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(54) **A TILTABLE ANTENNA ARRANGEMENT FOR PRINTED CIRCUIT BOARD ANTENNAS**

(57) A printed circuit board (PCB) for a mechanically tiltable antenna arrangement. The PCB comprises a cut-out track defining a tongue for holding the antenna arrangement on a front side of the PCB. The PCB is

formed in a bendable material allowing the tongue to be bent around a bending axis to a pre-determined angle, thereby mechanically tilting the antenna arrangement in the pre-determined angle.

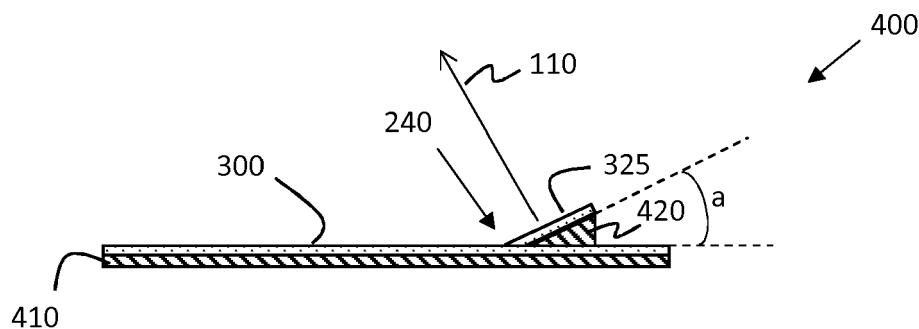


FIG. 4

Description

DESCRIPTION OF THE DISCLOSURE

[0001] The present disclosure relates to tiltable antenna arrangements. The disclosed antenna arrangements are suitable for use with radio detection and ranging (radar) transmitters and receivers in vehicular applications and for wireless communication systems in general.

[0002] Radar systems are sensor systems arranged to generate output comprising a series of reflection points as measured by radar receiver sensors. A radar transmitter and receiver together implement a radar transceiver.

[0003] Radar transceivers often use directive antenna arrangements to improve operating conditions. By focusing a beam of transmitted energy in a certain direction, more distinct echoes at higher signal to noise ratios (SNR) can be obtained. It is, however, often desired to cover a large field of view by the radar system. This can be achieved, either by implementing steerable antenna lobes that can be directed in different directions to scan the field of view, or by implementing a set of fixed antenna lobes that together cover the field of view and which can be switched between.

[0004] Mechanically directed antenna arrangements, such as tiltable horn antennas, can be used to generate fixed antenna lobes pointing in different directions. These antenna arrangements are often associated with a high manufacturing cost due to strict requirements on precision, especially at high carrier frequencies.

[0005] Mechanically steerable antenna arrangements comprise motors to mechanically adjust a pointing direction of the antenna lobe, such arrangements often have a large footprint.

[0006] Electrically steerable antenna arrays are associated with complicated control circuitry, which can be a drawback in many radar applications.

[0007] Fixed lobe antenna arrangements are less complicated and do not require sophisticated control circuitry. Patch antenna arrays can be used to generate beams in different pointing directions by amplitude and phase tapering. However, obtaining different pointing directions for the different fixed lobes may be difficult to achieve without sacrificing the antenna gain and without generating significant side lobes.

[0008] Antennas printed on a printed circuit board (PCB) are often cheap to manufacture and are also suitable for integration with the rest of the electronic circuitry, which is an advantage.

[0009] Consequently, there is a need for improved mechanically tiltable antenna arrangements that are easy to integrate on a PCB.

[0010] It is an object of the present disclosure to provide circuits, transceivers, vehicles, and methods which alleviate at least some of the above-mentioned problems.

[0011] There is disclosed herein a PCB for a mechanically tiltable antenna arrangement. The PCB comprises

at least one cut-out track defining a tongue for holding the antenna arrangement on a front side F of the PCB. The PCB is formed at least partly in a bendable material allowing the tongue to be bent around a bending axis to a pre-determined angle α , thereby mechanically tilting the antenna arrangement in the pre-determined angle α .

[0012] Amplitude and phase tapering at the antenna arrangement are not necessary in order to obtain a tilted antenna main lobe pointing direction, which is an advantage. The antenna gain can be kept high and since side-lobes can be kept low. The mechanically tiltable antenna arrangement can be manufactured for high frequency operation, since there is no need for connectors or long transmission lines. Rather, all necessary transmission lines and components are co-located on the same section of PCB, which is an advantage.

[0013] According to aspects, the antenna arrangement is a patch antenna or other PCB antenna arrangement arranged on the front side F of the PCB. The patch antenna allows for cost-efficient manufacturing with small foot-print, which is an advantage. Since the patch antenna is arranged integrally with the PCB, signal integrity can be assured in a less complicated manner compared to if connectors and the like is used.

[0014] According to aspects, one or more recesses are formed on a back-side B of the PCB opposite to the front side F and in connection to the tongue. The recesses are arranged parallel to the bending axis. The recesses simplify bending of the PCB, which permits the PCB to be manufactured in a less bendable material or to be manufactured in a hybrid PCB technology where the flexible top layer material is combined with low cost less bendable materials for the other layers, which is an advantage. Since the recesses are arranged parallel to the bending axis, the bending can be executed in a more controlled fashion with higher mechanical precision.

[0015] According to aspects, the PCB comprises a fixture having a wedge-shaped protrusion configured to contact the tongue and to bend the tongue to the pre-determined angle when pressed against the PCB 300. Thus, the shape of the wedge determines the bending angle and therefore also the end antenna diagram, i.e., the pointing direction of the antenna arrangement main lobe. The wedge can be machined or molded with high precision and low cost, which is an advantage. Several different wedge configurations can be used with the same PCB, which is an advantage since the antenna diagram is then decided on assembly, and not when manufacturing the PCB. This allows for a more flexible product. It is appreciated that other shapes than a wedge shape can be used with the same technical effect, e.g., rectangular protrusions, or elliptical protrusions.

[0016] According to aspects, the PCB comprises a plurality of cut-out tracks defining respective tongues for holding a corresponding plurality of antenna arrangements. The plurality of antennas can be used to collectively cover a field of view, which is an advantage. The different antenna arrangements can then be switched

between by a radar transceiver or the like or be used as an antenna array to actively steer a pointing direction of the antenna array.

[0017] According to aspects, the PCB comprises a plurality of layers, wherein one or more upper layers is formed in a flexible material and wherein remaining lower layers are formed in a less flexible material compared to the one or more upper layers. A recess is machined in the PCB from the back-side B through the remaining lower layers. This way the flexibility of the PCB at the point of bending can be increased, which allows for a more controlled bending.

[0018] There are also disclosed herein mechanically tiltable antenna arrangements and methods associated with the above-mentioned advantages

[0019] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The present disclosure will now be described more in detail with reference to the appended drawings, where:

Figure 1 schematically illustrates a three-sector transmit antenna arrangement;

Figure 2 illustrates a vehicle with radar sensors;

Figures 3a-3b schematically illustrate front and back sides of a section of printed circuit board;

Figure 4 shows a side view of a printed circuit board mounted on a fixture;

Figures 5-7 show top views of printed circuit board sections;

Figure 8 shows a side view of a printed circuit board; and

Figure 9 is a flow chart illustrating methods.

DETAILED DESCRIPTION

[0021] Figure 1 schematically illustrates a three-sector antenna arrangement 100. There are three different antennas having antenna lobes Tx1, Tx2, Tx3 arranged to point in different directions 110, 120, 130. The antenna arrangement 100 is mounted on a fixture 140. The ar-

rangement can be used for transmitting antennas and/or for receiving antennas. This fixture may in turn be a part of the frame or enclosure of the radar unit attached to a vehicle, such as a bumper or a door.

[0022] The three different transmit antennas together cover a field of view 105. A radar transceiver 150 connected to the antennas may switch between the different antenna lobes consecutively or in some other sequence.

[0023] Herein, unless otherwise indicated, an antenna main lobe, or antenna lobe, refers to the lobe of a directive antenna arrangement which is associated with largest gain. It is appreciated that an antenna diagram of a given directive antenna almost always comprises several different antenna lobes. There is, e.g., often a plurality of side lobes and also a back lobe. The main lobe is then the lobe associated with largest gain relative to the other lobes.

[0024] Figure 2 illustrates a vehicle 200 with radar sensors 210, 220, 230. There is one front sensor 210 configured with a field of view to cover the front of the vehicle. The back sensor 220 covers an area rear of the vehicle, while the side sensors 230 cover areas to either side of the vehicle 200.

[0025] With reference again to Figure 1; A patch antenna array can be designed by amplitude and phase tapering to tilt a main lobe as much as several tens of degrees. Three such patch antennas could then cover a field of view 105 of about 160 degrees by tilting each antenna some 53°. However, gain of the main lobe will be reduced if the array is steered out to far in angle and the side lobes in such an arrangement will be hard to keep at reasonably low gain, such as below -20 dB relative to the main lobe.

[0026] An alternative way to provide a large field of view is a mechanically tilted antenna or a combination of electrical and mechanical tilt. However, such systems operating at high carrier frequencies are difficult to design and manufacture, since connectors and long transmission lines often imply large losses and other problems, such as manufacturability and reliability issues. Thus, having individual directive antennas which are mounted separately on a fixture 140 pointing in different directions is a costly solution which likely also results in degraded performance.

[0027] The solutions presented herein avoid the above-mentioned problems associated with patch antenna arrays using phase and amplitude tapering to tilt a main lobe, and also problems with known mechanically tilted antenna solutions, by using a PCB formed at least partly in a bendable material. A patch antenna or other antenna device can then be arranged integrally with the PCB on a portion of the PCB which portion can then be bent to the desired tilting angle. This way, a mechanically tiltable antenna arrangement with high performance is obtained in a cost-effective manner. Since the antenna is formed integrally with the PCB, the manufacturability and reliability issues mentioned above are alleviated.

[0028] Figures 3a and 3b schematically illustrate front

and back sides of a printed circuit board 300 (PCB). An antenna arrangement 330 is arranged on the PCB. This antenna arrangement is a directive antenna arrangement configured to have a main lobe associated with a pointing direction. This main lobe often, but not always, points in a direction perpendicular to a plane of the PCB.

[0029] According to an example, a transceiver circuit 350 is arranged on the PCB connected to the antenna arrangement 330 at least partly via a transmission line 351, such as a microstrip line or the like.

[0030] The portion of the PCB where the antenna arrangement is configured is partly cut out from the PCB; A cut-out track 320 is formed in the PCB by, e.g., milling or machining a groove in the PCB. The cut-out track 320 defines a tongue 325. If the PCB is formed at least partly in some bendable material, the tongue 325 can be bent around a bending axis 326 at the base of the tongue and the antenna arrangement 330 thereby directed in different directions depending on the bending angle.

[0031] Figure 3b shows a back-side B of the PCB 300. In order to simplify bending of the tongue 325 in a controlled manner, one or more grooves or recesses may optionally be formed in the PCB. Thus, according to aspects, one or more recesses are formed on a back-side B of the PCB opposite to the front side F and in connection to the tongue 325. The recesses are arranged parallel to the bending axis 326 in order to simplify a controlled bending of the tongue 325. In case the PCB is a hybrid PCB formed from layers of flexible and non-flexible materials, then the recesses can be formed to extend through the non-flexible layers, allowing the flexible layers to bend. Such hybrid PCBs will be discussed below in connection to Figure 8.

[0032] Figure 4 shows a side view of the PCB 300 mounted on a fixture 410. The fixture 410 has a wedge-shaped protrusion 420 configured to contact the tongue 325 and to bend the tongue to the pre-determined angle α when pressed against the PCB 300. Thus, the shape of the wedge 420 determines the angle α .

[0033] Fixtures such as the fixture 410 can be cost-efficiently produced from a wide variety of different materials, such as aluminum, Polytetrafluoroethylene (PTFE) which is a synthetic fluoropolymer of tetrafluoroethylene, plastic. The fixture can be machined or molded to the desired shape with high precision.

[0034] The fixture can be fixedly attached to the PCB by means of, e.g., gluing or bolting. The fixture should preferably be a part of the frame or enclosure of the unit for which the antenna is used.

[0035] To summarize, Figures 3a, 3b, and 4 show a PCB 300 for a mechanically tiltable antenna arrangement 330. The PCB comprises at least one cut-out track 320 defining a tongue 325 for holding the antenna arrangement 330 on a front side F of the PCB. The PCB is formed at least partly in a bendable material 310 allowing the tongue 325 to be bent around a bending axis 326 to a pre-determined angle α , thereby mechanically tilting the antenna arrangement in the pre-determined angle α .

[0036] A number of different types of antennas can be arranged on the tongue and bent to the pre-determined angle α . However, a patch antenna arranged directly on the front side F of the PCB 300 is a preferred option.

5 Patch antennas are known and will not be discussed in more detail here. It is appreciated that an openended microstrip line, stub, or the like also constitutes a patch antenna, i.e., there is no requirement of a specific 'patch' arranged at an end of a transmission line for the antenna to be classified as a patch antenna.

10 **[0037]** According to some aspects, properties related to bending capability of the transmission line connection 351 are considered when specifying materials for use with the PCB. For instance, roll-annealed copper exhibits a suitable degree of flexibility, as do gold and silver. It is, however, appreciated that a wide variety of different materials can be used for the transmission line 351. A large degree of flexibility may also not be required in case the pre-determined angle α is small.

20 **[0038]** Young's Modulus is a mechanical property that measures the stiffness of a solid material. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material in the linear elasticity regime of a uniaxial deformation. A solid material will undergo elastic deformation when a small load is applied to it in compression or extension. Elastic deformation is reversible (the material returns to its original shape after the load is removed). At near-zero stress and strain, the stress-strain curve is linear, and the relationship between stress and strain is described by Hooke's law that states stress is proportional to strain. The coefficient of proportionality is Young's modulus. The higher the modulus, the more stress is needed to create the same amount of strain; an idealized rigid body would have an infinite Young's modulus. In practice, Young's moduli are given in megapascals (MPa or N/mm²) or gigapascals (GPa or kN/mm²).

35 **[0039]** According to some aspects, the PCB is formed at least partly in a material having a Young's modulus value below 5 GPa, preferably below 2 GPa and more preferably below 1 GPa. Non-glass woven circuit materials, with modulus less than 2 GPa such as Rogers corporation RO3003 (0.9 GPa) or RO3042 (1 GPa), together with roll annealed copper are likely to be bendable to relevant angles without performance or reliability degradation.

40 **[0040]** Modulus values for flex PCB substrates, such as Kapton Polyamide, are in the same order or slightly higher.

50 **[0041]** It is appreciated that a wide variety of different flexible PCB materials can be used. For instance, PTFE has the required properties. Polyimide, which is a polymer of imide monomers, may also be applicable according to some aspects. Different variants of plastic material can also be used.

55 **[0042]** In order to get an idea of the dimensions involved, a length L of the antenna arrangement 330 measured along an extension direction of the tongue is, ac-

cording to an example, 10 mm. Lengths from about 5 mm up to some 15 mm are conceivable for high frequency radar applications. This disclosure is, however, not limited to any particular dimension of antenna. It is appreciated that antenna dimensions are determined mainly based on operating frequency in a known manner.

[0043] The radius of a bending arc 240 formed by bending the tongue to the pre-determined angle α is according to an example on the order of $R=12.5$ mm. However, some materials may permit more pronounced bending arcs, e.g., on the order of 5 mm, while some other materials may be less flexible, in which case the bending arc radius may be on the order of 20 mm or more.

[0044] Figures 5-7 show top views of PCBs 500, 600, 700. The PCBs 500, 600, 700 comprise a plurality of cut-out tracks 320, 320' defining respective tongues 525, 625, 725 for holding a corresponding plurality of antenna arrangements 330. It is appreciated that the tongues can be arranged to be bent in different bending angles, and also in different directions. This allows for freedom in designing coverage of almost any given field of view.

[0045] Figure 5 shows one example where two tongues are arranged on either side of a fixed antenna arrangement 530. The two tongues are arranged bendable in different opposite directions to cover areas to the side of the area covered by the center antenna arrangement 530. It is noted that the PCB 500 comprises both bendable 330 and non-bendable 330' antenna arrangements.

[0046] Figure 6 shows a further example PCB 600 where four tongues have been machined to surround a non-bendable center antenna arrangement 650. The four tongues are arranged bendable in different directions. This way an antenna field of view corresponding to an ellipsoid or spherical surface segment can be generated.

[0047] The tracks can be machined as straight lines, but also in other shapes. Figure 7 shows one such example where a petal-shaped track 320' has been cut in the PCB 700.

[0048] The PCBs 500, 600, 700 may according to aspects comprise a fixture having wedge-shaped protrusions 420 configured to contact respective tongues 325 and to bend the tongues to pre-determined angles when pressed against the PCB, wherein the predetermined angles are configured such that the plurality of antenna arrangements collectively cover a field of view 105.

[0049] Figure 8 shows a side view of a hybrid PCB 800. The PCB 800 comprises a plurality of layers 810, 820, 830, 840. One or more upper layers 810 is formed in a flexible material and remaining lower layers 820, 830, 840 are formed in a less flexible material compared to the one or more upper layers. One or more recesses 850 are machined in the PCB from the back-side B through the remaining lower layers 820, 830, 840. This simplifies bending of the tongues discussed above, and allows for a cost-effective method to produce the bendable PCBs, since only the top layer or layers need to be formed in the bendable material, while remaining layers can be

formed in a stiffer material, such as regular FR4 PCB material.

[0050] FR-4 or FR4 is a NEMA grade designation for glass-reinforced epoxy laminate material. FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing).

[0051] According to aspects, the one or more upper layers 810 are formed at least partly from Polytetrafluoroethylene, PTFE. PTFE is a flexible material having suitable dielectric properties for this application. PTFE can be moulded into different shapes cost effectively and with high precision.

[0052] It is again appreciated that a wide variety of different flexible PCB materials can be used. For instance, Polyimide, which is a polymer of imide monomers, may be applicable according to some aspects. Different variants of plastic material can also be used.

[0053] Figure 7 is a flow chart illustrating methods. There is illustrated a method for manufacturing a PCB for a mechanically tiltable antenna arrangement 330. The method comprises;

forming S1 a PCB in a bendable material 310 allowing a tongue-shaped section of the PCB to be bent around a bending axis 326 to a pre-determined angle α ;

[0054] According to aspects, in case the PCB also comprises non-flexible layers, such as illustrated in Figure 8, recesses or the like must be formed in the PCB to allow bending of the PCB. cutting S2 one or more tracks 320 in the PCB to define tongues 325 for holding respective antenna arrangements 330 on a front side F of the PCB;

arranging S3 a fixture 410 with a protrusion 420 configured to contact at least one of the tongues 325 and to bend the tongue to the pre-determined angle α when the fixture is pressed against the PCB 300; and mounting S4 the fixture pressed against the PCB, thereby mechanically tilting the antenna arrangement 330 to the pre-determined angle α .

[0055] Consequently, the disclosed methods correspond to the mechanically tiltable antenna arrangement discussed above.

Claims

1. A printed circuit board (300, 400, 500, 600, 700, 800), PCB, for a mechanically tiltable antenna arrangement (330), the PCB comprising at least one cut-out track (320) defining a tongue (325, 525, 625, 725, 725') for holding the antenna arrangement (330) on a front side (F) of the PCB, wherein the PCB is formed at least partly in a bendable material (310) allowing the tongue (325, 525, 625, 725, 725') to be bent around a bending axis (326) to a pre-determined angle (α), thereby mechanically tilting the antenna arrangement in the pre-determined angle (α).

2. The PCB (300, 400, 500, 600, 700, 800) according to claim 1, wherein the antenna arrangement (330) comprises a patch antenna or a PCB antenna arranged on the front side (F) of the PCB.
3. The PCB (300, 400, 500, 600, 700, 800) according to claim 2, wherein a transmission line connection to the patch antenna arrangement, or other PCB-antenna, is formed at least partly from any of copper, roll annealed copper, silver or gold.
4. The PCB (300, 400, 500, 600, 700, 800) according to any previous claim, wherein one or more recesses are formed on a back side (B) of the PCB opposite to the front side (F) and in connection to the tongue (325, 525, 625, 725, 725') wherein the recesses are arranged parallel to the bending axis (326).
5. The PCB (300, 400, 500, 600, 700, 800) according to any previous claim, wherein the PCB is formed at least partly in a material having a Youngs modulus value below 5 GPa, preferably below 2 GPa and more preferably below 1 GPa.
6. The PCB (300, 400, 500, 600, 700, 800) according to any previous claim, wherein a length L of the antenna arrangement (330) measured along an extension direction of the tongue is between 5 mm and 15 mm, and preferably 10 mm.
7. The PCB (300, 400, 500, 600, 700, 800) according to any previous claim, wherein a radius of a bending arc (240) formed by bending the tongue to the pre-determined angle (a) is between R=5 mm and R=20 mm, and preferably R=12.5 mm.
8. The PCB (400) according to any previous claim, comprising a fixture (410) having a wedge-shaped protrusion (420) configured to contact the tongue (325) and to bend the tongue to the pre-determined angle (a) when pressed against the PCB (300).
9. The PCB (500, 600, 700) according to any previous claim, comprising a plurality of cut-out tracks (320, 320') defining respective tongues (525, 625, 725) for holding a corresponding plurality of antenna arrangements (330).
10. The PCB (500, 600, 700) according to claim 9, comprising a fixture having wedge-shaped protrusions (420) configured to contact respective tongues (325) and to bend the tongues to pre-determined angles when pressed against the PCB, wherein the pre-determined angles are configured such that the plurality of antenna arrangements collectively cover a field of view 105.
11. The PCB (800) according to any previous claim comprising a plurality of layers (810, 820, 830, 840), wherein one or more upper layers (810) is formed in a flexible material and wherein remaining lower layers (820, 830, 840) are formed in a less flexible material compared to the one or more upper layers, wherein a recess (850) is machined in the PCB from the back side (B) through the remaining lower layers (820, 830, 840).
12. The PCB (800) according to claim 10, wherein the one or more upper layers (810) are formed at least partly from Polytetrafluoroethylene, PTFE, Polyimide, or a Polymer film.
13. A mechanically tiltable antenna arrangement comprising a printed circuit board (300, 400, 500, 600, 700, 800) according to any of claims 1-12.
14. A radio frequency signal transceiver for radar operation and/or wireless communication comprising transceiver circuitry (350) and a mechanically tiltable antenna arrangement according to claim 13.
15. A method for manufacturing a printed circuit board (300, 400, 500, 600), PCB, for a mechanically tiltable antenna arrangement (330), the method comprising; forming (S1) a PCB in a bendable material (310) allowing a tongue-shaped section of the PCB to be bent around a bending axis (326) to a pre-determined angle (a); cutting (S2) one or more tracks (320) in the PCB to define tongues (325) for holding respective antenna arrangements (330) on a front side (F) of the PCB; arranging (S3) a fixture (410) with a protrusion (420) configured to contact at least one of the tongues (325) and to bend the tongue to the pre-determined angle (a) when the fixture is pressed against the PCB (300); and mounting (S4) the fixture pressed against the PCB, thereby mechanically tilting the antenna arrangement (330) to the pre-determined angle (a).

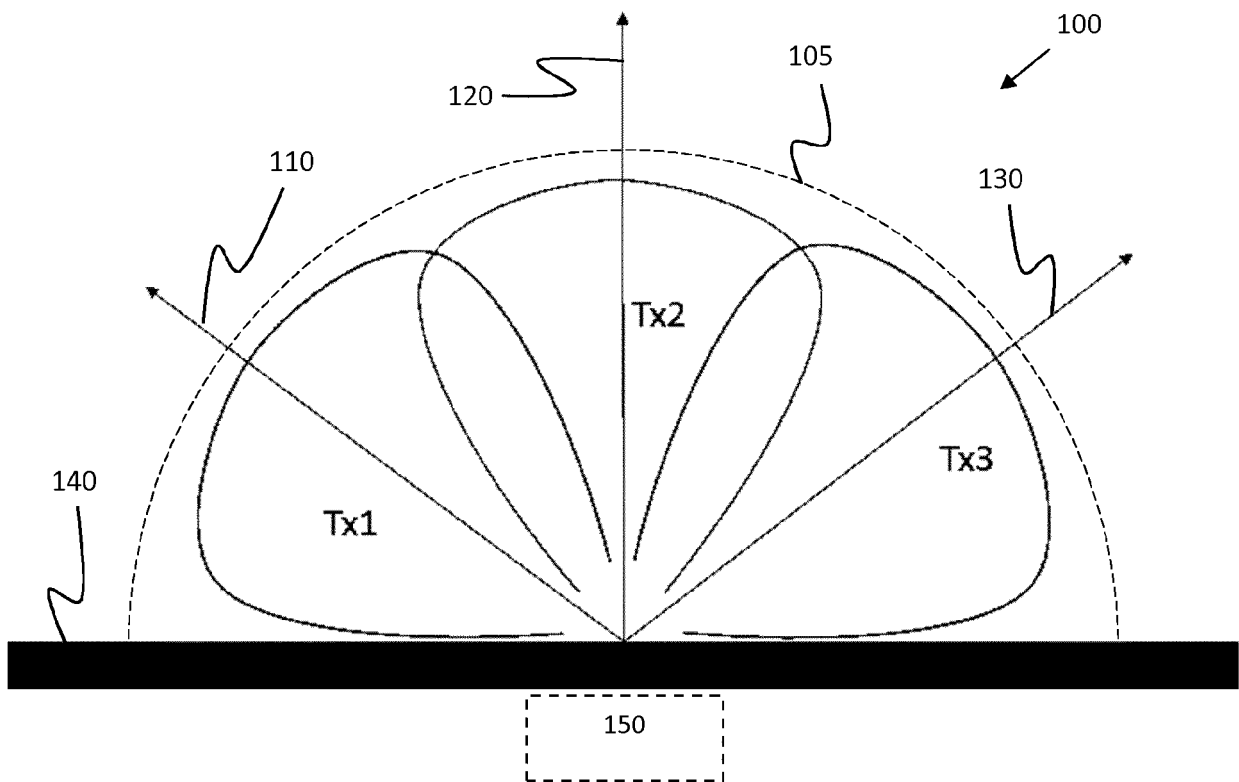


FIG. 1

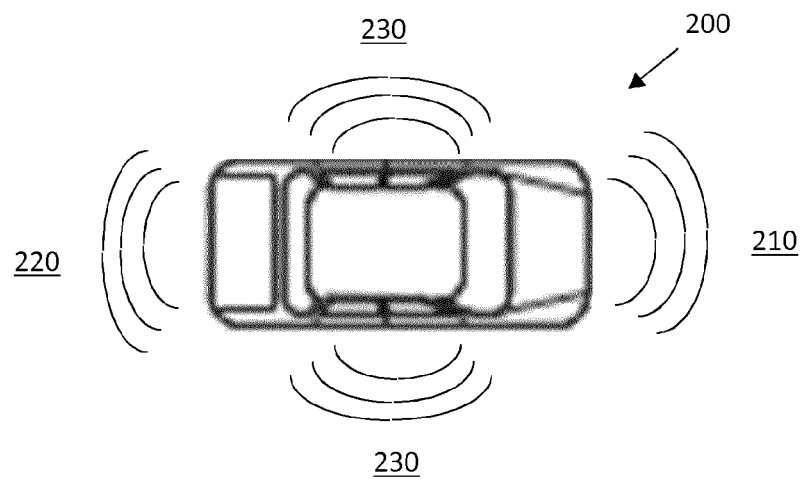


FIG. 2

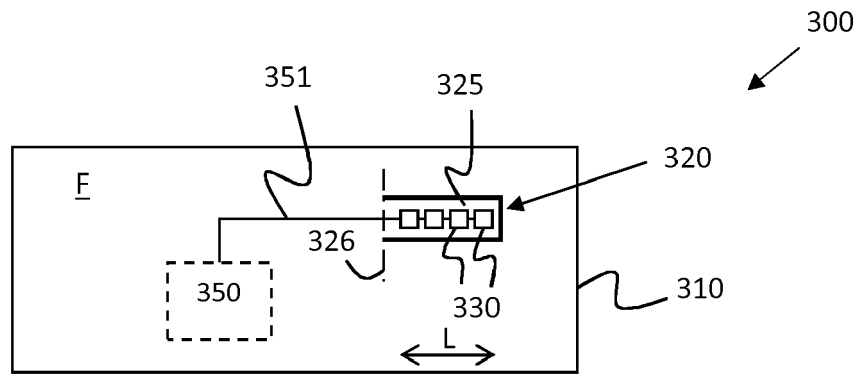


FIG. 3a

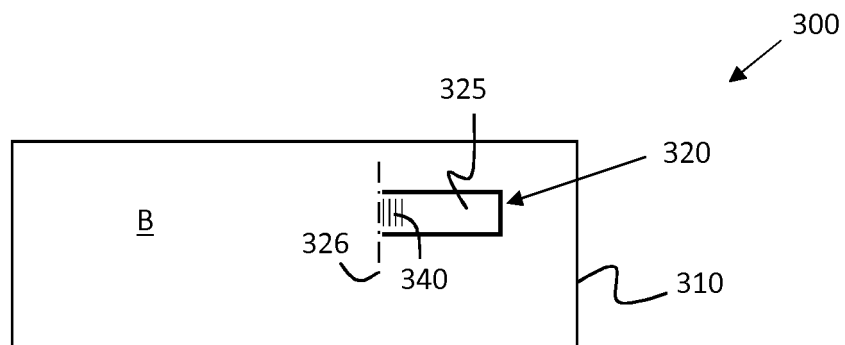


FIG. 3b

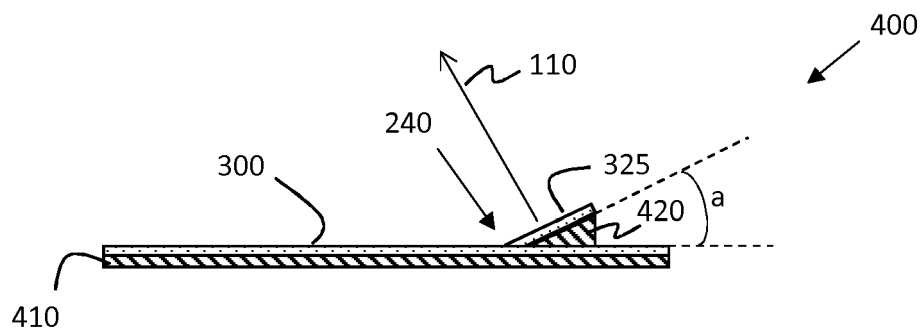


FIG. 4

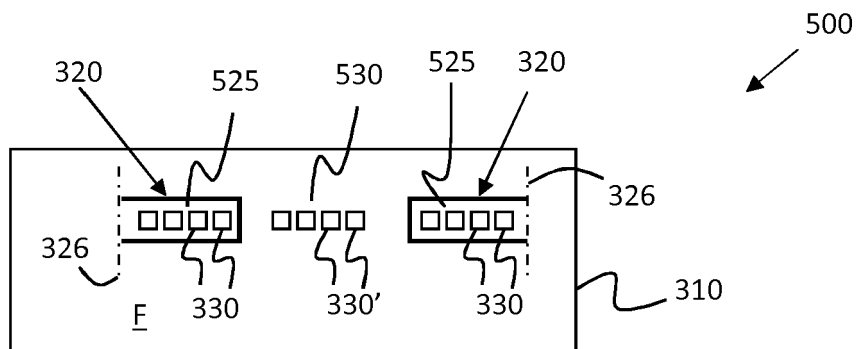


FIG. 5

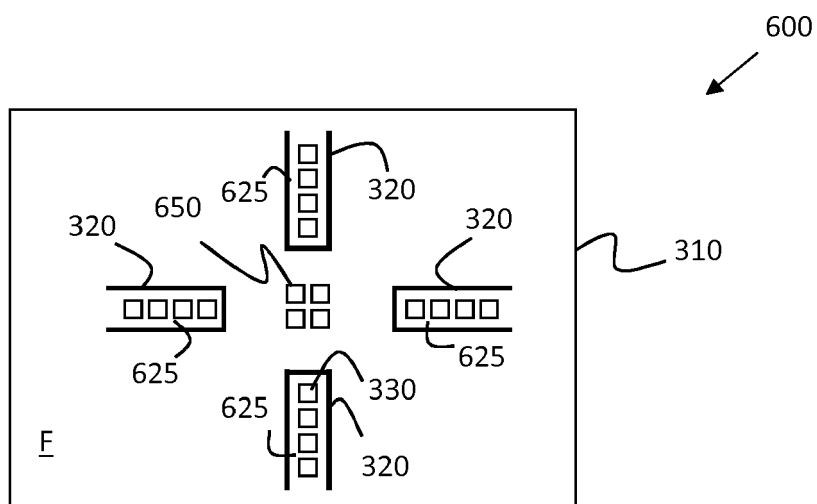


FIG. 6

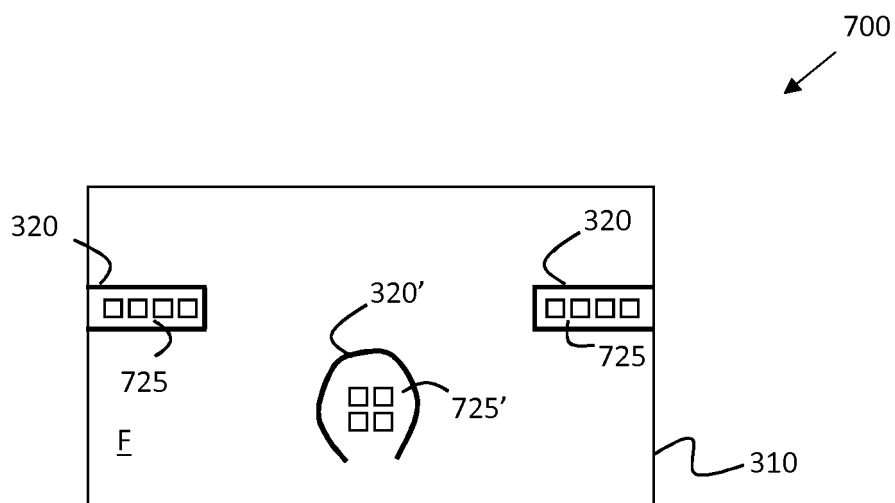


FIG. 7

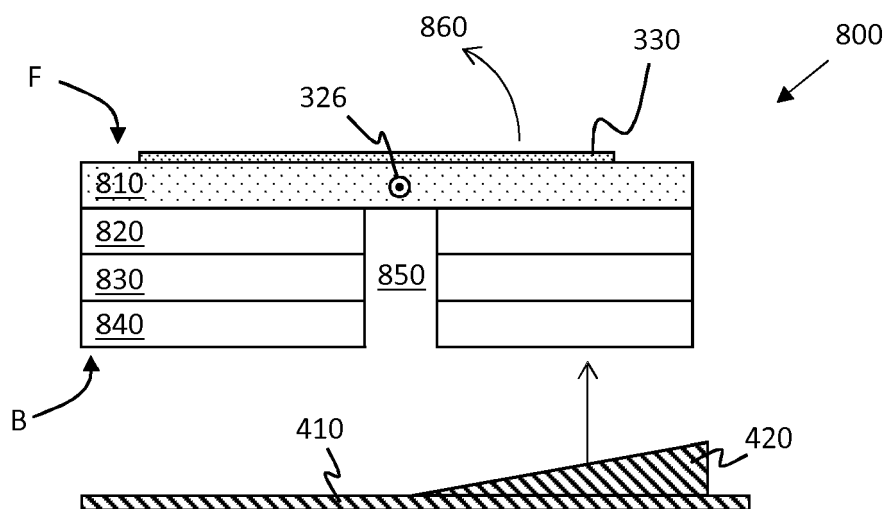


FIG. 8

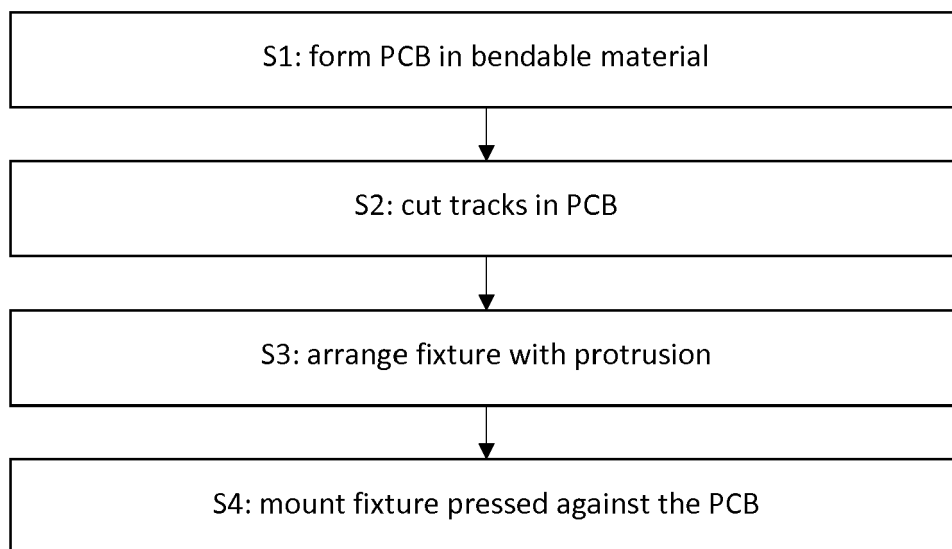


FIG. 9



EUROPEAN SEARCH REPORT

 Application Number
 EP 18 20 2763

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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)
X	WO 2004/042938 A2 (TANTIVY COMM INC [US]) 21 May 2004 (2004-05-21) * page 6, line 16 - line 22 * * page 8, line 18 - line 21 * * page 12, line 19 - page 15, line 9 * * page 16, line 1 - line 5 * * page 19, line 15 - line 32 * * figures 2-9 *	1-15	INV. H01Q1/12 H01Q1/32 H01Q1/38 H01Q3/06
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 14 May 2019	Examiner Wattiaux, Véronique
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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