(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 327 865 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
30.05.2018 Bulletin 2018/22

(21) Application number: **17206315.8**

(22) Date of filing: **02.03.2015**

(51) Int Cl.:
H01Q 9/04 *(2006.01)* ***H01Q 21/06*** *(2006.01)*
H01Q 21/24 *(2006.01)* ***H01Q 21/26*** *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Validation States:
MA

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
15157084.3 / 3 065 217

(71) Applicant: **Huawei Technologies Co., Ltd.**
Longgang District
Shenzhen, Guangdong 518129 (CN)

(72) Inventors:
- **Segador Alvarez, Juan**
  Munich (DE)
- **Madden, Steve**
  Munich (DE)
- **Flamini, Roberto**
  Munich (DE)
- **Biscontini, Bruno**
  Munich (DE)
- **Kokkinos, Titos**
  Munich (DE)
- **Feilner, Werner**
  Munich (DE)
- **Rist, Bernhard**
  Munich (DE)

(74) Representative: **Kreuz, Georg Maria**
Huawei Technologies Duesseldorf GmbH
Riesstrasse 8
80992 München (DE)

Remarks:
This application was filed on 11-12-2017 as a divisional application to the application mentioned under INID code 62.

(54) PROBE ARRANGEMENT FOR A PROBE-FED PATCH ANTENNA

(57) Provided is a probe arrangement for a probe-fed patch antenna, comprising a foot and a top and at least a first probe and a second probe, wherein the first probe and the second probe are electrically separated from each other, wherein each probe comprises a feeding portion, an intermediate portion and a termination portion, wherein the feeding portion extends from the foot to the top, wherein the intermediate portion and the termination portion are arranged at the top, wherein the intermediate portion extends at the top from the feeding portion to the termination portion, and wherein a width of the termination portion in a direction perpendicular to an extension direction of the intermediate portion is larger than a width of the intermediate portion in the direction perpendicular to the extension direction of the intermediate portion.

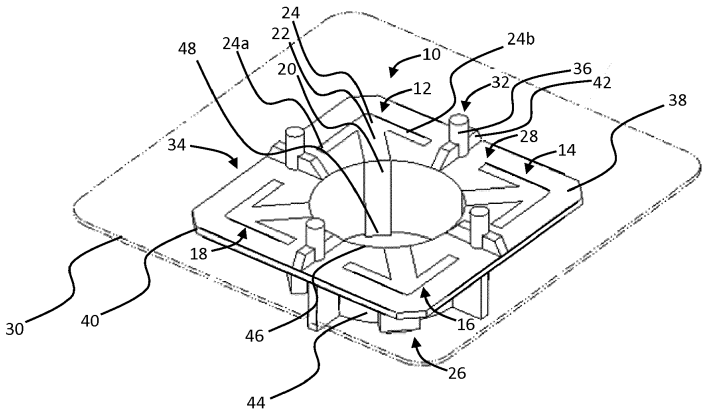


Fig. 1

EP 3 327 865 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a probe arrangement. In particular, the present invention relates to a probe arrangement for a probe-fed patch antenna.

BACKGROUND

[0002] Probe-fed patch antennas are a particular type of radio antennas which typically have a flat sheet or "patch" of an electrically conductive material, wherein the electro-magnetic radiation emitted by the patch is caused by a probe or a probe arrangement effecting currents in the patch. Furthermore, patch antennas are typically resonant, narrow band structures.

[0003] In order to get a second resonance to make a patch antenna broadband, it is known to make use of a second parasitic stacked patch. However, although being a very common and effective technique, the stacking of patches increases the dimensions of the patch antenna making it unsuitable for applications having strict size limitations.

SUMMARY

[0004] It is thus the object of the present invention to provide an improved probe arrangement to feed a patch antenna and in particular to provide an improved probe arrangement for a dual-polarized probe-fed patch antenna with superior cross polar discrimination and isolation levels.

[0005] The foregoing and other objects are achieved by the features of the independent claim. Further implementation forms are apparent from the dependent claims, the description and the figures.

[0006] According to a first aspect, a probe arrangement is provided which is in particular for a single electrically conductive patch and which comprises a foot and a top and at least a first probe and a second probe, wherein the first probe and the second probe are electrically separated from each other. Each probe comprises a feeding portion, an intermediate portion and a termination portion. The feeding portion extends from the foot to the top, in particular in a first direction. The intermediate portion and the termination portion are arranged at the top. The intermediate portion extends at the top from the feeding portion to the termination portion in a second direction that is in particular different from the first direction. A width of the termination portion in a third direction perpendicular to the second direction and in particular different from the first direction is larger than a width of the intermediate portion in the third direction.

[0007] Thus, the probe arrangement according to the first aspect may be configured to extend in all three dimensions. This facilitates achieving a second resonance when combining the probe arrangement with a single patch while maintaining a compact design of the probe arrangement, thereby making the probe arrangement according to the first aspect suitable for applications having strict size limitations. Furthermore, the compact design allows for placing four or more of the probes underneath a single patch, which particularly allows the probe arrangement according to the first aspect to be used for forming a dual-polarized patch antenna.

[0008] In a first implementation form of the probe arrangement according to the first aspect as such, the probe arrangement comprises four or more probes.

[0009] Having four or more probes is particularly advantageous in that it allows a single patch fed by the probe arrangement to emit dual-polarized radiation.

[0010] In a second implementation form of the probe arrangement according to the first aspect as such or according to the first implementation form of the first aspect, the intermediate portion and the termination portion of the probes are symmetric with regard to a symmetry plane perpendicular to the second direction, wherein the symmetry plane extends in particular through a center of the probe arrangement.

[0011] Thus, the intermediate portion and the termination portion of the probes are symmetric with respect to a main polarization plane, thereby improving the characteristics of the radiation pattern emitted by a single patch that is fed by the probes of the probe arrangement.

[0012] In a third implementation form of the probe arrangement according to the first aspect as such or according to any preceding implementation form of the first aspect, the intermediate portion and the termination portion of each probe form an arrow-shape.

[0013] By forming an arrow-shape, the probes of the probe arrangement allow for a particularly compact design which facilitates using the probes of the probe arrangement with a single patch while keeping the probes of the probe arrangement electrically big enough to have the needed inductance to compensate the probe to patch capacitance and to provide for the second resonance, thereby achieving broadband characteristics.

[0014] In a fourth implementation form of the probe arrangement according to the first aspect as such or according to any preceding implementation form of the first aspect, the probes are evenly distributed around a centerline of the probe arrangement, the centerline of the probe arrangement extending in particular in a vertical direction through a center of the probe arrangement.

[0015] By distributing the probes evenly around the centerline of the probe arrangement, the characteristics of the radiation pattern emitted by a single patch that is fed by the probe arrangement is improved as the probes of the probe arrangement are symmetric with regard to a rotation around the centerline about a predetermined angle determined by the number of probes.

[0016] In a fifth implementation form of the probe arrangement according to the first aspect as such or according to any preceding implementation form of the first aspect, each feeding portion has two input ports.

[0017] Having two input ports allows using two power amplifiers (PAs) with each probe pair, wherein each PA provides the same or a substantially same differential input signal to the probes of the probe pair, thereby lowering the power handled by each PA as the output power of different PAs providing the same input signal to the input ports of a single probe may be combined in the feeding portion of the probe to which the intermediate and the termination portion are connected in series. Moreover, each probe may also have three, four or more input ports, thereby further reducing the power output required from the three, four, or more PAs, respectively.

[0018] Furthermore, the impedance of a probe pair may be adjusted by changing the distance of the probes of the probe pair, so that PAs with even lower output power can be used. The low impedance of the probe pairs further simplifies the circuitry needed for interconnection with the PAs, reduces the losses and increases the operating bandwidth.

[0019] In a sixth implementation form of the probe arrangement according to the first aspect as such or according to any preceding implementation form of the first aspect, the probe arrangement further comprises a dielectric support, wherein a bottom side of the dielectric support forms the foot of the probe arrangement and a top layer of the dielectric support forms the top of the probe arrangement. A maximum cross-section dimension of the top layer is larger than a maximum cross-section dimension of the bottom side and the intermediate portion and the termination portion of each probe lie preferably within an outer edge of the top layer when seen from foot to top.

[0020] As used throughout the description and claims, the term "bottom side" is intended to be understood in a broad sense referring to an actual surface of the dielectric support as well as to a virtual surface of the dielectric support, a virtual surface being a planar area having a contour that bisects a closed peripheral edge of the dielectric support and in particular a planar area having a contour that bisects an edge of a tube of the dielectric support.

[0021] In a seventh implementation form of the probe arrangement according to the sixth implementation form of the first aspect, the probes are attached to a top surface (area) or a bottom surface (area) of the top layer or are at least in part integrated into the top layer.

[0022] Attaching the probes to or integrating the probes into top or bottom surface(s) (areas) of the top layer allows to plate, print or laminate the probes onto the dielectric support or into an etched, cut-out, cast, or molded recess in the dielectric support and relaxes the requirements imposed on the probes as compared to self-supporting probes which are also contemplated.

[0023] In an eighth implementation form of the probe arrangement according to the sixth or according to the seventh implementation form of the first aspect, the dielectric support comprises dielectric spacers which are arranged on the top surface of the top layer and which are configured to receive a (single) electrically conductive patch.

[0024] The dielectric spacers allow for attaching the (single) patch on the probe arrangement in a simple and thus efficient manner while ensuring a pre-determined distance as well as isolation between the (single) electrically conductive patch and the probes.

[0025] In a ninth implementation form of the probe arrangement according to any one of the sixth to the eighth implementation form of the first aspect, the dielectric support has an aperture, wherein the aperture is preferably located at a center of the top layer.

[0026] Having an aperture in the dielectric support, in particular in the top layer of the dielectric support, allows guiding the feeding portions of the probes through the aperture from the top surface of the top layer of the probe arrangement.

[0027] In a tenth implementation form of the probe arrangement according to any one of the sixth to the ninth implementation form of the first aspect, the feeding portions extend along an inner surface or an outer surface of a tube connecting foot and top, wherein a circumferential edge of the tube is preferably attached to an inner edge of the aperture.

[0028] Having the feeding portions extend along the inner surface or the outer surface of a tube connecting foot and top, the feeding portions may be plated, printed or laminated onto the inner surface or the outer surface of the tube or into an etched, cut-out, cast, or molded recess in the tube, thereby further relaxing the requirements imposed on the probes as compared to probes with self-supporting feeding portions which are also contemplated.

[0029] In an eleventh implementation form of the probe arrangement according to the first aspect as such or according to any preceding implementation form of the first aspect, a total height of the probe arrangement is less than a tenth of the wavelength for a central frequency of the probe arrangement, the central frequency being 700Hz or more, 1600 MHz or more, 2200 MHz or more, or 3200MHz or more.

[0030] Thus, the probe arrangement has an ultra-flat design that can be used for designing a broadband patch antenna by combing the probe arrangement with a patch antenna, making it possible to use the probe arrangement and in particular a patch antenna comprising the probe arrangement in typical frequency bands used in mobile communications such as 790-960 MHz, 1710-2170 MHz, 2300-2700 MHz or 3300-3800 MHz.

[0031] According to a second aspect, a probe-fed patch antenna is provided which comprises the probe arrangement according to the first aspect as such or which comprises the probe arrangement according to any preceding implementation form of the first aspect and which comprises a (preferably single) electrically conductive patch.

[0032] This allows achieving, by properly combining the intrinsic capacitance from the probe-patch transition

that can be controlled by changing the distance between the probe and the patch and the inductance introduced by the probe itself that can be controlled by changing for example the size of the intermediate or the termination portion, a second resonance at a desired frequency, thereby making the probe-fed patch antenna broadband.

[0033] In a first implementation form of the probe-fed patch antenna according to the second aspect as such, the probe-fed patch antenna comprises the dielectric support according to any one of the sixth to the ninth implementation form of the first aspect, wherein the (single) electrically conductive patch is arranged on the top surface of the top layer.

[0034] Having the (single) electrically conductive patch arranged on the top surface of the top layer and the probes attached to the bottom surface of the top layer or at least in part integrated into the top layer facilitates enforcing and maintaining a pre-defined distance between the patch and the probes.

[0035] In a second implementation form of the probe-fed patch antenna according to the first implementation form of the second aspect, the dielectric support, the probes, and the (single) electrically conductive patch are formed as one piece and are in particular formed from different materials.

[0036] Having the dielectric support, the probes, and the single electrically conductive patch formed as one piece allows manufacturing the probe-fed patch antenna as a Molded Interconnect Device (MID), thereby making the manufacturing process more efficient than assembling the probe-fed patch antenna from different components.

[0037] In a third implementation form of the probe-fed patch antenna according to the second aspect as such or according to any preceding implementation form of the second aspect, the probes are configured to induce currents to the (single) electrically conductive patch through capacitive coupling.

[0038] By inducing currents from the probes to the patch through capacitive coupling, no galvanic contact or soldering between the patch and the probes is required, thereby simplifying the manufacturing process and avoiding metal joints that may be a source of errors and passive intermodulation (PIM).

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] Further advantages and features of the invention will become apparent from the following description, in which the invention will be described on the basis of implementation examples with reference to the accompanying drawings, in which:

Fig. 1 is a schematic perspective view of an exemplary probe arrangement;

Fig. 2 is a schematic top view of the probe arrangement of Fig. 1;

Fig. 3 is a schematic section view of the probe arrangement of Fig. 1;

Fig. 4 shows a radiation pattern of the probe arrangement of Fig. 1;

Fig. 5 shows a modification of the exemplary probe arrangement of Figs. 1 to 3 in which each probe has two input ports;

Fig. 6 shows a modification of the exemplary probe arrangement of Figs. 1 to 3 or 5 for a single-polarized patch antenna;

Fig. 7 shows the probe arrangement of Fig. 6 combined with a circular patch;

Figs. 8 to 11 show modifications of the probe arrangements of Figs. 1 to 7 in regard to different termination portion shapes;

Fig. 12 shows a modification of the probe arrangements of Figs. 1 to 11;

Fig. 13 is a schematic horizontal section view of a probe-fed patch antenna;

Fig. 14 is a schematic vertical section view of the probe-fad patch antenna of Fig. 13;

Fig. 15 is a schematic bottom view of the probe-fad patch antenna of Fig. 13;

Fig. 16 is a schematic horizontal section view of a modification of the probe-fed patch antenna of Figs. 13 to 15; and

Fig. 17 is a schematic vertical section view of the probe-fad patch antenna of Fig. 16.

DETAILED DESCRIPTION OF IMPLEMENTATION EXAMPLES

[0040] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to implementation examples illustrated in the drawings and specific language will be used to describe the same. It will, nevertheless, be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated apparatus and such further applications of the principles of the invention as illustrated therein or being described in the above Summary section being contemplated as would normally occur now or in the future to one skilled in the art to which the invention relates.

[0041] Figs. 1 to 3 are schematic views of an exemplary probe arrangement 10. The probe arrangement 10 com-

prises four electrically conductive probes 12-18. Probes 12 and 16 form a first probe pair and probes 14 and 18 form a second probe pair. Each of the probes 12-18 comprises a feeding portion 20, an intermediate portion 22 and a termination portion 24 which are made of an electrically conductive material such as metal and which are connected in series.

[0042] The feeding portion 20 of each probe 12-18 extends in a first direction, i.e., from the foot 26 of the probe arrangement 10 to the top 28 of the probe arrangement 10. The intermediate portion 22 and the termination portion 24 of each probe 12-18 extend at the top 28 of the probe arrangement 10. The extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 of each probe pair lie in a same vertical plane, wherein the two vertical planes corresponding to the two probe pairs are preferably perpendicular to each other.

[0043] Preferably, as shown in Figs. 1 to 3, the extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 of each probe pair are parallel to each other and perpendicular to the first direction. Thus, the extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 of each probe pair lie on a same line which is orientated in a second direction and which is perpendicular to the first direction. Furthermore, the extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 of the first probe pair are preferably perpendicular to the intermediate portions 22 of the probes 12-18 of the second probe pair.

[0044] The intermediate portion 22 and the termination portion 24a, 24b of each probe 12-18 have substantially the same shape when seen in a direction D from the top 28 to the foot 26 of the probe arrangement 10, e.g., when seen in the vertical direction. In particular, the intermediate portions 22 and the termination portions 24a, 24b of the probes 12-18 of each probe pair are symmetric to each other in regard to a vertical plane through a center of the probe arrangement 10. The center of the probe arrangement 10 is located at the intersection of the extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 and the extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 preferably point from the center of the probe arrangement 10 to the circumference of the probe arrangement 10. Thus, the termination portion 24 of each probe 12-18 is farther away from the center of the probe arrangement 10 than the intermediate portion 22 of the respective probe 12-18. Moreover, each symmetry plane is perpendicular to the vertical plane in which the extension directions ED, ED', ED", ED"' of the intermediate portions 22 of the probes 12-18 of the respective probe pair lie.

[0045] Preferably, as shown in Figs. 1 and 2, the termination portion 24 of each probe 12-18 may comprise two protrusions 24a, 24b that extend to both sides of the extension direction ED, ED', ED", ED"' of the intermediate portion 22 of each probe 12-18 when seen in the direction D from the top 28 to the foot 26 of the probe arrangement 10. Thus, a width W of each termination portion 24, i.e., a dimension of a termination portion 24 in a third direction perpendicular to the extension direction ED of the respective intermediate portion 22, is larger than the width W' of the respective intermediate portion 22, i.e., a dimension of the respective intermediate portion 22 in the third direction.

[0046] As shown in Figs. 1 and 2, the protrusions 24a, 24b may comprise elongated members extending from the intermediate portion 22 at different sides of the extension direction ED, ED', ED", ED"' of the intermediate portion 22 of each probe 12-18 in directions which are perpendicular to each other. Thus, the shape of the intermediate portion 22 and the termination portion 24 of each probe 12-18 may be the shape of an arrow although other shapes are also contemplated.

[0047] A (preferably) single patch 30 may be attached to dielectric spacers 32 of a dielectric support 34 of the probe arrangement 10 to which the probes 12-18 of the probe arrangement 10 are attached. The patch 30 may be a planar plate of electrically conductive material and the shape of the patch 30 may be rectangular, preferably quadratic and in particular quadratic with rounded corners as shown in Fig. 2. The dielectric spacers 32 may comprise pins 36 which extend from a top surface 38 of a top layer 40 of the dielectric support 34 in a direction from the foot 26 to the top 28 of the probe arrangement 10 and fit into corresponding alignment holes in the patch 30. The dielectric spacers 32 may further comprise distance elements 42 on which the patch 30 rests when being attached to the dielectric spacers 32. The dielectric support 34 of the probe arrangement 10 may comprise three dielectric spacers 32 or four dielectric spacers 32 as shown in Figs. 1 to 3, or even more than four dielectric spacers 32. Moreover, the dielectric support 34 may be made of molded or cast plastics.

[0048] As shown in Figs. 2 and 3, the probes 12-18 may be integrated into the top layer 40 of the dielectric support 34 and the top layer 40 may have a central aperture. A tube 44 connecting the top layer 40 with the foot 26 of the probe arrangement 10 is attached to the central aperture. The termination portion 20 may be integrated into the tube 44. In particular, as shown in Fig. 1, an upper circumferential edge of the tube 44 may be attached to an inner edge 46 of the central aperture while a lower edge of the tube 44 forms the bottom side of the dielectric support 34.The bottom side of the dielectric support 34, i.e. the lower edge of the tube 44, may be attached to a reflector (not shown) to achieve a desired radiation pattern. As an alternative to integrating the probes 12-18 into recesses formed in the top layer 40 and in the tube 44 of the dielectric support 34, the dielectric support 34 may have a substantially planar surface that is plated with the probes 12-18. Furthermore, the top layer 40 may have a quadratic peripheral contour and in particular may have a quadratic peripheral contour with smoothed corners.

[0049] Furthermore, each probe 12-18 may have an input port 48 at its feeding portion 20.Each probe pair drives one polarization and constitutes a differential port that is connected to a power output port of a power amplifier (PA). By properly combining the intrinsic capacitance of the transition from the probes 12-18 to the patch 30, which can be controlled by changing the distance between the probe arrangement 10 and the patch 30, and the inductance introduced by the probes 12-18 itself, which can be controlled by changing for example the length of the intermediate portion 22 of each probe 12-18, it is possible to achieve a broadband probe-fed patch antenna, i.e. a broadband probe-fed patch antenna having a second resonance at a desired frequency. Furthermore, the impedance of each probe pair in a probe-fed patch antenna which has the probe arrangement 10 can be reduced by moving the probes 12-18 to the center of the probe arrangement 10, i.e. in a direction opposite to the respective extension direction ED, ED', ED", ED"'.

[0050] Another advantage of having the probe arrangement 10 shown in Figs. 1 to 3 is its rotational symmetry which leads to ideal levels of isolation between polarizations and outstanding Cross Polarization Discrimination (XPD) of more than 20 dB at +/- 90° as shown in Fig. 4. Moreover, although the probe arrangement 10 is designed to work with dual-linear polarization, a conversion to dual-circular polarization is also contemplated as within the knowledge of the person skilled in the art.

[0051] A modification of the probe arrangement 10 of Figs. 1 to 3 is shown in Fig. 5 as probe arrangement 10a. Each probe 12-18 of the probe arrangement 10a has two input ports 48a, 48b while the remaining features of the probe arrangement 10a are identical to the probe arrangement 10 shown in Figs. 1 to 3 and are not repeated for the sake of brevity. Having two input ports 48a, 48b at each probe 12-18 of the probe arrangement 10a allows that each probe pair can be connected to two PAs in parallel. This makes it possible to use PAs which are manufactured by CMOS technology and are driven by low bias voltage and have low output power. The output power of the respective PAs is combined in the feeding portions 20 of the probes 12-18 of the probe pair which serve as power combiners to the output power of the PAs connected to the input ports 48a, 48b of the feeding portions 20 of the respective probes 12-18. To further reduce the output power required by each PA, each probe 12-18 may comprise even more than two input ports 48a, 48b, e.g., three, four, five, six or more PAs, wherein each input port 48a, 48b can be connected to a corresponding PA.

[0052] While the probe arrangements 10, 10a referred to in Figs. 1 to 5 are intended for a dual-polarized patch antenna, Fig. 6 shows a modification of the probe arrangements 10, 10a which is intended for a single-polarized patch antenna. More particularly, the probe arrangement 10b of Fig. 6 is identical to the probe arrangement 10 of Figs. 1 to 3 or to the probe arrangement 10a of Fig. 5 but comprises only the first probe pair having the probes 12 and 18. The probe arrangement 10b may be combined with a rectangular patch 30, preferably with a quadratic patch 30 and in particular with a quadratic patch 30 having rounded corners as shown in Fig. 6 or may be combined with a circular patch 30a as shown in Fig. 7. Furthermore, the probe arrangements 10 and 10a as well as the probe arrangements which will be referred to in the following may also be combined with the circular 30a patch instead of with a rectangular patch 30, a quadratic patch 30 and or a quadratic patch 30 having rounded corners.

[0053] Figs. 8 to 11 show modifications of the probe arrangements 10 and 10a referred to in Figs. 1 to 5 in regard to the shape of the termination portions 24 of the probes 12-18. Furthermore, the termination portions shown in Figs 8 to 11 may also be applied to the probes 12, 16 of the probe arrangement 10b.

[0054] Fig. 8 shows a termination portion 24' having two elongated members 24a' and 24b' extending from the intermediate portion 22 at both sides of the extension direction ED of the intermediate portion 22, when seen in the vertical direction, i.e. from the top 28 to the foot 26 of the probe arrangement 10, 10a, 10b. However, unlike the elongated members 24a and 24b, the elongated members 24a' and 24b' do not extend in perpendicular directions as the angle enclosed by the elongated members 24a' and 24b' is less than 90°.

[0055] Fig. 9 shows a termination portion 24" which has a shape of a circle segment when seen in the vertical direction, i.e. from the top 28 to the foot 26 of the probe arrangement 10, 10a, 10b.The intermediate portion 22 is connected to the straight side of the circle segment.

[0056] Fig. 10 shows a termination portion 24"' having two elongated members 24a"' and 24b"' extending from the intermediate portion 22 at both sides of the extension direction ED of the intermediate portion 22, when seen in the vertical direction, i.e. from the top 28 to the foot 26 of the probe arrangement 10, 10a, 10b. However, unlike the elongated members 24a and 24b and the elongated members 24a' and 24b', the elongated members 24a"' and 24b"' enclose an angle of more than 90° and in particular enclose an angle of 180°. Hence, for the embodiment shown in the Fig. 10, the intermediate portion 22 and the termination portion 24"' of each probe form a T (when seen in the vertical direction).

[0057] Fig. 11 shows a termination portion 24"" which, when seen in the vertical direction, , i.e. from the top 28 to the foot 26 of the probe arrangement 10, 10a, 10b, has a shape of a circle segment from which a rectangular portion has been cut away, wherein the cut-away portion has a side in common with the circle segment. The intermediate portion 22 is connected to a resulting straight portion of the termination portion 24"" which is parallel to the straight side of the original circle segment.

[0058] Fig. 12 shows a modification of the probe arrangements 10, 10a-10f of Figs. 1 to 11, wherein the extension direction of the probes 12-18 is inversed, i.e., the extension directions ED, ED", ED"', ED"" point from the circumference of the probe arrangement 10g to the

center. Thus, the termination portion 24 of each probe 12-18 is closer to the center of the probe arrangement 10 than the intermediate portion 22 of the respective probe 12-18.

[0059] Figs. 13 to 15 are schematic views of a probe-fed patch antenna 50. The probe-fed patch antenna 50 comprises the patch 30 (only for illustration purposes transparent in Fig. 13) and the four probes 12-18 of the probe arrangement 10 which are arranged relative to each other and shaped as described in relation to Figs. 1 to 3. Moreover, the patch 30 and the four probes 12-18 of the probe arrangement 10h may also be modified in view of shape and arrangement as described with reference to Figs. 5 to 12.

[0060] The intermediate portion 22 and the termination portion 24 of the probes 12-18 in the probe arrangement 10h shown in Figs. 13 to 15 are attached to a bottom side 52 of a top layer 40' of a dielectric support 34' while the patch 30 is arranged on a top surface of the top layer 40' of the dielectric support 34'. Furthermore, the dielectric support 34' comprises a first member forming the top layer 40' and four arms which extend from the top layer 40' of the dielectric support 34' to the foot of the probe arrangement 10h. Each arm is plated with a respective termination portion 22 of the probes 12-18. The dielectric support 34' further comprises a second member forming a support layer 54 and a tube 44' extending perpendicularly from the support layer 54. Alternatively, the first and second member may be formed as one piece.

[0061] The contour of the support layer 54 is equal in size and shape to the contour of the top layer 40'. Moreover, the support layer 54 comprises apertures which fit in size and shape to the intermediate and the termination portions 22, 24 of the probe arrangement 10h. Hooks at the lower ends of the four arms of the first member engage with the bottom edge of the tube 44' when the tube 44' of the second member is inserted in between the four arms, thereby attaching the first member to the second member. In the attached state, the support layer 54 of the second member abuts on and supports the top layer 44' while the intermediate portions 22 and the termination portions 24 of the probe arrangement 10h are received in the apertures of the support layer 54.

[0062] Figs. 16 and 17 are schematic views of a modification of the probe-fed patch antenna 50 of Figs. 13 to 15. The modification relates to the size of the support layer 54' which in the probe-fed patch antenna 50' of Figs. 16 and 17 is smaller than the top layer 40' while being nevertheless large enough for receiving the intermediate portions 22 and the termination portions 24 of the probe arrangement 10h in the apertures of the support layer 54'.

[0063] Further embodiments of the present invention are provided in the following. It should be noted that the numbering used in the following section does not necessarily need to comply with the numbering used in the previous sections.

Embodiment 1. A probe arrangement (10, 10a-10h) for a probe-fed patch antenna (50, 50'), comprising: a foot (26) and a top (28); and at least a first probe (12) and a second probe (16); wherein the first probe (12) and the second probe (16) are electrically separated from each other; wherein each probe (12-18) comprises a feeding portion (20), an intermediate portion (22) and a termination portion (24-24""); wherein the feeding portion (20) extends from the foot (26) to the top (28); wherein the intermediate portion (22) and the termination portion (24-24"") are arranged at the top (28); wherein the intermediate portion (22) extends at the top (28) from the feeding portion (20) to the termination portion (24-24""); and wherein a width (W) of the termination portion (24-24"") in a direction perpendicular to an extension direction (ED) of the intermediate portion (22) is larger than a width (W') of the intermediate portion (22) in the direction perpendicular to the extension direction (ED) of the intermediate portion (22).

Embodiment 2. The probe arrangement (10, 10a-10h) of embodiment 1, comprising four or more probes (12-18).

Embodiment 3. The probe arrangement (10, 10a-10h) of embodiment 1 or 2, wherein the intermediate portion (22) and the termination portion (24-24"") of the probes (12-18) are symmetric with regard to a symmetry plane perpendicular to the extension direction (ED) of the intermediate portion (22) of the first probe (12).

Embodiment 4. The probe arrangement (10, 10a-10c, 10g, 10h) of any one of embodiments 1 to 3, wherein the intermediate portion (22) and the termination portion (24-24"") of each probe (12-18) form an arrow-shape.

Embodiment 5. The probe arrangement (10, 10a-10h) of any one of embodiments 1 to 4, wherein the probes (12-18) are evenly distributed around a centerline of the probe arrangement (10, 10a-10h).

Embodiment 6. The probe arrangement (10a) of any one of embodiments 1 to 5, wherein each feeding portion (20) has two input ports (48a, 48b).

Embodiment 7. The probe arrangement (10, 10a-10h) of any one of embodiments 1 to 6, further comprising a dielectric support (34, 34'), wherein a bottom side of the dielectric support (34, 34') forms the foot (26) of the probe arrangement (10, 10a-10h) and a top layer (40, 40') of the dielectric support (34, 34') forms the top (28) of the probe arrangement (10, 10a-10h); wherein a maximum cross-section dimension of the top layer (40, 40') is larger than a maximum cross-section dimension of the bottom side;

and wherein the intermediate portion (22) and the termination portion (24-24" ") of each probe (12-18) lie preferably within an outer edge of the top layer (40, 40') when seen from foot (26) to top (28).

Embodiment 8. The probe arrangement (10, 10a-10h) of embodiment 7, wherein the probes (12-18) are attached to a top surface (38) or a bottom surface of the top layer (40, 40') or are at least in part integrated into the top layer (40, 40').

Embodiment 9. The probe arrangement (10, 10a-10g) of embodiment 7 or 8, wherein the dielectric support (34, 34') comprises dielectric spacers (32) which are arranged on the top surface (38) of the top layer (40, 40') and which are configured to receive a single electrically conductive patch (30, 30a).

Embodiment 10. The probe arrangement (10, 10a-10f) of any of embodiments 7 to 9, wherein the dielectric support (34, 34') has an aperture and wherein the aperture is preferably located at a center of the top layer (40).

Embodiment 11. The probe arrangement (10, 10a-10f, 10h) of any one of embodiments 1 to 10, wherein the feeding portions (20) extend along an inner surface or an outer surface of a tube (44, 44') connecting the foot (26) and the top (28) and wherein a circumferential edge of the tube (44, 44') is preferably attached to an inner edge of the aperture.

Embodiment 12. A probe-fed patch antenna (50, 50') comprising the probe arrangement (10, 10a-10h) of any of embodiments 1 to 11 and an electrically conductive patch (30, 30'). Embodiment 13. The probe-fed patch antenna (50, 50') of embodiment 12 comprising the dielectric support (34, 34') of any one of embodiments 7 to 10, wherein the electrically conductive patch (30') is arranged on the top surface of the top layer (40').

Embodiment 14. The probe-fed patch antenna (50, 50') of embodiment 13, wherein the dielectric support (34'), the probes (12-18), and the electrically conductive patch (30) are formed as one piece.

Embodiment 15. The probe-fed patch antenna (50, 50') of any one of embodiments 12 to 14, wherein the probes (12-18) are configured to induce currents to the electrically conductive patch (30, 30') through capacitive coupling.

Claims

1. A probe arrangement (10, 10a-10h) for a probe-fed patch antenna (50, 50'), comprising:

a foot (26) and a top (28); and
four or more probes (12-18) comprising a first probe (12) and a second probe (16) forming a first probe pair and a third probe (14) and a fourth probe (18) forming a second probe pair;
wherein each probe (12-18) comprises a feeding portion (20), an intermediate portion (22) and a termination portion (24-24""), which are connected in series;
wherein the feeding portion (20) extends from the foot (26) to the top (28);
wherein the intermediate portion (22) and the termination portion (24-24" ") are arranged at the top (28);
wherein the intermediate portion (22) extends at the top (28) from the feeding portion (20) to the termination portion (24-24""); and
wherein a width (W) of the termination portion (24-24"") in a direction perpendicular to an extension direction (ED) of the intermediate portion (22) and within a vertical plane, in which the extension direction (ED) and the extension directions (ED'-ED"') of the intermediate portions (22) of the respective probes (12-18) lie, is larger than a width (W') of the intermediate portion (22) in the direction perpendicular to the extension direction (ED) of the intermediate portion (22) and within the vertical plane.

2. The probe arrangement (10, 10a-10h) of claim 1, wherein the intermediate portion (22) and the termination portion (24-24" ") of each of the probe pairs are symmetric to each other with regard to a symmetry plane perpendicular to the extension directions (ED, ED", ED"', ED"") of the intermediate portions (22) of the probe pair extending through a center of the probe arrangement (10, 10a-10h).

3. The probe arrangement (10, 10a-10c, 10g, 10h) of any one of claims 1 to 2, wherein the intermediate portion (22) and the termination portion (24-24" ") of each probe (12-18) form an arrow-shape.

4. The probe arrangement (10, 10a-10h) of any one of claims 1 to 3, wherein the probes (12-18) are evenly distributed around a centerline extending in a vertical direction through the center of the probe arrangement (10, 10a-10h).

5. The probe arrangement (10a) of any one of claims 1 to 4, wherein each feeding portion (20) has two input ports (48a, 48b).

6. The probe arrangement (10, 10a-10h) of any one of claims 1 to 5, further comprising a dielectric support (34, 34'),
wherein a bottom side of the dielectric support (34, 34') forms the foot (26) of the probe arrangement

(10, 10a-10h) and a top layer (40, 40') of the dielectric support (34, 34') forms the top (28) of the probe arrangement (10, 10a-10h);
wherein a maximum cross-section dimension of the top layer (40, 40') is larger than a maximum cross-section dimension of the bottom side; and
wherein the intermediate portion (22) and the termination portion (24-24"") of each probe (12-18) lie preferably within an outer edge of the top layer (40, 40') when seen from foot (26) to top (28).

7. The probe arrangement (10, 10a-10h) of claim 6, wherein the probes (12-18) are attached to a top surface (38) or a bottom surface of the top layer (40, 40') or are at least in part integrated into the top layer (40, 40').

8. The probe arrangement (10, 10a-10g) of claim 6 or 7, wherein the dielectric support (34, 34') comprises dielectric spacers (32) which are arranged on the top surface (38) of the top layer (40, 40') and which are configured to receive a single electrically conductive patch (30, 30a).

9. The probe arrangement (10, 10a-10f) of any of claims 6 to 8, wherein the dielectric support (34, 34') has an aperture and wherein the aperture is preferably located at a center of the top layer (40).

10. The probe arrangement (10, 10a-10f, 10h) of any one of claims 1 to 9, wherein the feeding portions (20) extend along an inner surface or an outer surface of a tube (44, 44') connecting the foot (26) and the top (28) and wherein a circumferential edge of the tube (44, 44') is preferably attached to an inner edge of the aperture.

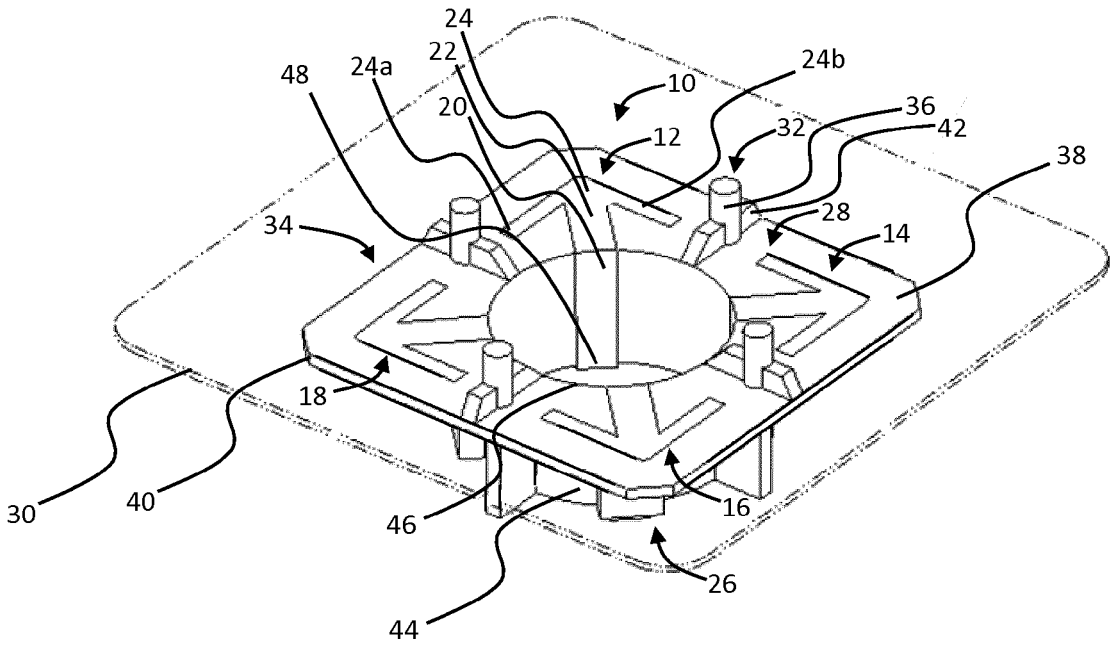
11. A probe-fed patch antenna (50, 50') comprising the probe arrangement (10, 10a-10h) of any of claims 1 to 10 and an electrically conductive patch (30, 30').

12. The probe-fed patch antenna (50, 50') of claim 11 comprising the dielectric support (34, 34'), wherein the electrically conductive patch (30') is arranged on the top surface of the top layer (40').

13. The probe-fed patch antenna (50, 50') of claim 12, wherein the dielectric support (34'), the probes (12-18), and the electrically conductive patch (30) are formed as one piece.

14. The probe-fed patch antenna (50, 50') of any one of claims 11 to 13, wherein the probes (12-18) are configured to induce currents to the electrically conductive patch (30, 30') through capacitive coupling.

15. The probe-fed patch antenna (50, 50') of any one of claims 11 to 14, wherein the electrically conductive patch (30, 30') is a plate of electrically conductive material.


24
22
48
24a
20
10
24b
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16
26
44

Fig. 1

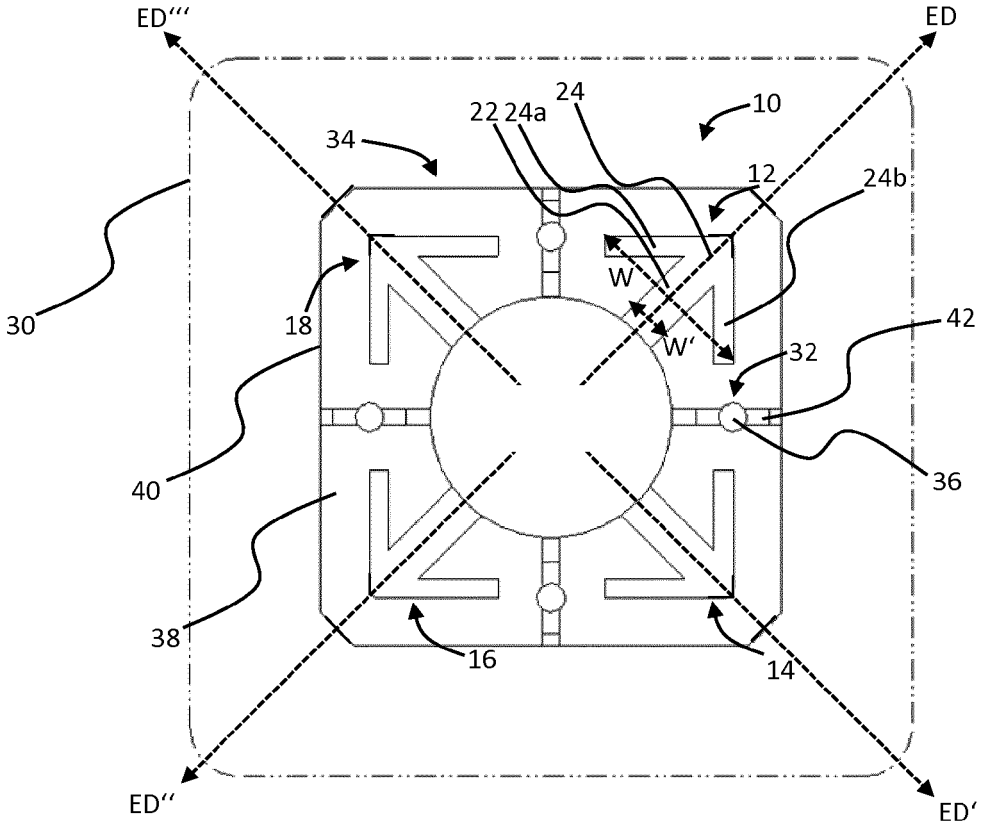

ED‘‘‘
ED
22
24a
24
10
34
12
24b
W
W‘
18
30
42
32
40
36
38
16
14
ED‘‘
ED‘

Fig. 2

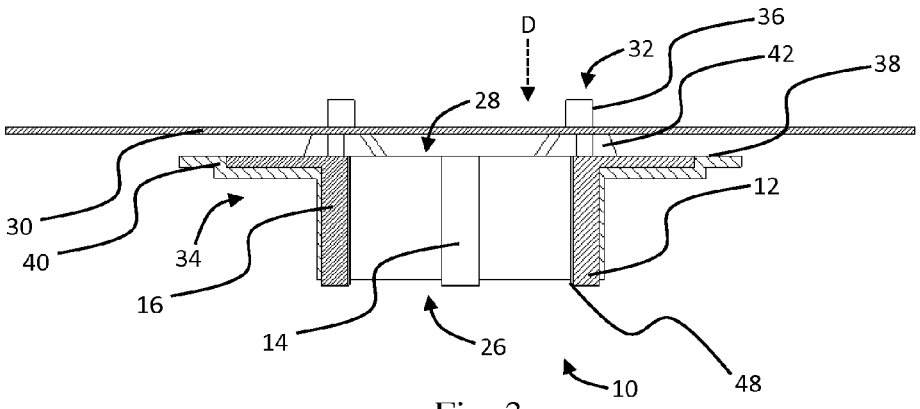


Fig. 3

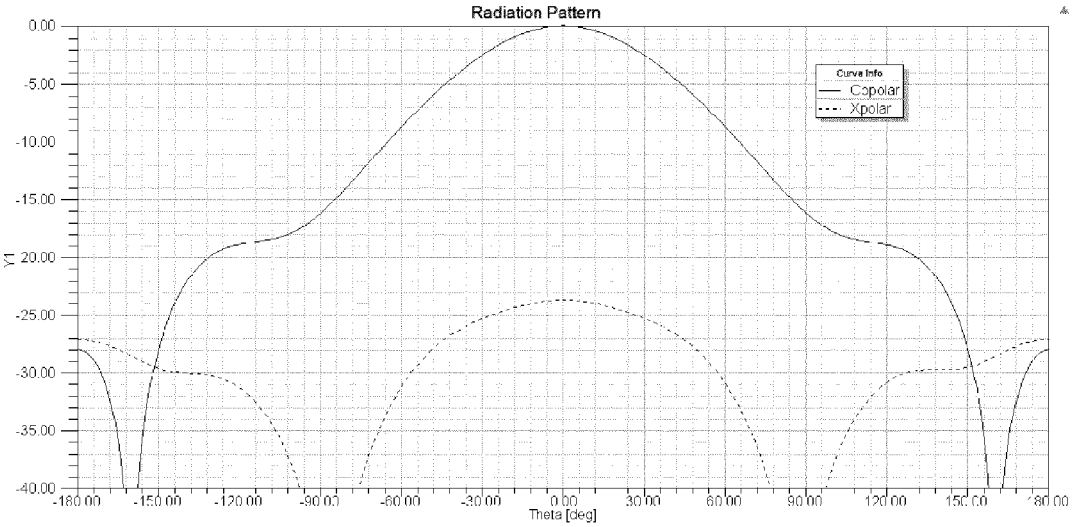


Fig. 4

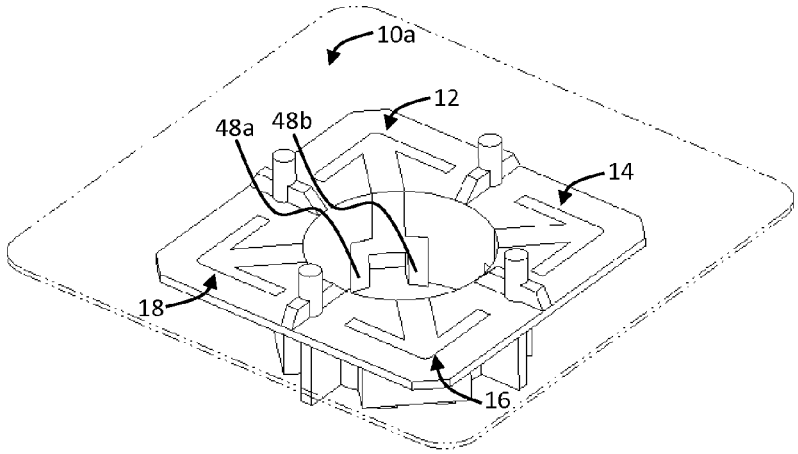


Fig. 5

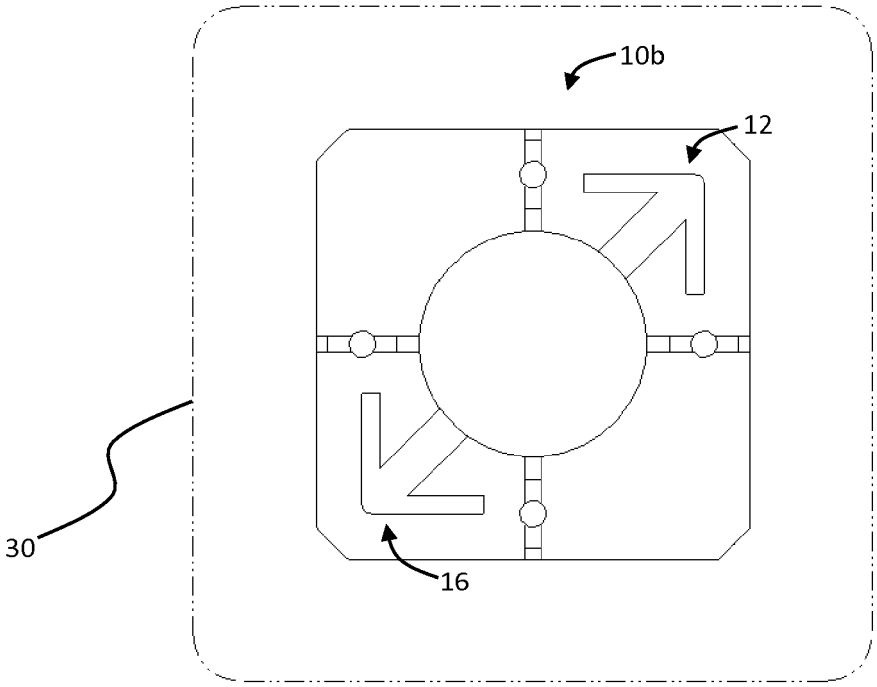


Fig. 6

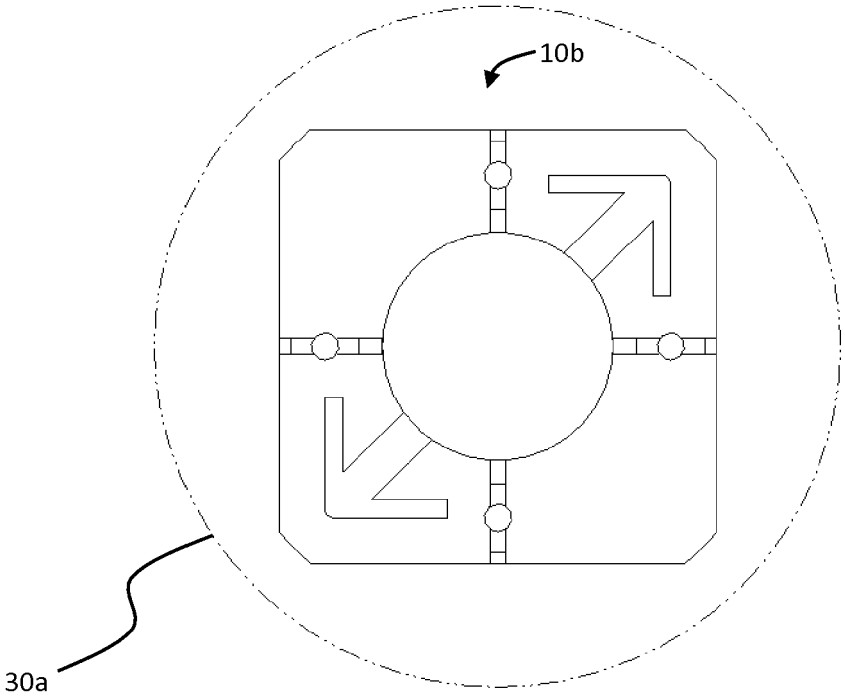


Fig. 7

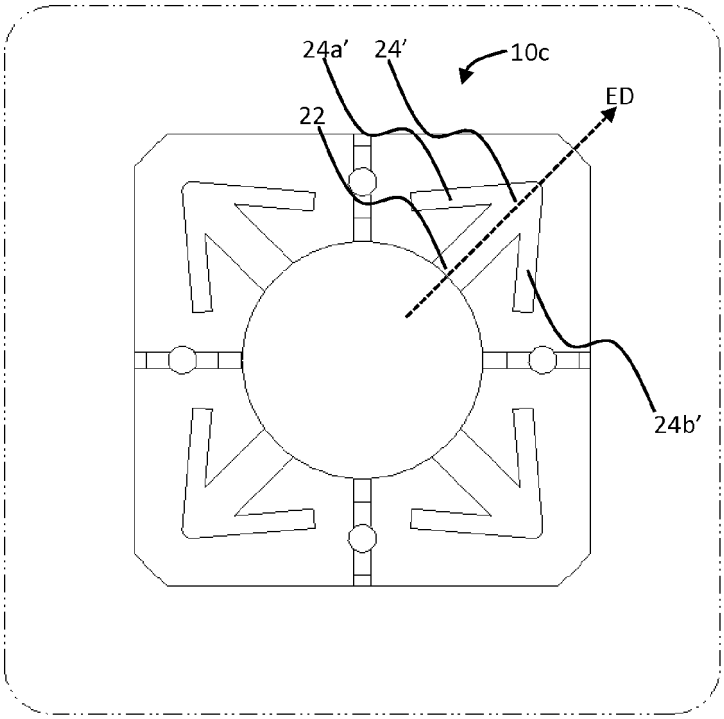


Fig. 8

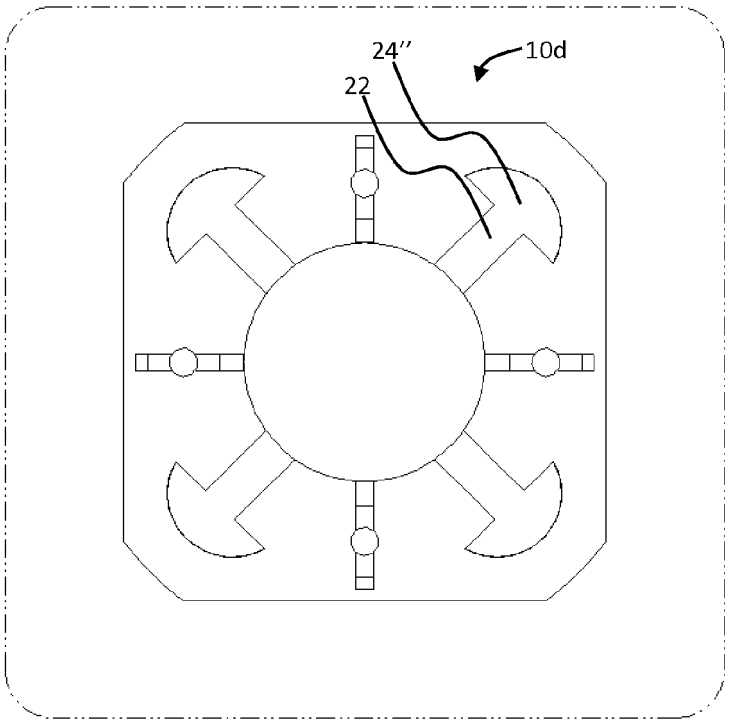


Fig. 9

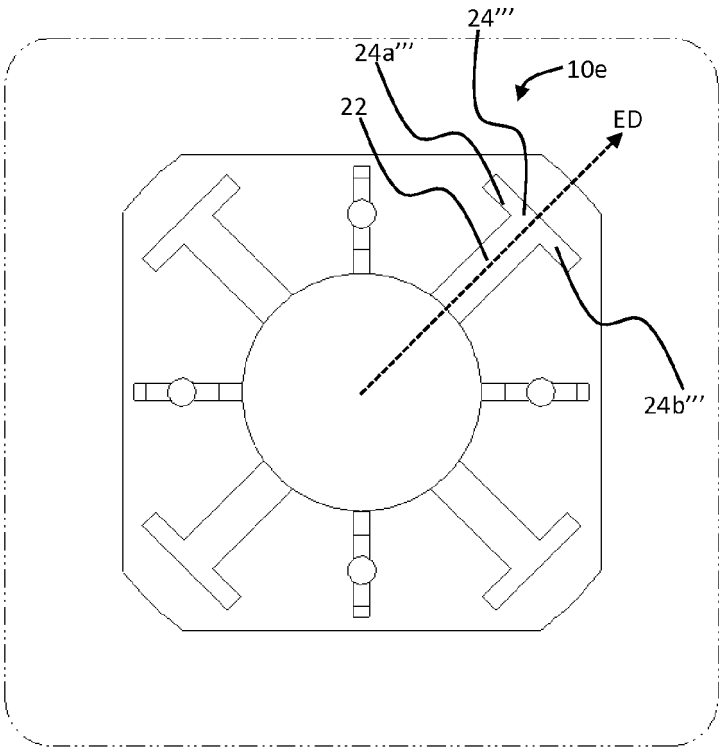
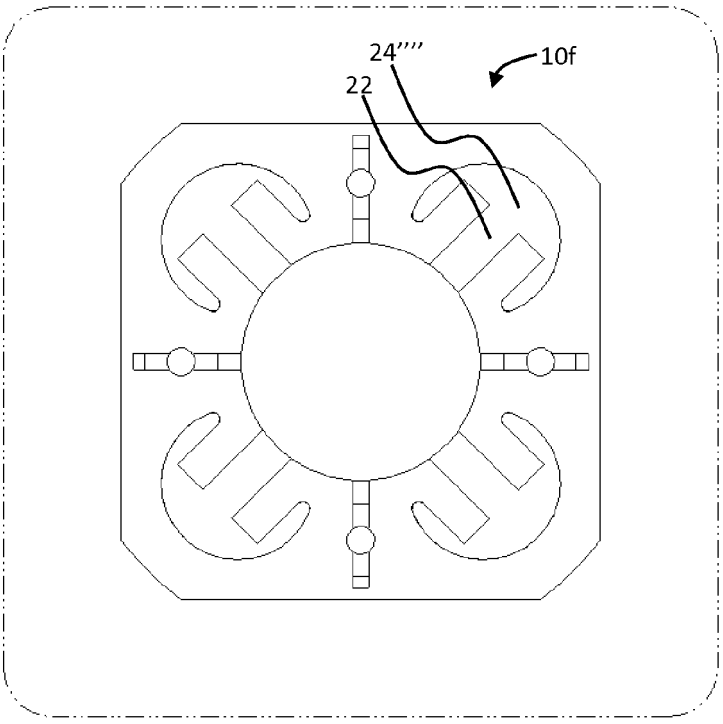


Fig. 10



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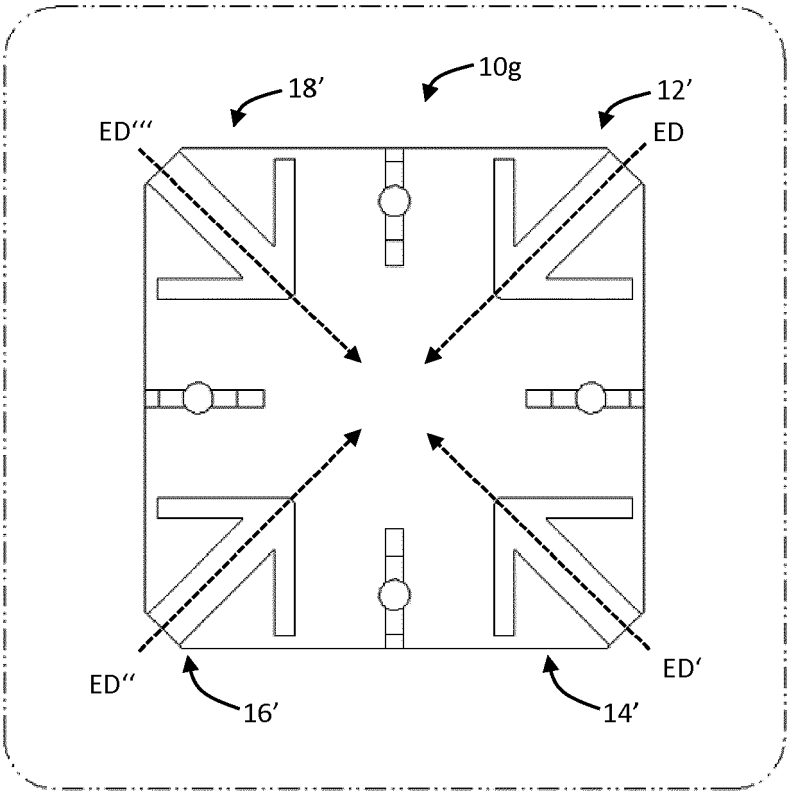

Fig. 12

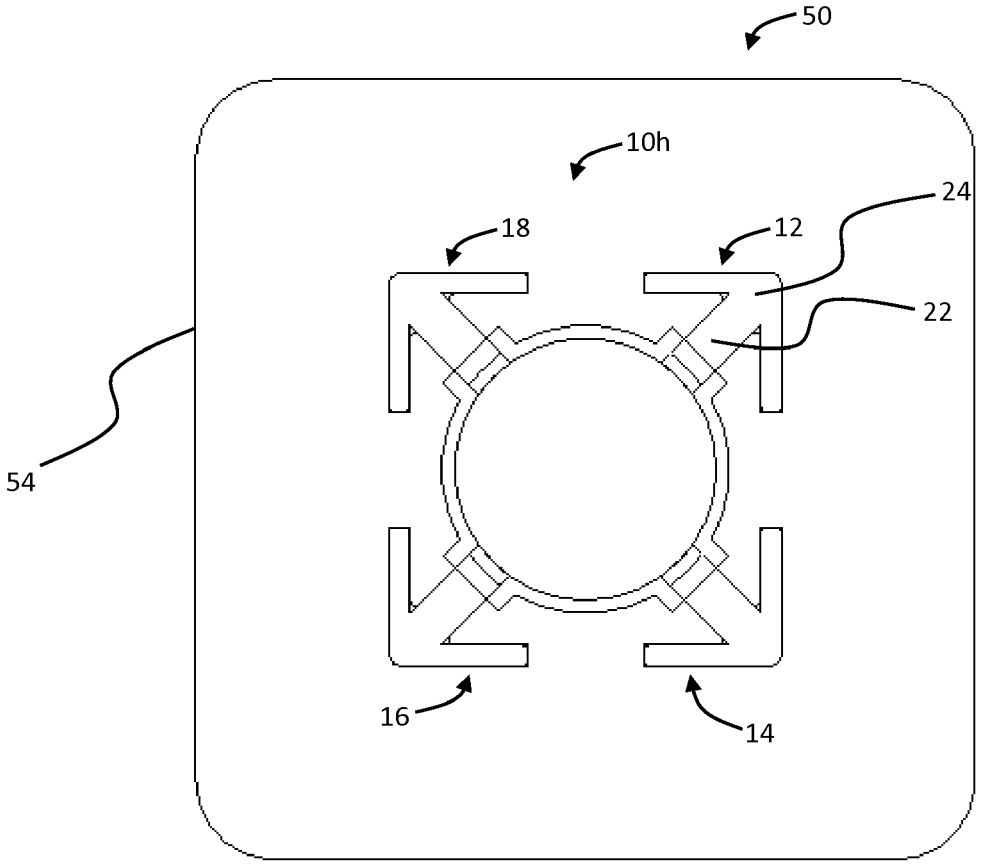

Fig. 13

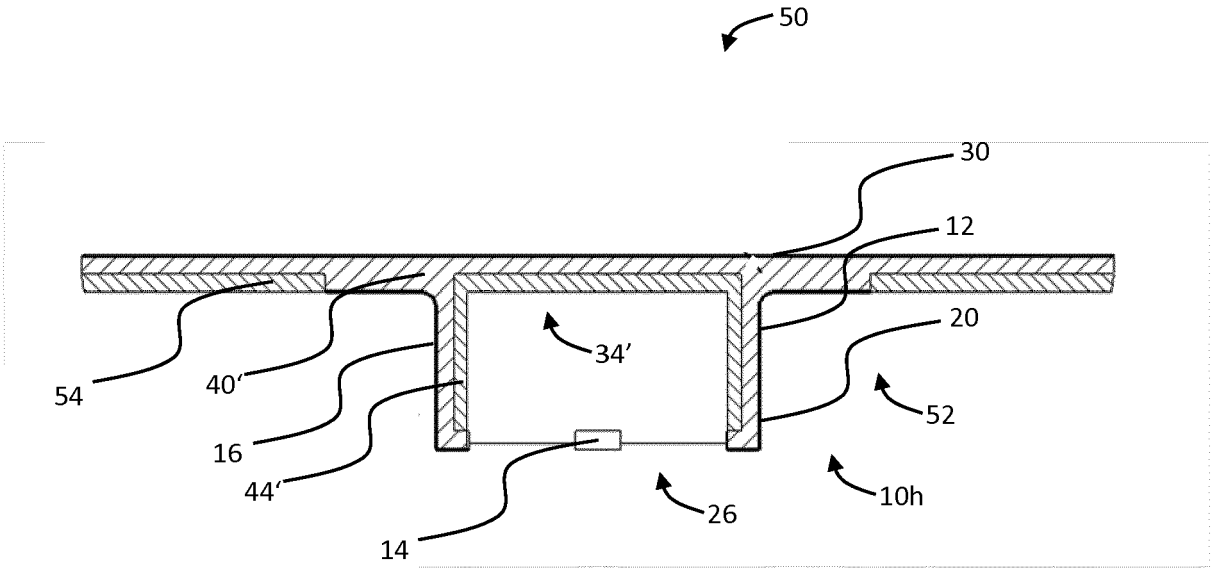

Fig. 14

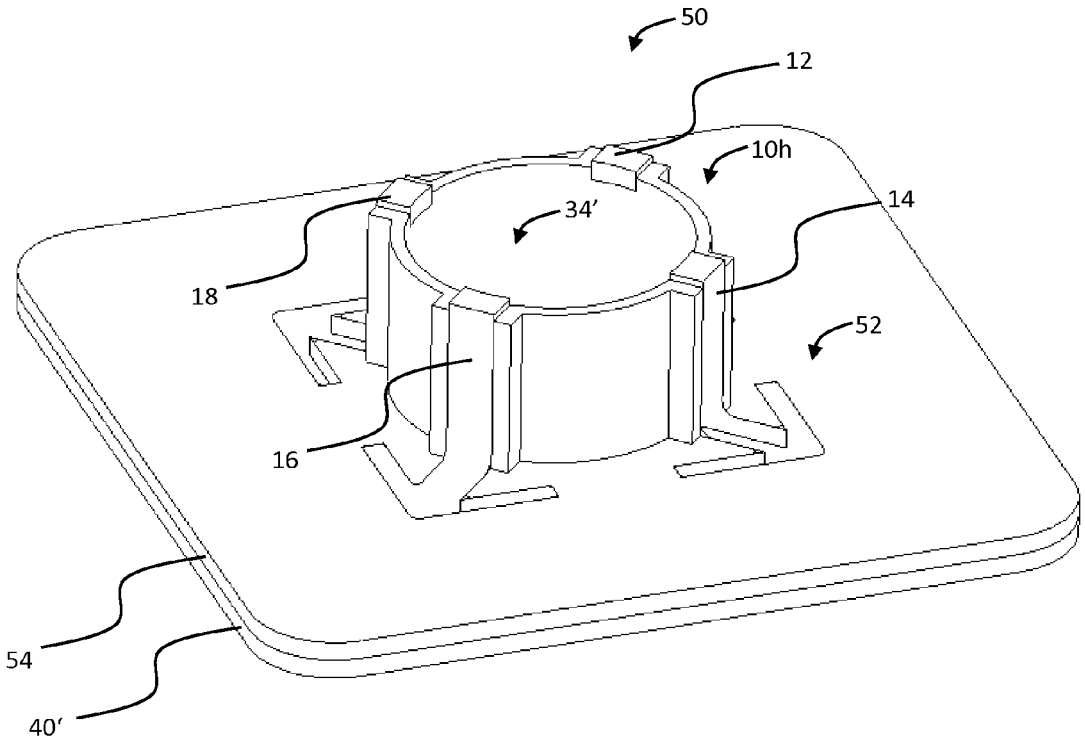

Fig. 15

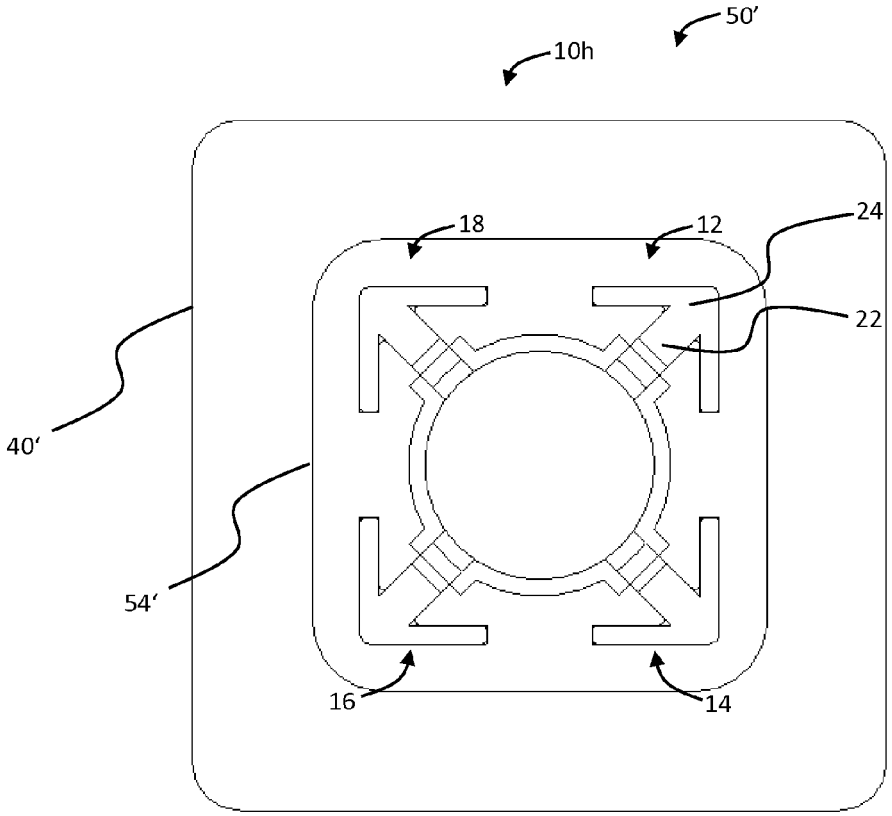

Fig. 16

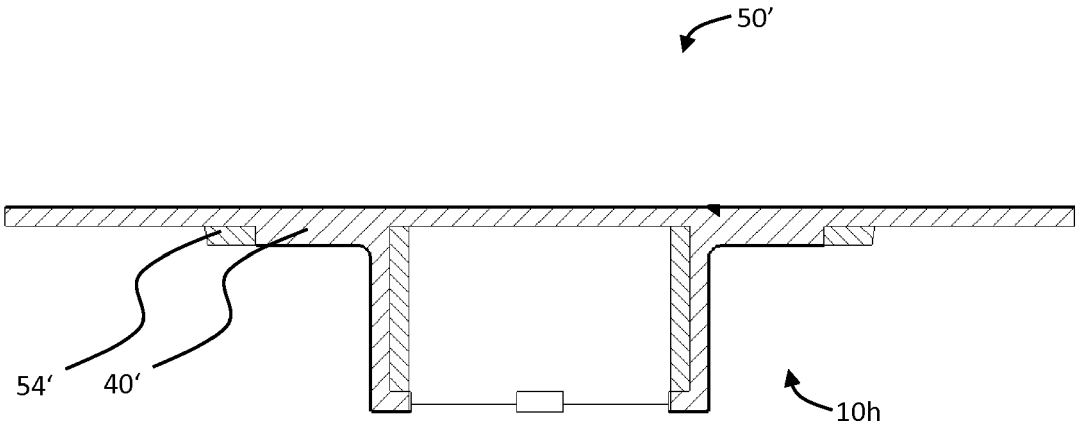

Fig. 17

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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 6315

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	MING-CHUN TANG ET AL: "A High-Directivity, Wideband, Efficient, Electrically Small Antenna System", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, vol. 62, no. 12, 1 December 2014 (2014-12-01), pages 6541-6547, XP055204967, ISSN: 0018-926X, DOI: 10.1109/TAP.2014.2361891 * Section II; page 6542 - page 6543; figures 1, 2 *	1-15	INV. H01Q9/04 H01Q21/06 H01Q21/24 H01Q21/26
A	US 2010/007571 A1 (RIEDEL MATTHIAS [DE]) 14 January 2010 (2010-01-14) * page 1, paragraph 7 - page 1, paragraph 9; figure 1 * * page 2, paragraph 29 - page 3, paragraph 32; figures 2,3 *	1-15	
A	Danpeng Xie ET AL: "Square Electrically Small EAD Antenna Array for RF Energy Harvesting from TV Broadcast Tower", , 4 November 2014 (2014-11-04), XP055204978, Retrieved from the Internet: URL:http://ieeexplore.ieee.org/ielx7/7057737/7067568/07067717.pdf?tp=&arnumber=7067717&isnumber=7067568 [retrieved on 2015-07-28] * Section II; page 1358 - page 1359; figures 1,2 *	1-15	TECHNICAL FIELDS SEARCHED (IPC) H01Q
A	EP 1 879 256 A1 (RYMSA [ES]) 16 January 2008 (2008-01-16) * page 4, column 6, paragraph 50 - page 5, column 7, paragraph 64; figures 1-5 *	1-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 April 2018	Blech, Marcel

CATEGORY OF CITED DOCUMENTS

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10-04-2018

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