the aircraft itself. In this way, the antenna of the antenna system may be located within the aircraft, e.g., inside the outer skin of the aircraft. This allows for easy replacement and maintenance of the antenna. In this application scenario, the cutout portion of the housing corresponds to a hole in the fuselage which is closed by the beamforming material. Since the antenna does not have to be placed on top of the fuselage on the outside of the aircraft, aerodynamic properties of the aircraft are not impacted in a negative manner compared to regular antenna systems that are placed on the outer skin of the aircraft. However, even in aircraft applications, the antenna system may comprise a distinct housing that can be placed inside an opening of the fuselage. This allows for a modular system design.

[0014] According to a further embodiment, the beamforming material is flush and/or conformal with peripheral regions of the housing that surround the cutout portion, wherein the beamforming material and the housing together build a common surface.

[0015] As described above, the beamforming material covers the cutout portion of the housing. In order to further increase aerodynamic properties, the beamforming material may be formed such that not even small protrusions with regard to the housing exist. This may be achieved by placing the beamforming material fully inside the cutout portion (the hole) in the housing. The beamforming material being flush with the housing thereby means that the beamforming material and the housing together build a common surface and the beamforming material and the housing are only distinguishable by the material but not their shapes. The beamforming material and the peripheral regions of the housing surrounding the cutout portions, i.e., the edges or borders of the hole inside the housing, therefore together build a surface without protrusions. The beamforming material may then be fixed to the housing, e.g., by adhesives for gluing the beam-

forming material together with the housing or (in corresponding applications) with the fuselage. However, any suitable method of connecting the beamforming material with the housing is conceivable. For example, the beamforming material may also comprise a fastening lip such that it can be placed inside the cutout portion from the inside of the housing and attached, e.g., by clips.

[0016] The beamforming material and the housing may have any conceivable shape. For example, the beamforming material and the peripheral regions of the housing surrounding the cutout portion may build a flat surface, a curved surface, or any other suitable shape. In aircraft applications, for example, the shape of the beamforming material may be curved so as to follow the curvature of the outer surface of the fuselage.

[0017] According to a further embodiment, the beamforming material covers the cutout portion of the housing such that peripheral regions of the beamforming material at least partially overlap with peripheral regions of the housing that surrounds the cutout portion.

[0018] In such configurations, the beamforming material spans a bigger area than the cutout portion of the housing and overlaps at its edges with the cutout portion. In other words, the beamforming material is a plate like structure that is bigger than the hole (cutout portion) in the housing and is placed on top of the hole, either from the inside or from the outside of the housing. The beamforming material may be fixed to the housing in any possible and suitable way, such as by adhesives between the peripheral regions of the beamforming material and the peripheral regions of the housing that surround the cutout portion. Other conceivable connections methods may be screwing or riveting.

[0019] According to a further embodiment, the beamforming material is placed in a groove running around peripheral regions of the housing that surround the cutout portion such that the beamforming material is framed by the groove.

[0020] For example, a groove may be formed around the cutout portion, i.e., at the edges of the cutout portion into which corresponding tongues of the beamforming material can be inserted, such as is done when connecting parquet boards. The beamforming material and the surrounding portions of the housing may again be fixed together by any suitable way, such as gluing, screwing, riveting, etc..

[0021] According to a further embodiment, the beamforming material is a metamaterial having a spatial geometric structure that transforms the electromagnetic waves emitted by the antenna towards the beamforming material in such a way as to achieve the desired radiation pattern at the outer surface of the beamforming material.

[0022] Metamaterials in general are engineered materials that have properties not found in naturally occurring materials. Such materials are made from assemblies of multiple elements fashioned from composite materials such as metals and plastics. These materials can be arranged in certain patterns, that are usually smaller than

the wavelengths of the electromagnetic radiation to be influenced. The influence on the impinging radiation does not (or at least not only) result from the physical properties of the used materials but from their arrangement. For example, internal reflection, transmission, and absorption characteristics of the metamaterial lead to a certain emitted signal on one side of the metamaterial, when electromagnetic waves impinge on the other side of the metamaterial. The metamaterial therefore transforms the impinging radiation and creates a distinct radiation pattern.

[0023] Therefore, appropriately designing the shapes, arrangements, sizes and orientations of the single composite materials used to build the metamaterial allows to develop materials that, on a macroscopic scale, influence electromagnetic waves in a desired way so as to achieve a desired radiation pattern. Any suitable metamaterial may be used as beamforming material, such as, but not limited to, metamaterials comprising split-ring resonators, metamaterials having a positive refractive index, metamaterials having a negative refractive index or any other metamaterial suitable to achieve the desired radiation pattern.

[0024] Depending on the microscopic structure of the metamaterial, different radiation properties on the outer surface of the metamaterial can be achieved. Therefore, in principle any desired radiation pattern can be achieved by appropriately designing the structure of the metamaterial. Hence, usage of metamaterials as beamforming material allows to achieve the same radiation pattern that would be achieved when the antenna, or rather the emitting element of the antenna, would be protruding from the housing.

[0025] As will be readily apparent to one of ordinary skill in the art, metamaterials can in principle be designed to influence impinging electromagnetic waves in a multitude of ways. The design of the metamaterial for the desired radiation pattern can be determined, e.g., by computer simulations of different configurations of metamaterials.

[0026] According to a further embodiment, the metamaterial comprises multiple layers, wherein the multiple layers together build a three-dimensional structure designed to achieve the desired radiation pattern.

[0027] In particular, the three-dimensional structure or pattern of the metamaterial can be designed such that the desired radiation pattern is achieved on the outer surface of the metamaterial while also enabling to receive signals impinging on the outer surface at the antenna. The particular design of the metamaterial may be specified using computer models and simulations, as will be readily apparent to one of ordinary skill in the art.

[0028] According to a further embodiment, the three-dimensional structure builds a self-repeating geometrical pattern.

[0029] According to a further embodiment, the beamforming material is covered by an electromagnetically transparent protective layer at the outside of the housing.

[0030] Such a protective layer may be thin compared to the beamforming material and may either be placed only above the beamforming material or above the beamforming material and the surrounding peripheral regions of the cutout portion. The latter design further improves isolation with regard to the environment.

[0031] The protective layer may be any suitable layer that is transparent for electromagnetic waves. It may, for example, be any suitable radome material or a paint coating.

[0032] According to a further embodiment, the beamforming material has asymmetric beamforming properties and focusses electromagnetic waves impinging onto the outer surface of the beamforming material from the outside of the housing towards the antenna.

[0033] By appropriately modelling the structure of the beamforming material, such as the metamaterial described above, asymmetric beamforming properties may be achieved, so that the antenna can simultaneously be used as a transmitter antenna and as a receiver antenna (RX/TX feeder). In particular, the beamforming material can be designed to focus electromagnetic waves penetrating the beamforming material from the outer surface into the antenna. Further, the beamforming material is designed to radiate signals impinging on the inner surface of the in a predefined pattern on the outer surface, as described above. Asymmetric beamforming properties means that the influence of the beamforming material depends on the direction of the electromagnetic waves. When transforming electromagnetic waves that impinge the inner surface of the beamforming material, this causes a first radiation pattern emitted by the outer surface. However, in the other direction, when electromagnetic waves impinge the outer surface of the beamforming material, it causes a second radiation pattern emitted by the inner surface towards the antenna, wherein the second radiation pattern is different to the first radiation pattern.

[0034] According to a further embodiment, the antenna is a radar antenna.

[0035] According to a further embodiment, the antenna is a bidirectional communication antenna.

[0036] The communication antenna thereby may be any kind of communication antenna.

[0037] According to a further embodiment, the antenna system further comprises an isolating structure. The isolating structure provides electromagnetic isolation of the antenna regarding regions of the housing surrounding the antenna and outside the space between the cutout portion and the antenna.

[0038] Electromagnetic waves coming into the housing of the antenna system laterally, i.e., transverse to the sending direction (the connecting line of the antenna and the beamforming material), or from the back of the antenna may lead to disturbances of the intended radiation pattern. Therefore, isolating structures may be provided shielding the antenna from electromagnetic radiation from the lateral sides or the back side, without influencing the antenna radiation directed to the beamforming ma-

terial. Such isolating structures may, for example, include sheets of permalloy or any other suitable isolating material.

[0039] According to a second aspect, an aircraft is provided. The aircraft comprises a fuselage and an antenna system as described above. The fuselage of the aircraft is the housing of the antenna system so that the antenna is arranged within the fuselage of the aircraft.

[0040] Such arrangement has already been described above. The antenna may be placed directly inside the fuselage of the aircraft and can be fixed in position within the fuselage, such that the sending direction is perpendicular to a wall of the fuselage. For example, the antenna may be fixed to a stringer or other structural component of the aircraft. The cutout portion may be a hole in the fuselage in front of the antenna. For example, the antenna could be a horn antenna whose horn is directed towards the fuselage from the inside of the aircraft. The beamforming material, such as a metamaterial, would then be placed inside the hole of the fuselage. This arrangement allows to achieve radiation patterns similar to the patterns created by antennas located outside the aircraft on the fuselage without introducing any additional drag forces on the aircraft. The antenna system may be designed according to any of the embodiments described above, but the fuselage of the aircraft corresponds to the housing of the antenna system.

[0041] In summary, the description provides an antenna system for an aircraft that does not add any protruding structures to the fuselage of the aircraft. The antenna of the antenna system can be placed inside the fuselage and does not need to be mounted on the fuselage outside the aircraft. This allows for easy maintenance or replacement of the antenna. In particular, by using a beamforming material that is flush with a housing of the antenna (such as the fuselage of the aircraft) as an aperture for the antenna, it is possible to achieve a desired radiation pattern outside the fuselage without introducing any adverse aerodynamic effects. This allows to use the necessary antenna arrangements, such as radar or communication antennas while still complying with aerodynamic requirements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] In the following, exemplary embodiments are described in more detail having regard to the attached figures. The illustrations are schematic and not to scale. Identical reference signs refer to identical or similar elements. The figures show:

Fig. 1 A schematic three-dimensional view of an antenna system having a metamaterial aperture and creating a desired radiation pattern.

Fig. 2 A cut view of the antenna system of fig. 1 along cut plane A.

Fig. 3 A schematic top view of a housing of an antenna system without the antenna and without the beamforming material.

Fig. 4 A schematic partial cut view of a housing of the antenna system having a beamforming material at a cut out portion of the housing with the beamforming material being flush with the housing surface.

Fig. 5 A schematic partial cut view of a housing of the antenna system having a beamforming material at a cut out portion of the housing with the beamforming material being overlapping with the housing surface.

Fig. 6 A schematic partial cut view of a housing of the antenna system having a beamforming material at a cut out portion of the housing with the beamforming material being held by a groove in peripheral regions of the cut out portion.

Fig. 7 A schematic view of an aircraft with an antenna system similar to that shown in fig. 1 and 2 in a side view (a) and in a cut illustration viewed from the front of the aircraft (b).

DETAILED DESCRIPTION

[0043] Figs. 1 and 2 show schematic representations of an antenna system 10 according to an exemplary embodiment. In fig. 1, the antenna system 10 is shown in a three-dimensional perspective view. Fig. 2 shows a cut view of the antenna system 10 when viewed from cut plane A. The antenna system 10 comprises an antenna 11, a housing 12, and a beamforming material 13. In fig. 1 and 2, the housing 12 is a cuboid having an inner space that is surrounded by six walls 26-28, i.e., four side walls 26 (only two visible), a bottom wall 28 and a top wall 27. Although the housing 12 is shown as being a cuboid, the housing 12 may also have any other conceivable shape such as spherical, parabolic, elliptical, etc. However, this enumeration is only exemplary and other shapes are possible, too. In particular, the housing 12 of the antenna system 10 may be the fuselage 20 of an aircraft 100, as will be described further below with reference to fig. 7, or an outer hull of any other vehicle or device, such as the body frame of a car or other vehicle.

[0044] The top wall 27 of the housing 12 includes a cutout portion 14, which corresponds to a hole in the top wall 27 giving access to the inner space of the housing 12. The cutout portion 14 can be seen best in fig. 3, which shows a top view of the housing 12 without the antenna 11 and without the beamforming material 13. In the embodiment depicted in fig. 1 to 6, the cutout portion 14 is quadratic in shape. However, the cutout portion may have any conceivable and suitable shape. For example, the cutout portion may also be circularly or elliptically

shaped.

[0045] The antenna 11 may be any kind of antenna, such as a radar antenna or a communication antenna and may be a bidirectional antenna (i.e., a transmitter and receiver antenna) or a unidirectional antenna. The antenna 11 is placed below the cutout portion 14 and therefore, (since the beamforming material 13 is placed in the cutout portion 14, as described in more detail further below) also below the beamforming material 13. With respect to the housing 12, the antenna 11 is oriented so as to radiate towards the beamforming material 13. In other words, the radiation elements of the antenna 11 are directed towards the beamforming material 13. In figs. 1 and 2, the antenna is shown as being a horn antenna having a horn which is used to send out electromagnetic waves 15. However, other antennas 11 may be used, too.

[0046] The beamforming material 13 is a substantially flat material or member having an inner surface 22 and an outer surface 23. The shape and size of the beamforming material 13 generally corresponds to the shape and size of the cutout portion 14 of the housing 12. The beamforming material 13 is placed in or above the cutout portion 14 (the hole in the housing 12) in such a way as to close the cutout portion 14. For this, different configurations are conceivable, some of which will be explained further below with reference to figs. 4 to 6. Thereby, the inner surface 22 is directed towards the inner space and the outer surface 23 is directed away from the housing 12, i.e., in figs. 1 to 6, away from the top wall 27 of the housing 12. The beamforming material 13 generally is sized such that it receives all of the radiation coming from the antenna 11. However, it is also possible that only part of the radiation impinges on the beamforming material 13.

[0047] The beamforming material 13 may be any material that transforms electromagnetic waves 15 passing through it in a certain way. However, the beamforming material 13 does not only transmit the electromagnetic waves 15 but does create a certain desired radiation pattern 16 on the outer surface 23. In other words, the beamforming material 13 receives electromagnetic waves 15 from the antenna 11 at the inner surface 22 and transforms them in such a way as to create a desired radiation pattern 16 which is emitted from the outer surface 23 of the beamforming material 13. In figs. 1, 2 and 7, the radiation pattern 16 is shown as being a spherical radiation distribution that is propagated from the outer surface 23 of the beamforming material 13. However, this illustration is only exemplary and depending on the structure of the beamforming material 13, any desired radiation pattern 16 may be achieved. For example, and without limitation, the radiation pattern 16 may be an azimuthal distribution or a lobe-like distribution. Such distributions may be achieved, e.g., by designing the internal structure of the beamforming material 13 such that it comprises certain internal reflection, absorption and other characteristics relevant for the transmission properties of the electro-

magnetic waves 15 through the beamforming material 13. Also, the beamforming material 13 may be specifically chosen for the used frequency band of the antenna 11.

[0048] Preferably, the beamforming material 13 is a metamaterial 13. Such metamaterials 13 may be made from composite materials comprising metal and plastics materials. The used materials are arranged to build assemblies of certain geometric structures or patterns, that are usually substantially smaller than the wavelength of the electromagnetic radiation 15 for which the metamaterial 13 is used. Thereby, the geometric structures or patterns may be uniform and self-repeating. However, the patterns may also be distinct for different areas of the metamaterial 13. Such metamaterials 13 allow to implement electromagnetic properties, e.g., transmission and beamforming properties, that are not achievable with naturally occurring materials. Further, the metamaterial 13 may be single or multi layered. In multi layered configurations, every layer may have a different pattern or the same pattern than the other layers. Appropriately designing the geometric configuration of the single elements of the metamaterial 13 allows to achieve a desired radiation pattern 16 at the outer surface of the metamaterial 13. In particular, the metamaterial may also be designed to comprise asymmetric electromagnetic properties, so that the beamforming material/metamaterial 13 may be used for sending electromagnetic waves 15 received from the antenna 11 in a certain radiation pattern 16 from the outer surface 23 as well as for receiving electromagnetic waves at the outer surface 23 and focusing these waves from the inner surface 22 into the antenna 11. In this way, the antenna 11 may be used as bidirectional antenna 11, such as a communication antenna.

[0049] Fig. 2 further shows a protective layer 19 which is not depicted in fig. 1. Such a protective layer may, for example, be a standard radom layer or a paint coating which is transparent for the respective electromagnetic radiation. The protective layer 19 acts as a protection against adverse environmental influences such as adverse weather conditions. However, such a protective layer 19 is optional. The beamforming material/metamaterial 13 may also comprise the necessary protective properties without any additional protective layer 19. Further, in fig. 2 the protective layer 19 covers the whole top wall 27 in which the cutout portion 14 is arranged. However, such protective layer 19 may also only cover the beamforming material/metamaterial 13 itself, without the surrounding regions of the housing 12.

[0050] Figs. 4 to 6 show different possible arrangements and connections of the beamforming material/metamaterial 13 with respect to the housing 12.

[0051] Fig. 4 shows an arrangement where the beamforming material 13 is flush with peripheral regions 18 of the housing 12 surrounding the cutout portion 14. In other words, in this configuration, peripheral regions 17 of the beamforming material 13 are contacting the peripheral regions 18 of the housing in a common plane, such that

the edges of the beamforming material 13 abut inner edges of the housing 12 directed towards the cutout portion 14. Therefore, the beamforming material 13 does not protrude from the housing 12. If, as indicated above and described with fig. 7, the housing is the fuselage 20 of an aircraft 100, therefore additional drag forces on the aircraft 100 are avoided, improving the aerodynamic properties of the aircraft while still providing the necessary antenna properties. The beamforming material 13 may, for example, be glued, screwed, riveted or otherwise connected to the housing 12. However, this enumeration is only exemplary in nature and other connections are possible, too.

[0052] Fig. 5 shows an arrangement where the beamforming material 13 is larger in the planar direction than the cutout portion 14 and covers the cutout portion 14. In this configuration, the peripheral regions 17 of the beamforming material 13 overlap with the peripheral regions 18 of the housing 12. The beamforming material 13 does protrude slightly from the housing 12. However, this protrusion is way smaller than, e.g., the protrusion produced by a regular antenna that is mounted on the fuselage 20 of an aircraft 100. The beamforming material 13 may again, as in fig. 4, be connected to the housing 12 in any suitable way, such as gluing, screwing, riveting, etc.

[0053] Fig. 6 shows a similar configuration of the beamforming material 13 with regard to the housing 12 as fig. 4. However, in fig. 6, the beamforming material comprises protrusions on the edges, which are inserted in a corresponding groove 24 of the housing 12, or, more specifically, of the edges of the housing 12 at the peripheral regions 18. The beamforming material may again be fixedly connected to the housing 12 by any suitable means, such as screwing, gluing, riveting. However, the beamforming material 13 may also be held in place by the friction between the beamforming material 13 (or rather the corresponding protrusions on the edges of the beamforming material) and the corresponding groove 24 in the housing 12.

[0054] Fig. 7 shows a schematic view of an aircraft 100 having the antenna system 10 described above. Fig. 7 (a) thereby shows a side view of the aircraft 100. Fig. 7 (b) shows a sectional view along cut line B-B in Fig. 7 (a). The fuselage 20 of the aircraft 100 corresponds to the housing 12 of the antenna system 10. The antenna 11 is fixed in position inside the fuselage 20 by an antenna fixing structure 25. The beamforming material/metamaterial 13 is inserted in the cutout portion 14 and closes the cutout portion 14, as described above with regard to the antenna system 10 in general. Although shown as being placed at the side of the aircraft 100, the antenna system 10 may be located at any possible location around the aircraft 100.

[0055] The cutout portion 14 of the housing 12 (i.e., the fuselage 20) is a hole in the fuselage 20 at a position where the antenna 11 is supposed to radiate electromagnetic radiation away from the aircraft 100 and/or from

which direction the antenna is supposed to receive electromagnetic radiation.

[0056] The beamforming material/metamaterial 13 may be connected to the fuselage 20, i.e., the cutout portion 12 of the fuselage/the housing 20, 12, according to any one of the arrangements shown in figs. 4 to 6, although in fig. 7 shown as being flush with the fuselage 20.

[0057] The antenna fixing structure 25 may be any structure suitable to fix the antenna inside the fuselage 20 at the desired position. In particular, the antenna fixing structure 25 may connect the antenna body with structural elements of the aircraft 100, such as with stringers of the aircraft 100 and holds the antenna 10 in a position in front of the inner surface 22 of the beamforming material 13.

[0058] The antenna system 10, in particular the usage of the beamforming material/metamaterial 13 in the described way, allows to place the antenna 11 inside the aircraft 100. Protrusions on the outside of the fuselage 100 are therefore avoided, while the antenna is still enabled to radiate electromagnetic waves outside the fuselage 20 in a desired radiation pattern 16 by means of the beamforming properties of the metamaterial 13.

Therefore, since protrusions on the fuselage 20 of the aircraft 100 are avoided, aerodynamic properties of the aircraft are enhanced, in particular by reducing drag forces on the aircraft 100. Also, placing the antenna 11 inside the aircraft 100 allows for easier maintenance and replacement of the antenna 11.

[0059] It should be noted that "comprising" or "including" does not exclude other elements or steps, and "one" or "a" does not exclude a plurality. It should further be noted that features or steps that have been described with reference to any of the above embodiments may also be used in combination with other features or steps of other embodiments described above. Reference signs in the claims are not to be regarded as limitation.

LIST OF REFERENCE SIGNS

[0060]

10	Antenna system
11	Antenna
12	Housing
13	Beamforming material, metamaterial
14	Cutout portion
15	Electromagnetic waves
16	Radiation pattern
17	Peripheral region of the beamforming material
18	Peripheral region of the cutout portion
19	Protective layer
20	Fuselage, housing
21	Isolating structure
22	Inner surface
23	Outer surface
24	Groove

- 25 Antenna fixing structure
- 26 Side walls
- 27 Top wall
- 28 Bottom wall
- 100 Aircraft

Claims

1. Antenna system (10), comprising:

an antenna (11);
 a housing (12) at least partially enclosing the antenna (11); and
 a beamforming material (13);
 wherein the housing (12) comprises a cutout portion (14);
 wherein the antenna (11) is oriented inside the housing (12) such that the antenna (11) radiates electromagnetic waves (15) towards the cutout portion (14) and an inner surface (22) of the beamforming material (13);
 wherein the cutout portion (14) of the housing (12) is covered by the beamforming material (13); and
 wherein the beamforming material (13) is configured to receive the electromagnetic waves (15) emitted by the antenna (11) and to modify these electromagnetic waves (15) such that a desired radiation pattern (16) is generated outside the housing (12) and emitted by an outer surface (23) of the beamforming material (13).

2. The antenna system (10) of claim 1, wherein the beamforming material (13) is flush and/or conformal with peripheral regions (18) of the housing (12) that surround the cutout portion (14), wherein the beamforming material (13) and the housing (12) together build a common surface.

3. The antenna system (10) of claim 1, wherein the beamforming material (13) covers the cutout portion (14) of the housing (12) such that peripheral regions (17) of the beamforming material (13) at least partially overlap with peripheral regions (18) of the housing (12) that surrounds the cutout portion (14).

4. The antenna system (10) of any one of the preceding claims, wherein the beamforming material (13) is placed in a groove (24) running around peripheral regions (18) of the housing that surround the cutout portion (14) such that the beamforming material (13) is framed by the groove (24).

5. The antenna system (10) of any one of the preceding claims, wherein the beamforming material (13) is a metamaterial (13) having a spatial geometric structure that transforms the electromagnetic waves (15)

emitted by the antenna (11) towards the beamforming material (13) in such a way as to achieve the desired radiation pattern (16) at the outer surface (23) of the beamforming material.

6. The antenna system (10) of claim 5, wherein the metamaterial (13) comprises multiple layers, wherein the multiple layers together build a three-dimensional structure designed to achieve the desired radiation pattern (16).

7. The antenna system (10) of claim 6, wherein the three-dimensional structure builds a self-repeating geometrical pattern.

8. The antenna system (10) of any one of the preceding claims, wherein the beamforming material (13) is covered by an electromagnetically transparent protective layer (19) at the outside of the housing (12).

9. The antenna system (10) of any one of the preceding claims, wherein the beamforming material (13) has asymmetric beamforming properties and focusses electromagnetic waves impinging onto the outer surface (23) of the beamforming material (13) from the outside of the housing (12) towards the antenna (11).

10. The antenna system (10) of any one of the preceding claims, wherein the antenna (11) is a radar antenna (11).

11. The antenna system (10) of any one of claims 1 to 9, wherein the antenna (11) is a bidirectional communication antenna (11).

12. The antenna system (10) of any one of the preceding claims, further comprising an isolating structure (21), wherein the isolating structure (21) provides electromagnetic isolation of the antenna (11) regarding regions of the housing (12) surrounding the antenna (11) and outside the space between the cutout portion (14) and the antenna (11).

13. Aircraft (100) comprising:

a fuselage (20); and
 an antenna system (10) according to any one of the preceding claims;
 wherein the fuselage (20) is the housing (12) of the antenna system (10) so that the antenna (11) is arranged within the fuselage of the aircraft (100).

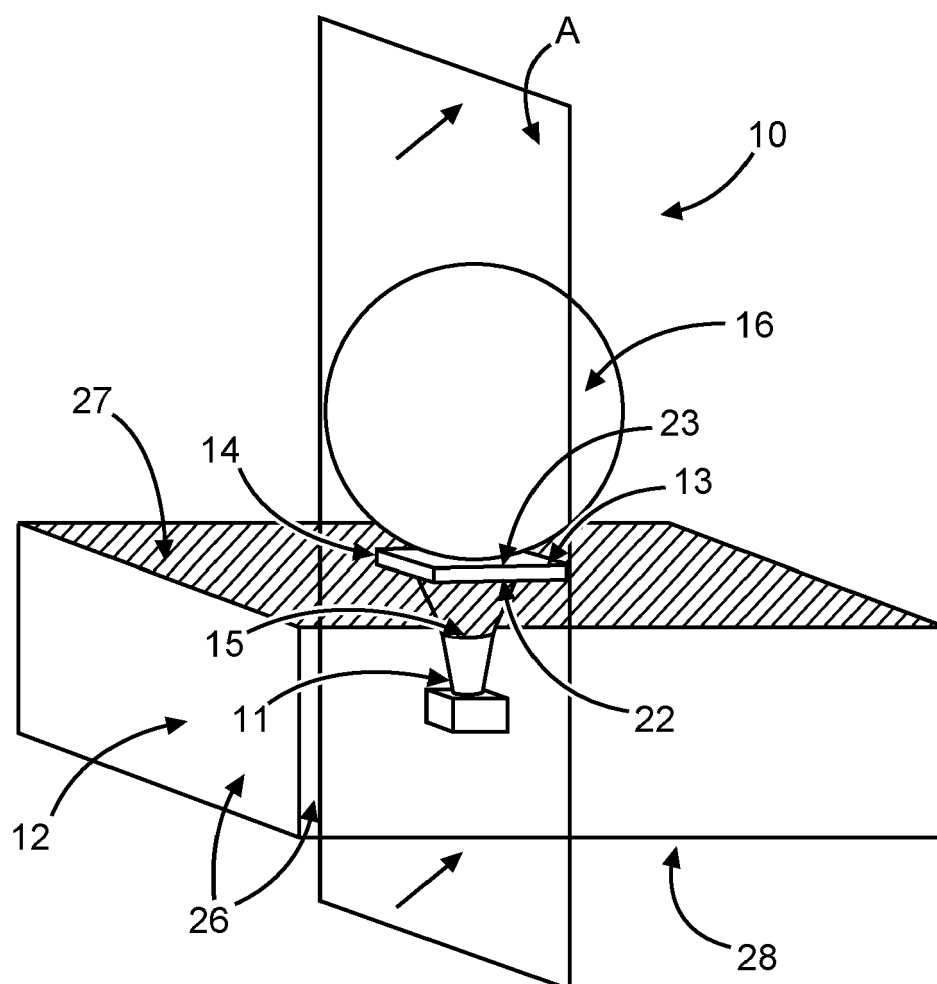
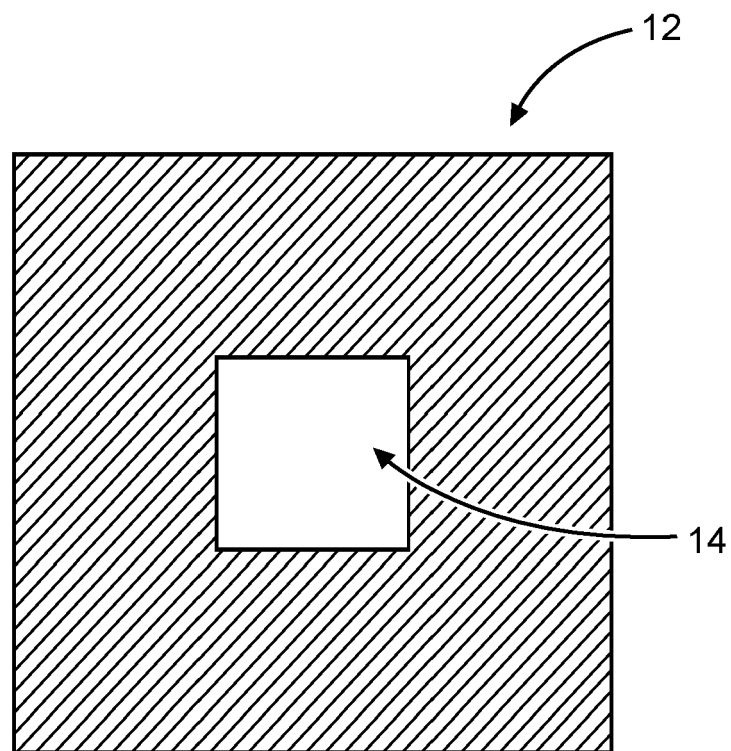
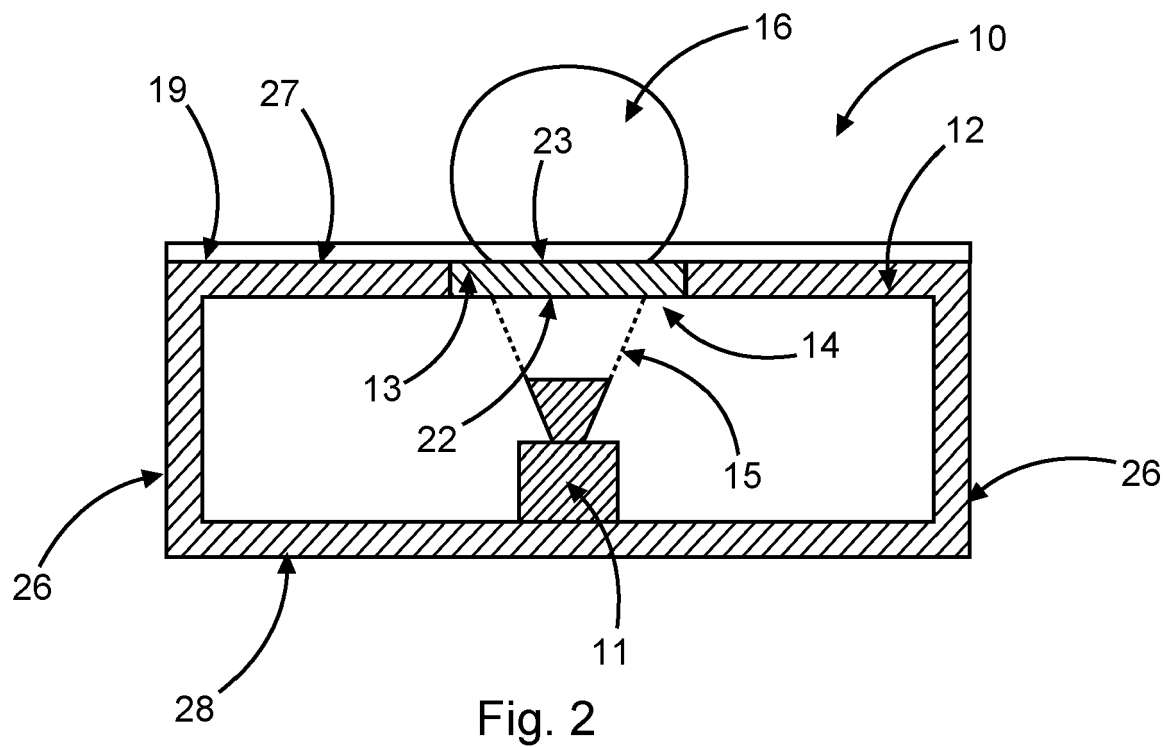


Fig. 1



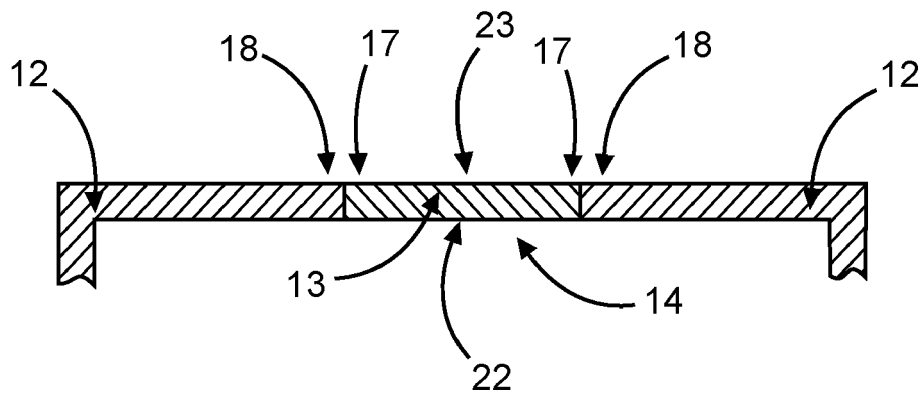


Fig. 4

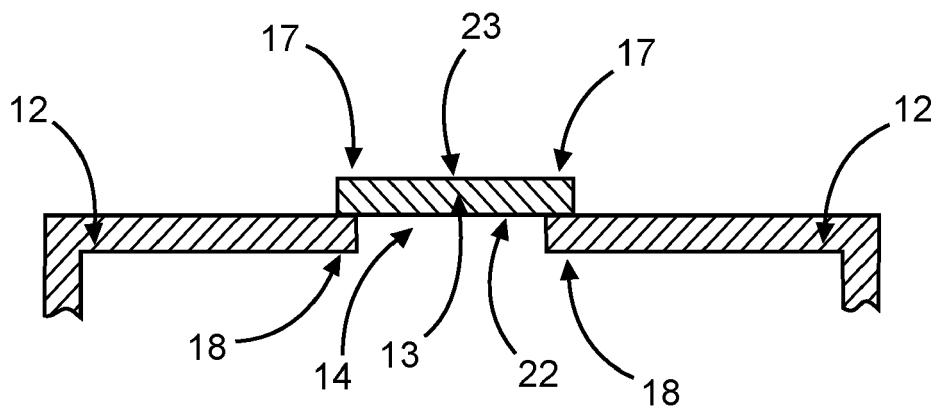


Fig. 5

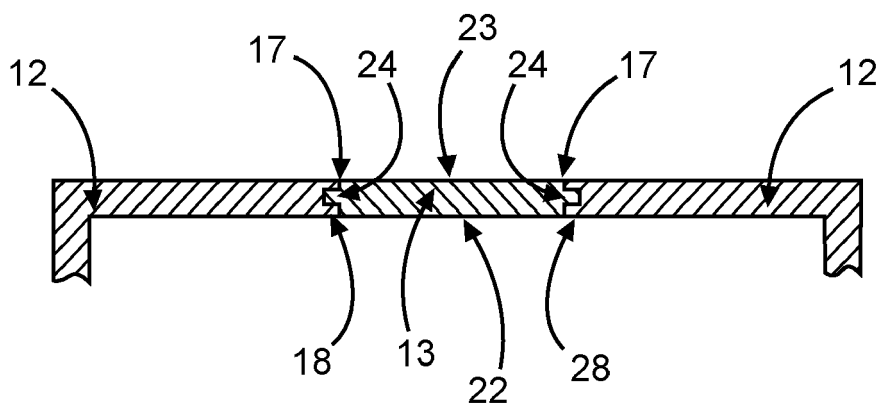


Fig. 6

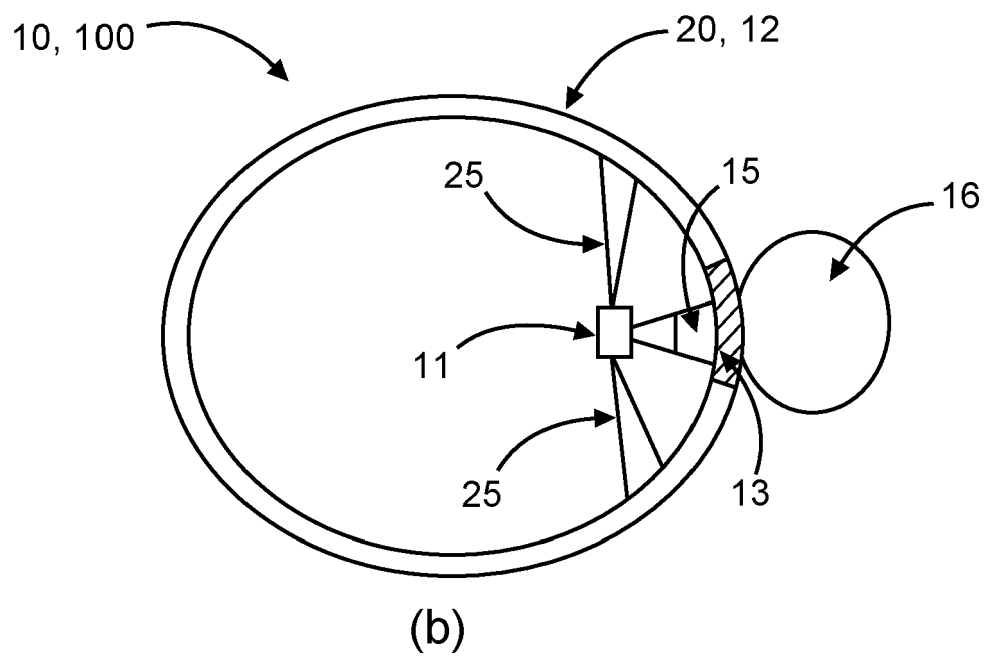
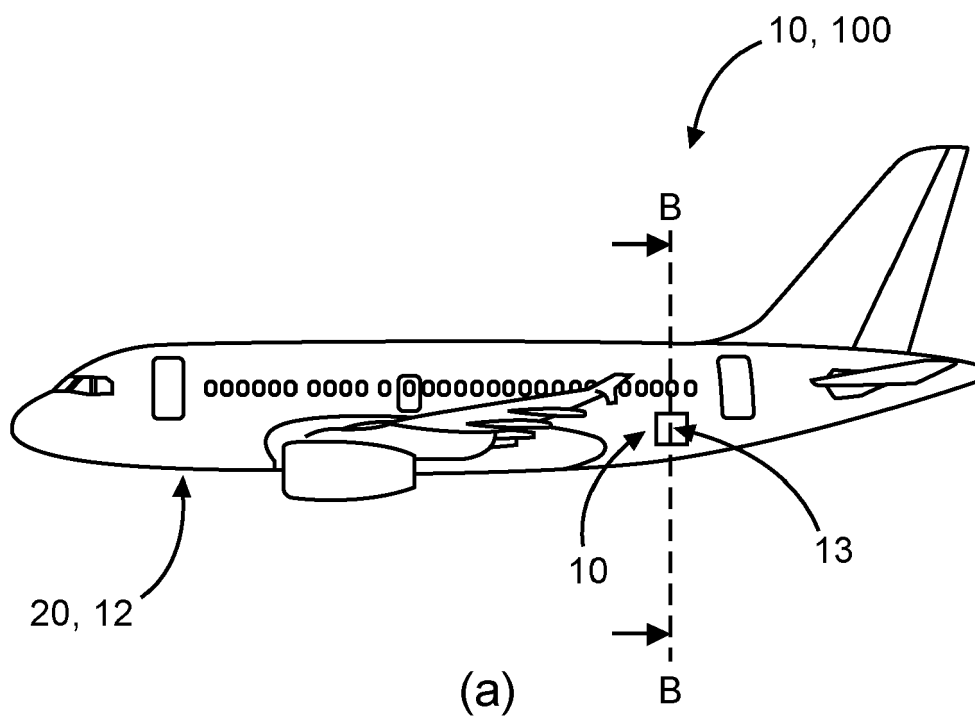


Fig. 7



EUROPEAN SEARCH REPORT

Application Number

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X	EP 0 896 749 B1 (BOSCH GMBH ROBERT [DE]) 22 January 2003 (2003-01-22) * figures 3-5 * * page 1, lines 7-9, 16-22 * * page 2, line 27 - page 3, line 4 * * page 3, lines 10-17, 23-29 * * page 5, lines 2-22 * * page 9, line 6 - page 10, line 15 * -----	1, 2, 4, 5, 7, 9-11, 13	TECHNICAL FIELDS SEARCHED (IPC) H01Q
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Place of search The Hague		Date of completion of the search 29 April 2022	Examiner Gehrmann, Elke
CATEGORY OF CITED DOCUMENTS 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	

**ANNEX TO THE EUROPEAN SEARCH REPORT
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