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(54) **POLARIZED YAGI ANTENNA**

(57) The present disclosure relates to an antenna, in particular, a Yagi antenna. The antenna may radiate with a linear polarization or with a circular polarization. The antenna comprises a ground layer and two or more ring-shaped segments arranged one after the other along an axis, the two or more segments comprising a first segment and a second segment. Further, the antenna comprises an antenna feed. The first segment comprises a

first insulating layer and a first conductive layer. The first insulating layer is arranged between the ground layer and the first conductive layer. The second segment comprises a second insulating layer and a second conductive layer. The second insulating layer is arranged between the first conductive layer and the second conductive layer. Further, the antenna feed is connected to the ground layer and to the first conductive layer.

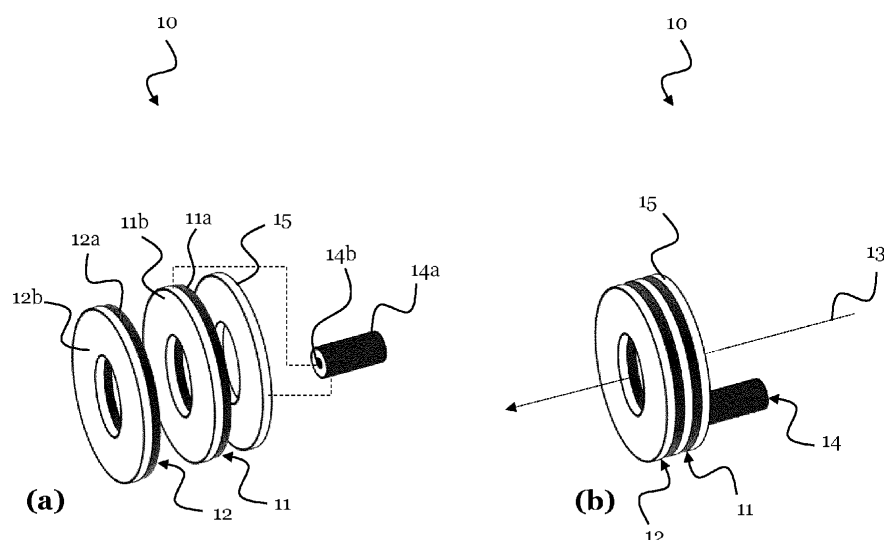


FIG. 1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to an antenna, in particular, to a Yagi antenna. The antenna of this disclosure may radiate with a linear polarization or with a circular polarization. Furthermore, due to its small footprint, the antenna is well suited to be integrated into a vehicle, in particular, an airborne vehicle like an airplane, a helicopter, or a drone.

BACKGROUND OF THE INVENTION

[0002] Different types of antennas have been used for integration into vehicles, in particular, airborne vehicles. For example, an omnidirectional antenna, a planar antenna (e.g., patch antenna), or a planar antenna array have been used.

[0003] The drawback of these types of antennas is that they are typically of rather large size, and integration into the above-mentioned vehicles is thus difficult. Due to their large size, these types of antennas are also quite heavy, which is a particular disadvantage for the use in a small airborne vehicle like a drone. Moreover, these types of antennas and respectively their integration into said vehicles is rather expensive.

SUMMARY OF THE INVENTION

[0004] In view of the above, embodiments of this disclosure aim to provide an improved antenna for integration into a vehicle, particularly an airborne vehicle. An objective thereby is to provide a new antenna design, in particular, for a YAGI antenna, which has a smaller footprint than a conventional type of antenna at a similar or higher antenna gain. Accordingly, another goal of this disclosure is to provide the antenna with an increased antenna gain at the same footprint as a conventional antenna. Another aim of this disclosure is to make the antenna low of weight, in order to allow its integration into small airborne vehicles like drones. Furthermore, the antenna should be easy to manufacture and of low cost.

[0005] These and other objectives are achieved by the embodiments of this disclosure provided in the independent claims. Advantageous implementations of the embodiments are further defined in the dependent claims.

[0006] Generally, embodiments of this disclosure propose an antenna, which includes a ground layer, and a plurality of ring-shaped insulating layers and ring-shaped conductive layers, which are alternately arranged one after the other along an axis of the antenna and, for instance, on the ground layer. The ground layer and the first conductive layer after the ground layer (in direction along the axis) are used to feed the antenna with an antenna feed. Thereby, the antenna may radiate with a linear polarization or with a circular polarization.

[0007] A first aspect of this disclosure provides an antenna comprising:

a ground layer; two or more ring-shaped segments arranged one after the other along an axis, the two or more ring-shaped segments comprising a first segment and a second segment; and an antenna feed; wherein the first segment comprises a first insulating layer and a first conductive layer, the first insulating layer being arranged between the ground layer and the first conductive layer; wherein the second segment comprises a second insulating layer and a second conductive layer, the second insulating layer being arranged between the first conductive layer and the second conductive layer; and wherein the antenna feed is connected to the ground layer and to the first conductive layer.

[0008] The antenna of the first aspect can be built in a compact manner, i.e., may have a small footprint. For example, the antenna can be included in an antenna area or antenna aperture of 7x7 mm or less. Of course, a larger antenna is also possible.

[0009] Due to the design of the antenna of the first aspect, with the two or more ring-shaped segments, the antenna exhibits a high gain compared to, for instance, a patch antenna with similar footprint. Already with four ring-shaped segments, the antenna may show a gain of 10 dB or more. The gain of the antenna can be further increased by increasing the number of the ring-shaped segments, wherein the gain of the antenna may reach 20 dB or more.

[0010] Notably, each ring-shaped segment in this disclosure is a part of the antenna, and may be formed by a disc-shaped segment having a hole in its center. The disc-shaped segment and the central hole, which form a ring-shape segment, are preferably both circular. Furthermore, the circular disc-shaped segment and the circular hole in its center are preferably concentric. Accordingly, in the antenna of the first aspect, each conductive layer and each insulating layer is a ring-shaped layer (i.e. a disc-shaped, preferably circular, layer with a hole in its center). Likewise, the ground layer may be a ring-shaped layer, or may be a circular disk-shaped layer without a hole. However, the ground layer may also have a different shape, for example, it may have a square shape, a rectangular shape, or an octagonal shape. Different ring-shaped segments of the antenna may have the same size (i.e. the same outer diameter), but may also differ in size (i.e. may differ in their outer diameter).

[0011] Further, the antenna of the first aspect may be a broadband antenna, i.e., it may have broadband characteristic. That is, the antenna may have a high bandwidth, i.e., it may radiate in a large range of frequencies. In particular, the use of the ring-shaped antenna segments enables these broadband characteristics of the antenna. This is mainly due to the fact, that the inside circle (circumference around the central hole) may be excited to resonate, and the outside circle (outer circumference of the segment) may be excited to resonate, or in between. The bandwidth of the antenna of the first aspect can be 35 GHz or more.

[0012] Notably, an insulating layer may be a substrate

layer that has an insulating behavior, i.e., is electrically insulating. The insulating layer may, for instance, be made of dielectric material. A conductive layer may be electrically conducting, and may be formed on such substrate layer to form together a ring-shaped segment. However, a ring-shaped segment can also be formed in a different manner. The conductive layer may, for instance, be made of metal. Also the ground layer may be made of metal.

[0013] Further, the antenna feed may comprise one or more coaxial cables. Each of the one or more coaxial cables may comprise an outer shield connected to the ground layer, and may comprise an inner core connected to the first conductive layer of the first segment. Alternatively, the antenna feed may comprise a printed circuit board, which is connected to the ground layer and first conductive layer of the first segment. The antenna feed may also comprise one or more through-connections (e.g., extending through the first insulating layer and/or through a substrate base on which the ground layer is provided), wherein the through-connections may connect the antenna feed to the first conductive layer and/or to the ground layer.

[0014] In an implementation form of the antenna of the first aspect, the two or more ring-shaped segments comprise one or more further segments, each further segment comprising a further insulating layer and a further conductive layer, wherein each further insulating layer is arranged between two conductive layers of the second conductive layer and the further conductive layers.

[0015] Accordingly, multiple insulating layers and multiple conductive layers can be arranged in an alternating manner along the axis (and, for example, on the ground layer). In particular, the insulating and conductive layers may be stacked - starting with an insulating layer on the ground layer - in a direction along the axis. Each pair of a ring-shaped further insulating layer and a ring-shaped further conductive layer forms one of the one or more further ring-shaped segments. By increasing the number of the (further) ring-shaped segments arranged along the axis, the gain of the antenna can be further increased.

[0016] In an implementation form of the antenna of the first aspect, the two or more ring-shaped segments are DC-isolated from one another.

[0017] This means that no DC current can flow from one ring-shape segment to the other. The segments are electrically isolated from each other (at least regarding DC current). Only the first segment may be actively fed by using the antenna feed, which is connected to the first segment, particularly, to the first conductive layer of the first segment. The other ring-shaped segments are not configured and respectively connected to be actively feed by the antenna feed, but these other ring-shaped segments are configured to resonate and radiate together with the first ring-shaped segment, when the first ring-shaped segment is accordingly fed by the antenna feed.

[0018] In an implementation form of the antenna of the first aspect, the two or more ring-shaped segments

number 22 segments or less.

[0019] Accordingly, the number of ring-shaped segments may be a range of 2-22 ring-shaped segments (including the first and the second segment). With 22 ring-shaped segments, an antenna gain of 22 dB or more can be achieved, in particular, for an antenna area of 7x7 mm or less.

[0020] In an implementation form of the antenna of the first aspect, the two or more ring-shaped segments are stacked along the axis, wherein adjacent segments of the two or more ring-shaped segments are attached to each other by an insulating material.

[0021] In this manner, a compact antenna having a high antenna gain can be manufactured in a simple manner. The insulating material may be an insulating glue, epoxy, or resin. The insulating material may fill the holes of the ring-shaped segments when the two or more ring-shaped segments are attached to one another. The insulating material may also be a substrate material. For instance, the conductive layers of the different segments may be embedded into a substrate material (e.g., a substrate block), which the forms the insulating layers in the assembled antenna, and may also surround one or more or all the ring-shaped segments.

[0022] In an implementation form of the antenna of the first aspect, the second segment is larger in diameter than each other segment of the two or more ring-shaped segments.

[0023] The larger second segment increases the broadband characteristics of the antenna, i.e., increases the bandwidth of the antenna.

[0024] In an implementation form of the antenna of the first aspect, the diameter of the second segment is larger by at least 5-10% than a diameter of each other segment of the two or more ring-shaped segments.

[0025] In particular, the diameter of the second segment may be 5-10% larger than the diameter of that segment of the other ring-shaped segments, which has the largest diameter. In this way, a broadband antenna with a bandwidth of 35 GHz or more, or even 37 GHz or more, can be achieved.

[0026] In an implementation form of the antenna of the first aspect, the antenna feed is configured to feed the first segment such that the antenna radiates with a linear polarization or a circular polarization.

[0027] For instance, the antenna feed may be configured to feed the first segment with one coaxial cable, such that the antenna radiates with the linear polarization. Alternatively, the antenna feed may be configured to feed the first segment with more than one coaxial cable, such that the antenna radiates with the circular polarization. Accordingly, the antenna is configured to radiate with linear polarization or with circular polarization. That is, the antenna may be a linear polarized antenna or a circularly polarized antenna.

[0028] In an implementation form of the antenna of the first aspect, the antenna feed comprises a first coaxial cable and a second coaxial cable, wherein an inner core

of the first coaxial cable is connected at a different position to the first conductive layer than an inner core of the second coaxial cable.

[0029] In an implementation form of the antenna of the first aspect, the antenna feed is configured to feed the first segment with the first and the second coaxial cable such that the antenna radiates with a circular polarization.

[0030] Accordingly, the antenna is configured to radiate with a circular polarization. That is, the antenna is a circular polarized antenna. For instance, the connection positions of the coaxial cables can be arranged shifted by 90° on the ring-shaped first segment (with reference to the circumference of the ring-shaped first segment), in order to enable feeding the first segment with a phase shift that results in the antenna radiating with the circular polarization.

[0031] In an implementation form of the antenna of the first aspect, the antenna feed comprises a third coaxial cable, wherein an inner core of the third coaxial cable is connected at a different position to the first conductive layer than the inner cores of the first and second coaxial cables.

[0032] In an implementation form of the antenna of the first aspect, the antenna feed is configured to feed the first segment selectively with the first and the second coaxial cable or with the first and the third coaxial cable, such that the antenna respectively radiates with a first linear polarization or with a second linear polarization.

[0033] Accordingly, the third coaxial cable enables a switching of the antenna between the first and the second linear polarization. For instance, left and right linear polarizations may be switched in this manner.

[0034] In an implementation form of the antenna of the first aspect, each insulating layer is a substrate layer made of at least one of TSM30, Teflon, and ceramic.

[0035] A substrate layer may generally be made of a substrate material, wherein a substrate material may generally be a dielectric material having a dielectric constant in a range of 2-4.

[0036] In an implementation form of the antenna of the first aspect, the two or more ring-shaped segments are embedded into a substrate block.

[0037] The substrate block maybe made of the same material as the insulating layers, e.g., substrate layers. The insulating layers may also be formed by the substrate material of the substrate block, wherein the conductive layers of the individual ring-shaped segments may be embedded and arranged such in the substrate block, that the substrate material distances each adjacent pair (along the axis) of the ring-shaped conductive layers. Also the ground layer maybe embedded into the substrate block.

[0038] The substrate block may further protect the ring-shaped antenna segments, and may stabilize the whole assembly of the antenna of the first aspect. Furthermore, the substrate block can define the form factor of the antenna. For instance, the substrate block may have the shape of a cube or a cuboid, wherein a cross-section of

the substrate block (perpendicular to the axis) may have an area of 7x7 mm or less.

[0039] In an implementation form of the antenna of the first aspect, the antenna is a Yagi antenna.

[0040] A Yagi antenna (or Yagi-Uda antenna) is a directional antenna comprising two or more parallel resonant antenna elements in an end-fire array. These two or more parallel resonant antenna elements may be implemented by the two or more ring-shaped segments in this disclosure. A Yagi antenna further comprises a single driven element connected to a radio transmitter and/or receiver through a transmission line. This single driven element may be implemented by the first segment connected through the antenna feed in this disclosure. A Yagi antenna further has additional "parasitic elements" with no electrical connection. These additional elements may be implemented by the second segment and the one or more further segments in this disclosure. A Yagi antenna may further include a so-called reflector and any number of directors. In this disclosure, the ground layer may also act as reflector. The antenna of the first aspect may further comprise one or more directors.

[0041] In particular the antenna of the first aspect may be a planar linear or circular polarized Yagi antenna.

[0042] That is, this disclosure may provide a Yagi antenna, which is configured to transmit a linearly polarized or a circularly polarized radiation.

[0043] A second aspect of this disclosure provides an antenna array, wherein the antenna array comprises one or more antennas according to the first aspect or any implementation form thereof. The antennas of the first aspect may be arranged in one or more rows and or one or more columns of the antenna array. Each antenna of the first aspect may be fed individually, or multiple or all antennas of the first aspect may be fed together.

[0044] A third aspect of this disclosure provides a method for manufacturing an antenna, the method comprising: providing a ground layer; arranging two or more ring-shaped segments one after the other along an axis, the two or more ring-shaped segments comprising a first segment and a second segment; providing an antenna feed; wherein the first segment comprises a first insulating layer and a first conductive layer, the first insulating layer being arranged between the ground layer and the first conductive layer; wherein the second segment comprises a second insulating layer and a second conductive layer, the second insulating layer being arranged between the first conductive layer and the second conductive layer; and wherein the antenna feed is connected to the ground layer and to the first conductive layer.

[0045] The method of the third aspect may have implementation forms to manufacture any implementation form of the antenna of the first aspect described above. The method of the third aspect achieves the same advantages as the antenna of the first aspect and its implementation forms described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] The above described aspects and implementation forms (embodiments of this disclosure) are explained in the following description with respect to the enclosed drawings, wherein:

- FIG. 1 shows an antenna according to an embodiment of this disclosure in (a) and exploded view, and (b) an assembled view.
- FIG. 2 shows an antenna according to an embodiment of this disclosure in an exploded view.
- FIG. 3 shows an antenna according to an embodiment of this disclosure in an exploded view.
- FIG. 4 shows an antenna according to an embodiment of this disclosure in an exploded view.
- FIG. 5 shows an antenna according to an embodiment of this disclosure in an exploded view.
- FIG. 6 shows an antenna according to an embodiment of this disclosure in an assembled view.
- FIG. 7 shows an antenna according to an embodiment of this disclosure in an assembled view.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0047] FIG. 1 shows an antenna 10 according to an embodiment of this disclosure. In particular, FIG. 1 shows the antenna 10 in (a) in an exploded view and in (b) in an assembled view. The antenna 10 may be a Yagi antenna. The antenna 10 may further be configured to radiate with a linear polarization and/or with a circular polarization. For instance, it may be possible to switch the antenna 10 to radiate either with a linear polarization or with a circular polarization. Due to a small form factor (footprint), the antenna 10 is well suited to be integrated, or attached to, a vehicle, in particular, an airborne vehicle like an airplane, helicopter, or drone.

[0048] The antenna 10 comprises a ground layer 15, and at least two ring-shaped segments, wherein FIG. 1 illustrates an example of the antenna 10 with a first ring-shaped segment 11 and a second ring-shaped segment 12. The two shown ring-shaped segments 11, 12 are both shaped disc-like and have a hole provided at their center. The ring-shaped segments 11, 12, may have the same diameter (as exemplarily shown in FIG. 1), but may also have different diameters, as will be explained below. The ground layer 15 is also shown ring-shaped in FIG. 1, but this is only one of several examples.

[0049] The antenna 10 further comprises an antenna feed 14, which may, for example, comprise at least one coaxial cable. The at least one coaxial cable may form

the antenna feed 14. As an example, an antenna 10 having only one coaxial cable as the antenna feed 14 is shown in FIG. 1.

[0050] The first segment 11 and the second segment 12 are both arranged on an axis 13, which maybe an optical axis of the antenna 10. That means, that radiation that is transmitted by the antenna 10 may be mainly transmitted along this axis 13, i.e., may be directed along this axis 13. Generally, the two or more segments of the antenna 10, which include the first segment 11 and the second segment 12, are arranged one after the other along the axis 13.

[0051] As shown further in FIG. 1, the first segment 11 comprises a first insulating layer 11a (e.g., a first substrate layer with insulating behavior), which may be provided on the ground layer 15, and a first conductive layer 11b provided on the first insulating layer 11a. This means that the first insulating layer 11a is arranged between the ground layer 15 and the first conductive layer 11b of the first segment 11. The individual layers 11a and 11b of the first segment 11 are each ring-shaped, and may be attached together by using, for instance, an insulating glue, epoxy, or resin. The glue, epoxy, or resin may thereby fill the holes of the ring-shaped layers 11a and 11b of the first segment 11. However, the different layers 11a and 11b of the first segment 11 may also be attached to another in a different manner, and moreover the holes of the different layers 11a and 11b of the first segment 11 may also be free, i.e., maybe filled with air. Notably, the ground layer 15 may serve as a ground connection of the antenna 10, and may further serve as a reflector for radiation provided by the antenna 10. The ground layer 15 may be ring-shaped as shown, or may be circular (without hole). The ground layer 15 may alternatively have the shape of a square, of a rectangle, or of an octagon. When the antenna 10 radiates, the radiation may be mainly directed along the axis 13 in a direction away from the ground layer 15, and this directivity may be supported by the ground layer 15.

[0052] The second segment 12 comprises a second insulating layer 12a (e.g. a second substrate layer with insulating behavior), and a second conductive layer 12b provided on the second insulating layer 12a. Since the one or more ring-shaped segments 11, 12 of the antenna 10 are arranged one after the other along the axis 13, the second insulating layer 12a is arranged between the first conductive layer 11b and the second conductive layer 12b. Thereby, the second insulating layer 12a may be arranged on and/or may be attached to the first conductive layer 11b.

[0053] FIG. 1 schematically indicates in (a) that the antenna feed 14 is connected to the first segment 11, in particular, is connected to the first conductive layer 11b. Further, the antenna feed 14 is connected to the ground layer 15. For example, as illustrated, the antenna feed 14 may comprise at least one coaxial cable, which comprises an outer shield 14a and an inner core 14b. In particular, as indicated by the dashed lines in (a), the outer

shield 14a may be connected to the ground layer 15, and the inner core 14b may be connected to the first conductive layer 11b of the first segment 11. This may be true for each coaxial cable, if the antenna feed 14 comprises more than one coaxial cable. The antenna feed 14 is connected particularly only to the first segment 11 (not the second segment 12 or further segments). The antenna feed 14 is configured to feed the first segment 11 such that the antenna 10 radiates with a linear polarization or with a circular polarization.

[0054] Notably, each insulating layer 11a, 12a may be a substrate layer having (electrical) insulating behavior. Thereby, substrate material may, for instance, comprise at least one of Teflon, ceramic and TSM30. TSM30 describes a polyamide 66/6 copolymer (nylon 66/6) material filled with 30% mineral. Further, each conductive layer 11b, 12b may be made of metal, i.e., may be metal layer. Thereby, the metal may comprise at least one of aluminum and copper. The metal of the conductive layer 11b, 12b may be provided as a sheet, particularly a thin-sheet, on the insulating substrate layer 11a, 12a.

[0055] FIG. 2 shows an antenna 10 according to an embodiment of this disclosure, which builds on the embodiment shown in FIG. 1. Same elements in FIG. 1 and FIG. 2 are labelled with the same reference signs, and may be implemented in an identical manner.

[0056] FIG. 2 shows that the two or more ring-shaped segments of the antenna 10 may comprise, in addition to the first segment 11 and the second segment 12 shown in FIG. 1, one or more further segments 20. In FIG. 2, three further segments 20 are illustrated, as an example, in addition to the first segment 11 and the second segment 12.

[0057] Each ring-shaped further segment 20 may comprise a further insulating layer 20a and a further conductive layer 20b, as FIG. 2 illustrates in the magnification of one of the further segments 20 (left side, indicated by dashed line). The further insulating layers 20a may be implemented like the insulating layers 11a and 12a, and the further conductive layers 20b may be implemented like the conductive layers 11b and 12b, for example, as described above. The further ring-shaped segments 20 are arranged such one after the other along the axis 13, that each further insulating layer 20a is arranged between two conductive layers 12b, 20 of the second conductive layer 12b and the further conductive layers 20b. In particular, the insulating layer 20a of one of the further segments 20 is arranged between the second conductive layer 12b of the second segment 12 and its own further conductive layer 20b, while the further insulating layer 20a of each other further segments 20 arranged along the axis 13 is arranged between its own further conductive layer 20b and the further conductive layer 20b of the further segment 20, which is arranged before it on the axis 13 (referring to the direction away from the ground layer 15).

[0058] FIG. 2 also shows that the two or more ring-shaped segments 11, 12, 20 may be provided on a sub-

strate base 21. The substrate base 21 may be made of substrate material (see above), and/or may be a part of a substrate block or a housing of the antenna 10. The substrate base 21 may additionally serve as a reflector and/or director for the antenna radiation of the antenna 10. Moreover, the substrate base 21 may be provided with the ground layer 15, for instance, a metal layer may be formed on the substrate base 21. The ground layer 15 may, in this case, have the shape of the substrate base 21, wherein in FIG. 2 a square-shaped ground layer 15 is exemplarily depicted.

[0059] FIG. 3 shows an antenna 10 according to an embodiment of this disclosure, which builds on the embodiments shown in FIG. 1 and FIG. 2, respectively. Same elements in these figures are again labelled with the same reference signs, and may be implemented in an identical manner.

[0060] The antenna 10 shown in FIG. 3 exemplarily includes six ring-shaped segments - namely the first segment 11, the second segment 12, and four further segments 20. Thereby, FIG. 3 shows also that the second segment 12 may have a larger diameter than all the other segments 11, 20 of the antenna 10. In particular, the diameter of the second segment 12 may be larger by at least 5-10% than each other diameter of each other segment 11, 20 of the antenna 10. The diameters of all the other segments 11, 20 may be the same or may be different. In the latter case, if the other diameters are different, then the largest other diameter of the other segments 11, 20 is still 5-10% smaller than the diameter of the second segment 12.

[0061] FIG. 3 further shows that the first segment 11 may be connected by two coaxial cables, which in this example form the antenna feed 14. The two coaxial cables may be used to feed the first segment 11. In particular, FIG. 3 shows that the two coaxial cables forming the antenna feed 14 may be connected to the first segment 11 at different positions, namely, with an offset of substantially 90° moving along the circumference of the first segment 11. That is, the two connection positions may be offset by an angle of 90° with respect to the center of the hole of the first segment 11. In this way, the first segment 11 can be fed using the antenna feed 14 having the two coaxial cables, such that the antenna 10 radiates with a circular polarization.

[0062] FIG. 4 shows an antenna 10 according to an embodiment of this disclosure, which builds on any of the previously described embodiments. Again, same elements shown in the respective figures are labelled with the same reference signs, and may be implemented in an identical manner.

[0063] In particular, FIG. 4 shows the antenna 10 of FIG. 3 in a different side view perspective. It can be seen that each of the first segment 11, the second segment 12 and exemplary four further segments 20 has the shape of a thin ring or ring-like layer. In particular, a diameter of each ring-shaped segment 11, 12, 20 maybe much larger than the thickness of the same ring-shaped seg-

ment 11, 12, 20. Thereby, a thickness of any ring-shaped segment 11, 12, 20 may be defined by its extension along the axis 13.

[0064] In FIG. 4, also the two coaxial cables forming the antenna feed 14 in this example, including their different connection positions at the first segment 11, are visible.

[0065] FIG. 5 shows an antenna 10 according to an embodiment of this disclosure, which builds on the previously described embodiments. Again, same elements shown in the respective figures are labelled with the same reference signs, and may be implemented in an identical manner.

[0066] FIG. 5 shows in particular that the antenna feed 14 - here exemplarily comprising two coaxial cables - may be embedded and/or may extend through the substrate base 21. The coaxial cables are thereby exposed, so that they can be connected to, for example, a radio unit. The substrate base 21 may be part of a substrate block, and the first segment 11 may be configured to be fed by means of the exposed antenna feed 14, in order to cause the antenna 10 to transmit radiation.

[0067] FIG. 6 shows an antenna 10 according to an embodiment of this disclosure, which builds on the previously described embodiments. Again, same elements shown in the respective figures are labelled with the same reference signs, and may be implemented in an identical manner.

[0068] In FIG. 6, the two or more ring-shaped segments 11, 12, 20 of the antenna 10 are not visible, as they are embedded into a substrate block 60. It can be seen that the ring-shaped segments, in particular the first ring-shaped segment 11, may nevertheless be fed by connection to the antenna feed 14, which may comprise one or more coaxial cables (exemplarily two coaxial cables forming the antenna feed 14 are shown), which are exposed as they extend from the substrate block 60.

[0069] The substrate block 60 maybe made of a substrate material, which may include at least one of Teflon, ceramic, and TSM30. The substrate block 60 may comprise the substrate base 21, which is shown in FIG. 2. That is the substrate block 16 may also comprise the ground layer 15, for instance, as an embedded metal layer. The two or more ring-shaped segments 11, 12, 20 may also be embedded into the substrate block 60. Further, the two or more ring-shaped segments 11, 12, 20 may be attached to one another within the substrate block 60, for instance, by means of an insulating glue, epoxy, or resin. The glue, epoxy, or resin may have a dielectric constant in a range of 2-4, in particular, in a range of 2.8-3.2. Also the entire assembly of the ring-shaped segments 11, 12, 20 may be embedded into a glue, epoxy, or resist material having an insulating behavior. The epoxy, glue, or resist material may thereby fill the free spaces in between the ring-shaped segments 11, 12, 20, wherein these free spaces are created by the holes.

[0070] FIG. 7 shows an antenna 10 according to an embodiment of this disclosure, which builds on the pre-

viously described embodiments. Again, same elements shown in the respective figures are labelled with the same reference signs, and may be implemented in an identical manner.

[0071] In particular, FIG. 7 shows that the two or more ring-shaped segments 11, 12, 20 are embedded into the substrate block 60, but at least one ring-shaped segment is exposed at a front side. In particular, the front-most ring-shaped segment 11, 12, 20 is exposed (front-most referring to the arrangement of the segments on the axis 13 away from the ground layer 15), wherein the front-most ring shaped segment may be the second segment 12 or a further segment 20 of the two or more ring-shaped segments. This exposure may support the directivity of the radiation provided by the antenna 10.

[0072] In summary, the present disclosure provides an antenna 10, which may specifically be a Yagi antenna. The antenna 10 may be operated to radiate with either a linear polarization or with a circular polarization. The antenna 10 is advantageously of a small form factor (has a small footprint), and is therefore is well-suited for integration into a small vehicle, especially an airborne vehicle. Even though the footprint of the antenna 10 is small, the antenna 10 shows considerable gain, which is higher than for a conventional antenna with a similar footprint. In other words, the antenna 10 may have a smaller footprint than a conventional antenna having the same gain (e.g., a patch antenna). The gain of the antenna 10 depends on the number of the ring-shaped segments 11, 12, 20. As discussed above, the number of the ring-shaped segments 11, 12, 20 maybe in a range of 2-22.

Claims

1. An antenna (10) comprising:

- a ground layer (15);
 - two or more ring-shaped segments (11, 12, 20) arranged one after the other along an axis (13), the two or more ring-shaped segments (11, 12, 20) comprising a first segment (11) and a second segment (12); and
 - an antenna feed (14);
- wherein the first segment (11) comprises a first insulating layer (11a) and a first conductive layer (11b), the first insulating layer (11a) being arranged between the ground layer (15) and the first conductive layer (11b);
- wherein the second segment (12) comprises a second insulating layer (12a) and a second conductive layer (12b), the second insulating layer (12a) being arranged between the first conductive layer (11b) and the second conductive layer (12b); and
- wherein the antenna feed (14) is connected to the ground layer (15) and the first conductive layer (11b).

2. The antenna (10) according to claim 1, wherein:

the two or more ring-shaped segments (11, 12, 20) comprise one or more further segments (20), each further segment (20) comprising a further insulating layer (20a) and a further conductive layer (20b); and
each further insulating layer (20a) is arranged between two conductive layers (12b, 20b) of the second conductive layer (12b) and the further conductive layers (20b).

3. The antenna (10) according to claim 1 or 2, wherein the two or more ring-shaped segments (11, 12, 20) are DC-isolated from one another.

4. The antenna (10) according to one of the claims 1 to 3, wherein the two or more ring-shaped segments (11, 12, 20) number 22 segments or less.

5. The antenna (10) according to one of the claims 1 to 4, wherein the two or more ring-shaped segments (11, 12, 20) are stacked along the axis (13), wherein adjacent segments of the two or more ring-shaped segments (11, 12, 20) are attached to each other by an insulating material.

6. The antenna (10) according to one of the claims 1 to 5, wherein the second segment (12) is larger in diameter than each other segment (11, 20) of the two or more ring-shaped segments (11, 12, 20).

7. The antenna (10) according to claim 6, wherein the diameter of the second segment (12) is larger by at least 5-10% than a diameter of each other segment (11, 20) of the two or more ring-shaped segments (11, 12, 20).

8. The antenna (10) according to one of the claims 1 to 7, wherein the antenna feed (14) is configured to feed the first segment (11) such that the antenna (10) radiates with a linear polarization or with a circular polarization.

9. The antenna (10) according to one of the claims 1 to 8, wherein:

the antenna feed (14) comprises a first coaxial cable and a second coaxial cable; and
an inner core (14b) of the first coaxial cable is connected at a different position to the first conductive layer (11b) than an inner core (14b) of the second coaxial cable.

10. The antenna (10) according to claim 9, wherein the antenna feed (14) is configured to feed the first segment (11) with the first and the second coaxial cable such that the antenna (10) radiates with a circular

polarization.

11. The antenna (10) according to claim 9 or 10, wherein:

the antenna feed (14) comprises a third coaxial cable; and
an inner core (14b) of the third coaxial cable (14) is connected at a different position to the first conductive layer (11b) than the inner cores of the first and second coaxial cables.

12. The antenna (10) according to claim 11, wherein the antenna feed (14) is configured to feed the first segment (11), selectively with the first and the second coaxial cable or with the first and the third coaxial cable, such that the antenna (10) respectively radiates with a first linear polarization or with a second linear polarization.

13. The antenna (10) according to one of the claims 1 to 12, wherein each insulating layer (11a, 12a, 20a) is a substrate layer made of at least one of TSM30, Teflon, and ceramic.

14. The antenna (10) according to one of the claims 1 to 13, wherein the two or more ring-shaped segments (11, 12, 20) are embedded into a substrate block (60).

15. The antenna (10) according to one of the claims 1 to 14, wherein the antenna (10) is a Yagi antenna.

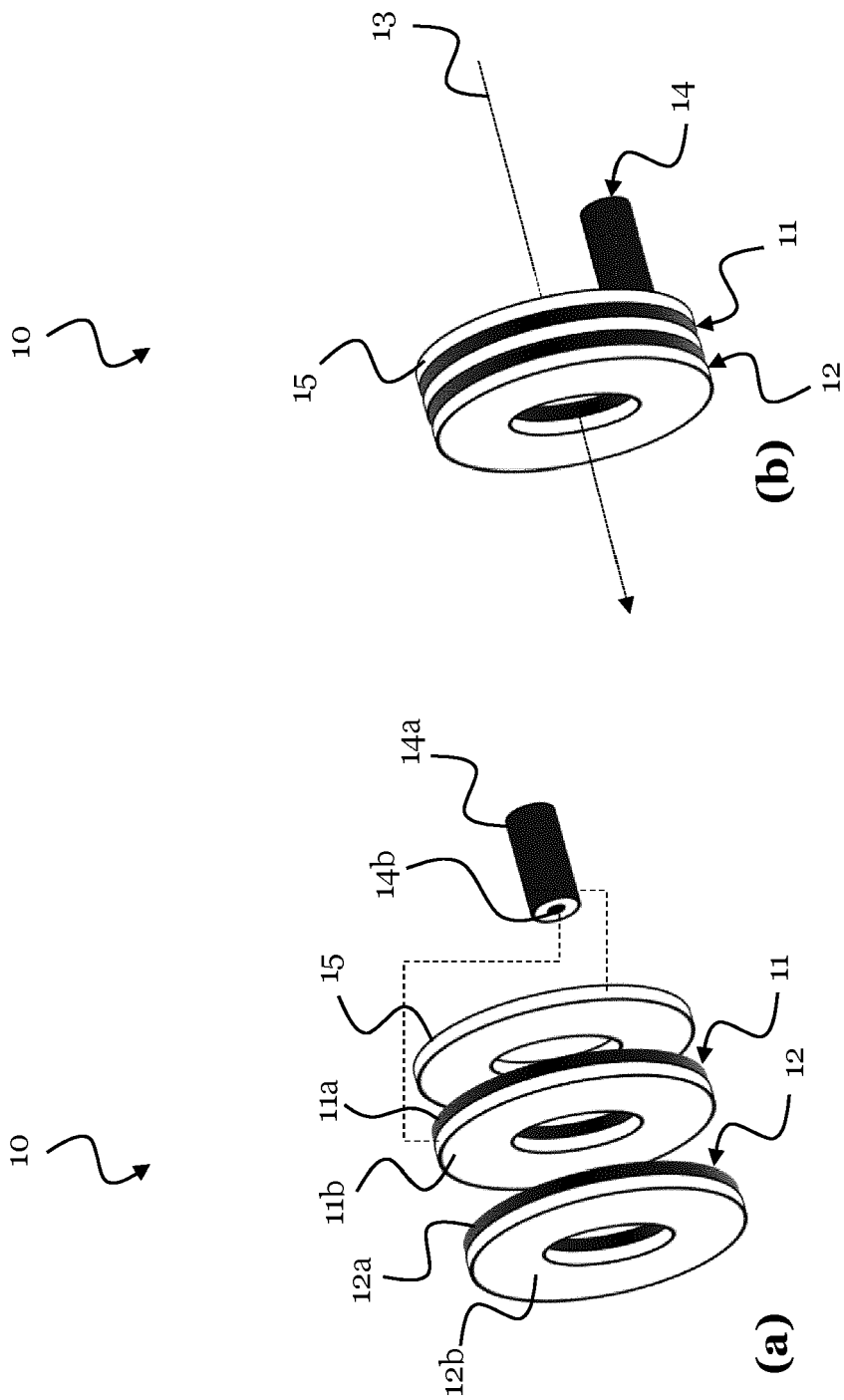


FIG. 1

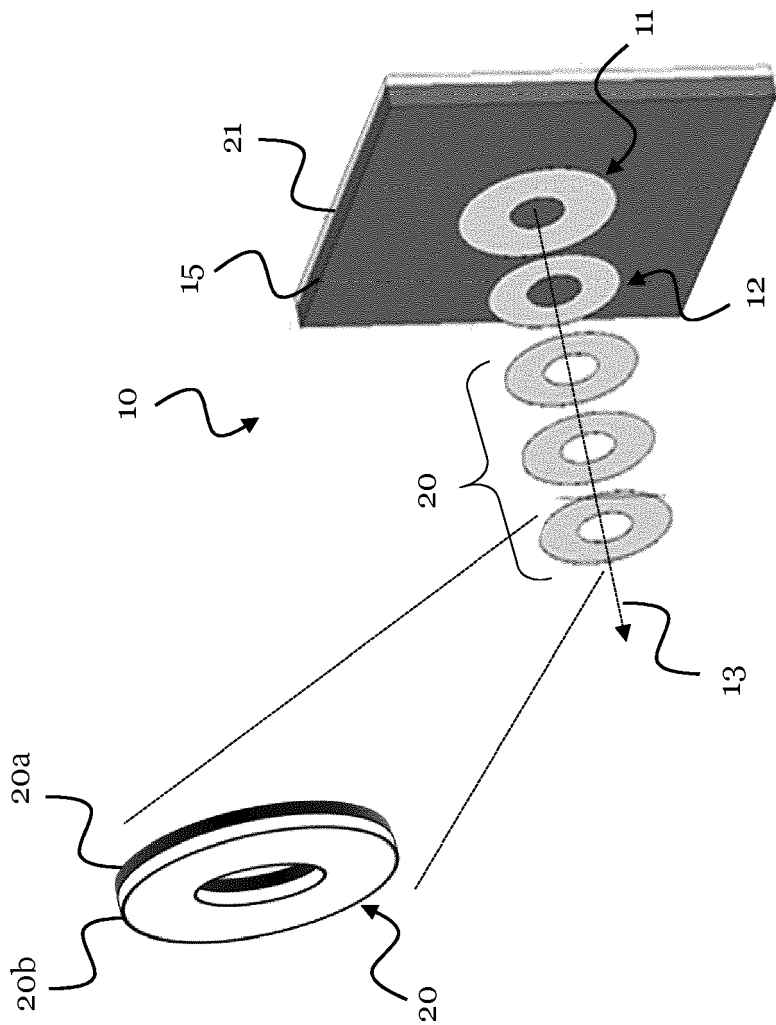


FIG. 2

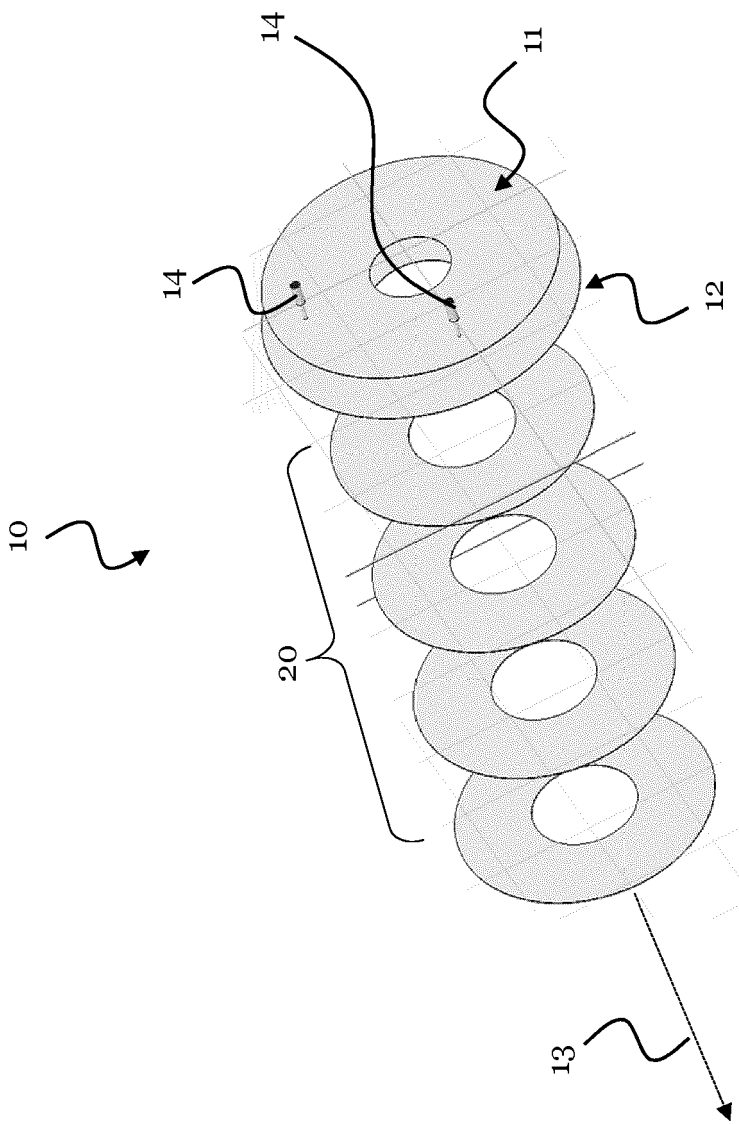


FIG. 3

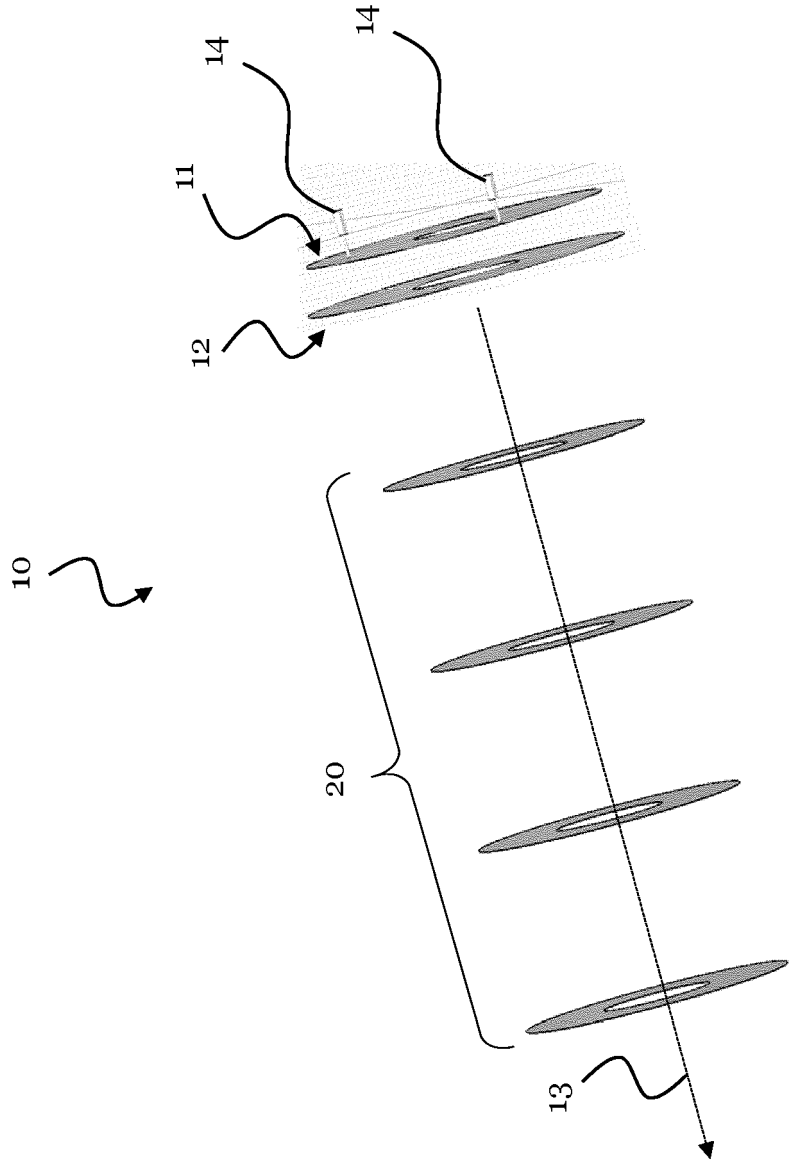
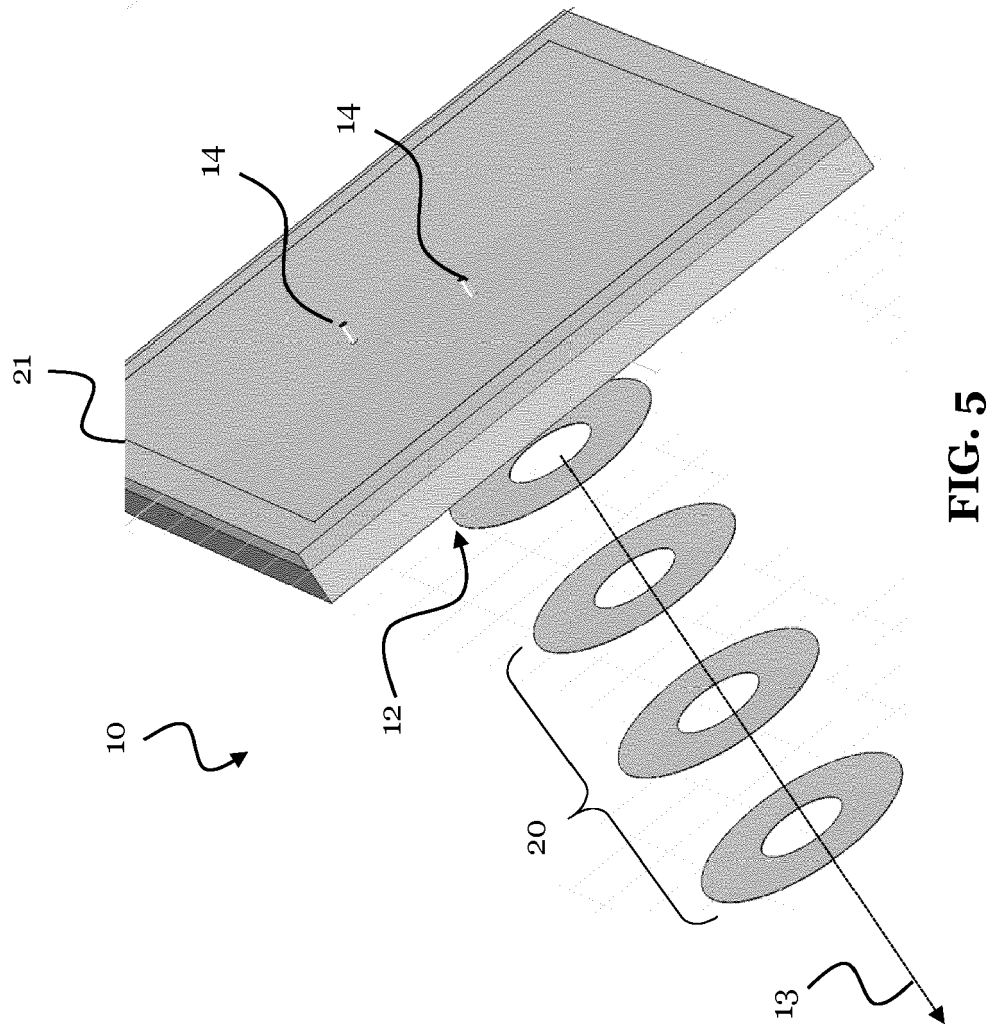


FIG. 4



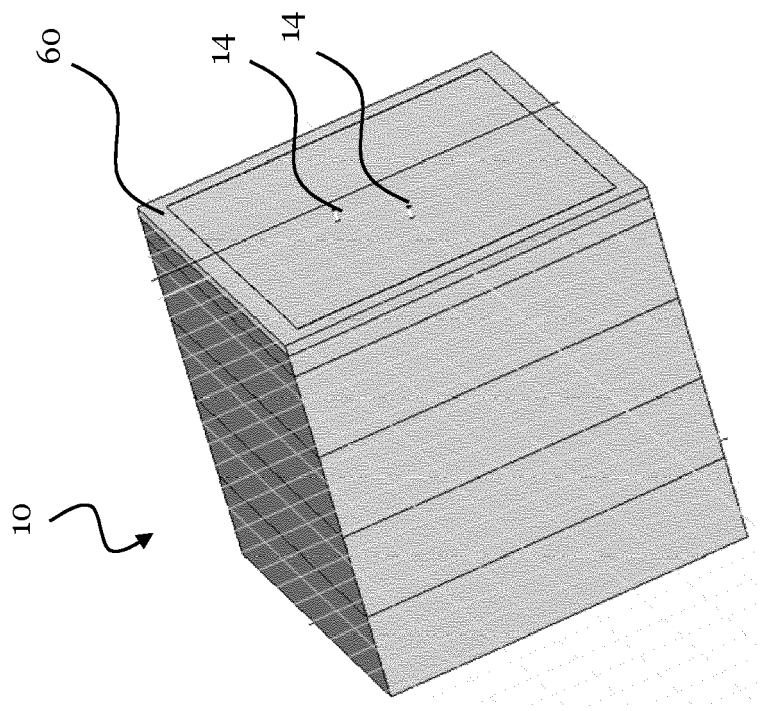


FIG. 6

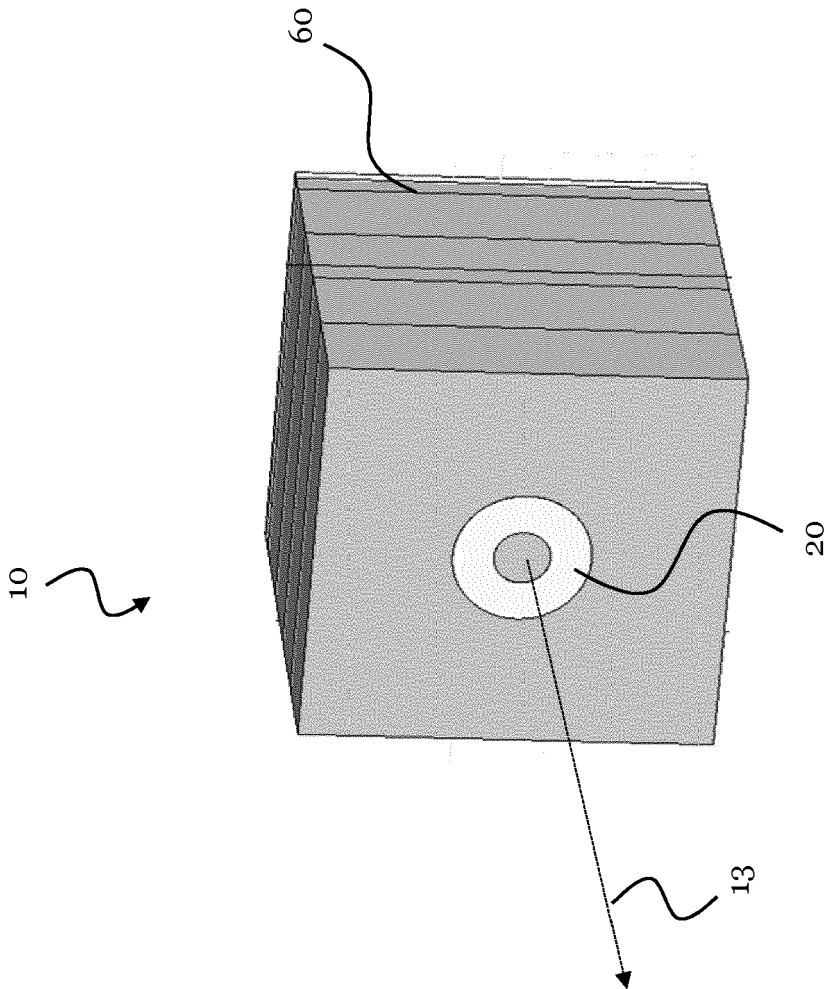


FIG. 7



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Application Number

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1	The present search report has been drawn up for all claims		
Place of search The Hague		Date of completion of the search 6 December 2021	Examiner Wattiaux, Véronique
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	

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
1 The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 6 December 2021	Examiner Wattiaux, Véronique
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The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82