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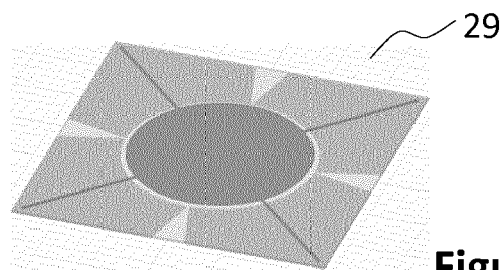
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(54) **A COMPACT, WIDEBAND, MULTIPLE INPUT HYBRID SLOT ANTENNA WITH IMPROVED DIVERSITY**

(57) A novel antenna topology with multiple inputs on a hybrid slot-type antenna radiating element is realized on two layers of a printed circuit board using multiple feeders connected to a central conductive surface on a first layer and multiple slots connected to a central non-conductive surface on a second layer, the central surfaces having similar shapes but different sizes to create an interval that behaves as a slot antenna by radiating electromagnetic waves. To increase the decorrelation between the multiple directional radiation patterns cor-

responding to the different inputs the antenna uses a main printed circuit board as part of the antenna design to improve the decorrelation and the multiple inputs locations and multiple slot shapes are chosen in this objective. The antenna is adapted to be integrated directly in a receiver for the reception of broadcast television such as ATSC but can also be integrated into an indoor device connected to a television receiver. In this case, the indoor device would not require any installation nor particular positioning.



(combined view)

Figure 2F

Description

1. TECHNICAL FIELD

[0001] The present disclosure relates to an antenna adapted to be integrated in an apparatus for receiving a digital signal, and more particularly a broadcast television signal using multiple inputs multiple outputs (MIMO) technology.

2. BACKGROUND ART

[0002] Reception of broadcast television conventionally uses an aerial antenna connected to the receiver through a coaxial cable. Such installation is cumbersome since it requires a solid fixture of the aerial antenna, typically on the roof of the premises, and implies passing cables through the premises up to the receiver device. Furthermore, the quality of the reception depends on the orientation of the antenna towards the emitting station and is subject to unwanted alterations when the winds blow strongly. A common alternative is to use in-door antennas, but such antennas are typically very sensitive to the positioning: moving them from several centimetres or rotating them of several degrees has huge impact on the quality of the signal reception. A more consumer friendly and more reliable setup would be to integrate the antenna directly into the receiver device, or into a separate in-door device that would not require further installation nor precise positioning. One issue with such objective is that the antenna size is directly related to the wavelength corresponding to the operating frequency. For example, ATSC uses a Hi-VHF Band and a UHF band that correspond respectively to wavelength of typically 150 cm (at VHF frequency of 200 MHz) and 60 cm (at UHF frequency of 500 MHz). Moreover, the size increases with antenna directionality and relative bandwidth (typically 21% in the Hi-VHF band and 40% in the UHF band). The need of more than 4 directional radiation patterns aggravates the size problem and raises the issue of decorrelation between the radiation patterns. Moreover, the antenna system must work properly despite the proximity of the receiver main board which is realized on a multi-layer Printed Circuit Board (PCB).

[0003] This kind of requirements is encountered in MIMO systems where multiple decoupled antennas must comply with a high level of integration of electronic components in increasingly small devices. However, directionality (even moderate) is not required and the operating frequency such as WiFi 2.4 GHz and 5 GHz and even the frequencies used on Mobile Networks are significantly higher than the frequency used in TV broadcast. For example, in a IEEE AP-S URSI 2013 publication entitled "A Compact Printed 4x4 MIMO-UWB Antenna with WLAN Band Rejection", Nguyen et al presented a compact Ultra Wide Band MIMO antenna that uses 4 monopoles grouped orthogonal to each other in a square of 60 mm x 60 mm. The electrical size of the antenna system

at the lowest frequency (i.e. 2.85 GHz), is equal to $0.57\lambda \times 0.57\lambda$ where λ is the wavelength corresponding to the lowest frequency of 2.85 GHz. Though compact, if we use the same concept for our lowest antenna frequency (i.e. $f = 174 \text{ MHz} - \lambda = 172 \text{ cm}$) it leads to an antenna size of 98 cm x 98 cm, which is not acceptable for integration into an indoor device.

[0004] The present disclosure has been designed with the foregoing in mind.

3. SUMMARY

[0005] A novel antenna topology with multiple inputs on a hybrid slot-type antenna radiating element is realized on two layers of a printed circuit board using multiple feeders connected to a central conductive surface on a first layer and multiple slots connected to a central non-conductive surface on a second layer, the central surfaces having similar shapes but different sizes to create an interval that behaves as a slot antenna by radiating electromagnetic waves. To increase the decorrelation between the multiple directional radiation patterns corresponding to the different inputs the antenna uses a main printed circuit board as part of the antenna design to improve the decorrelation and the multiple inputs locations and multiple slot shapes are chosen in this objective. The antenna is adapted to be integrated directly in a receiver for the reception of broadcast television such as ATSC but can also be integrated into an indoor device connected to a television receiver. In this case, the indoor device would not require any installation nor particular positioning.

[0006] A first aspect of the disclosure is directed to a printed circuit board antenna having multiple inputs, the antenna comprising a first layer and a second layer, the first layer comprising a plurality of conductive tracks feeding a central conductive surface, the second layer comprising a central non-conductive surface within a conductive area and a plurality of slots extending the non-conductive surface towards an edge of the printed circuit board, wherein the central conductive surface of first layer and the central non-conductive surface of the second layer have similar shape with different sizes to create an interval between the surfaces that behaves as a slot antenna and radiates electromagnetic waves.

[0007] In variant embodiments of first aspect:

- at least one of slots of the second layer is triangular, whose base is located on the edge of the printed circuit board and directed to the circular slot;
- the central conductive surface of first layer and the central non-conductive surface of the second layer are shaped in the form of a disc;
- the number of conductive tracks is one among two, three, four, five, six, seven and eight;
- the outer extremities of the conductive tracks are located in the corners of the printed circuit board;
- for at least one conductive track, the outer extremity

of the at least one conductive track is located at the edge of the printed circuit board between the corners and the center of the edge of the printed circuit board.

- at least one conductive track is using single stub tuning to be matched in the VHF band;
- the shape of the central conductive surface of first layer and the non-conductive central of the second layer is one among a triangle, a square, a polygon, a star, an oval and an ovoid;
- the conductive surfaces are printed on the printed circuit board.
- the non-conductive surfaces are etched into the printed circuit board.
- the size of the interval is 5mm for broadcast television reception or 1.5mm for WiFi reception.

[0008] A second aspect of the disclosure is directed to a device for receiving communications, the device comprising the antenna according to the first aspect and a main board, wherein the main board is positioned to improve the decorrelation between the inputs of the antenna.

4. BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

- **Figure 1** illustrates an annular slot antenna according to the prior art;
- **Figure 2A** shows a top view of a Multiple Input Hybrid Slot (MIHS) antenna according to a non limiting first exemplary embodiment of the disclosed principles,;
- **Figure 2B** shows a bottom view of a Hybrid Multiple Input Hybrid Slot (MIHS) antenna according to a non limiting first exemplary embodiment of the disclosed principles;
- **Figure 2C** shows a combined view in perspective of a Multiple Input Hybrid Slot (MIHS) antenna according to a non limiting first exemplary embodiment of the disclosed principles;
- **Figure 2D** shows a top view of a Multiple Input Hybrid Slot (MIHS) antenna according to a non limiting second exemplary embodiment of the disclosed principles using triangular slots;
- **Figure 2E** shows a bottom view of a Multiple Input Hybrid Slot (MIHS) antenna according to a non limiting second exemplary embodiment of the disclosed principles using triangular slots;
- **Figure 2F** shows a combined view in perspective of a Multiple Input Hybrid Slot (MIHS) antenna according to a non limiting second exemplary embodiment of the disclosed principles using triangular slots;
- **Figure 2G** shows a Multiple Input Hybrid Slot (MIHS) antenna according to a non-limiting second exemplary embodiment of the disclosed principles in a perspective view with size information;
- **Figure 3A** shows the radiation directivity of the MIHS antenna of second exemplary embodiment without

main board;

- **Figure 3B** shows the radiation directivity of the MIHS antenna of second exemplary embodiment with main board;
- **Figure 3C** shows the achieved directivity for the antenna of the second embodiment in the azimuth plane when switching between the four radiation patterns without the main board;
- **Figure 3D** shows the achieved directivity for the antenna of the second embodiment in the azimuth plane when switching between the four radiation patterns with the main board;
- **Figure 4** shows an example of antenna according to a specific and non-limiting embodiment of the disclosed principles wherein the feeding points are modified;
- **Figure 5** shows an example of antenna according to a specific and non-limiting embodiment of the disclosed principles using an asymmetric setup;
- **Figure 6** shows an example of antenna according to a specific and non-limiting embodiment of the disclosed principles using single stub tuning;
- **Figure 7** shows six examples of antenna according to specific and non-limiting embodiments of the disclosed principles with different number of inputs;
- **Figure 8** shows an example of antenna according to specific and non-limiting embodiments of the disclosed principles with eight inputs;
- **Figure 9** shows six examples of positioning of the main board regarding the antenna, according to specific and non-limiting embodiments of the disclosed principles.

[0010] It should be understood that the drawing(s) are for purposes of illustrating the concepts of the disclosure and are not necessarily the only possible configuration for illustrating the disclosure.

5. DESCRIPTION OF EMBODIMENTS

[0011] The present description illustrates the principles of the present disclosure. All examples and conditional language recited herein are intended for educational purposes to aid the reader in understanding the principles of the disclosure and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions.

[0012] Moreover, all statements herein reciting principles, aspects, and embodiments of the disclosure, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure. Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented

herein represent conceptual views of illustrative circuitry embodying the principles of the disclosure.

[0013] **Figure 1** illustrates an annular slot antenna according to the prior art. **Figure 1** shows three schematic views of the ASA 10. The two left hand views 10A, 10B represent respectively a top side 10A and a bottom side 10B of the ASA 10. The right-hand view represents the elements present both at the top and bottom sides of the ASA 10 in a combined view. The top side 10A of the ASA is a non-conductive substrate 12 comprising a metallized microstrip line 11. The bottom side 10B of the ASA 10 is a conductive ground plane 15 comprising an annular slot 16. When the metallized microstrip line 11 is driven by a signal at a given frequency, the annular slot 16 radiates electronic waves in a way similar to a dipole antenna. The slot nature of the ASA presents also some interesting features, such as, the easy integration of active devices in the slot for radiation pattern or frequency reconfiguration of the antenna. Another advantage of a slot antenna such as the ASA is the natural decoupling between the antenna and the rest of the circuits which could be realized either on the space available backside of the ground plane where the radiating slot is etched or on a separate printed circuit board (PCB) which is shielded by the slot ground plane. This makes the ASA antenna a good candidate for being integrated in electronic devices such as communication devices. However, the principles of an ASA antenna still have to be adapted for providing a multiple inputs antenna with improved decorrelation between the radiation patterns corresponding to the different inputs.

[0014] The term "slot" is used throughout the disclosed principles to refer to a non-conductive area etched in a conductive area within a same layer of for example a PCB. The slot represents a hole cut out of for example a metalized surface thus breaking the electrical continuity.

[0015] **Figure 2A, 2B, 2C** show a Multiple Input Hybrid Slot (MHIS) antenna according to a non-limiting first exemplary embodiment of the disclosed principles. **Figure 2A** illustrates a top view, **figure 2B** a bottom view and **figure 2C** a combined view in perspective. In this embodiment, four inputs are used. Other embodiments will use less inputs, for example two or three or will use more inputs such a six or eight to adapt to other kind of applications. According to the first embodiment, the MHIS antenna 20 is a printed circuit board antenna comprising a first layer 20A and a second layer 20B separated by a non-conductive substrate. In the first embodiment, the first layer is on top and the second layer is on the bottom. The first layer 20A comprises a plurality of conductive tracks 21A, 21B, 21C, 21D feeding a central conductive surface 22, i.e. the conductive tracks being connected to the central conductive surface. Outer extremities of the conductive tracks, thus on the edge of the printed circuit board, are feeding points where the signal is input. The first layer 20A is for example made of a non-conductive substrate 23, on which the conductive tracks such as

microstrip lines 21A, 21B, 21C, 21D and a central conductive surface 22 are printed. The central conductive surface 22 is a metallized surface of any shape, for example a disc shape as illustrated in figures 2A, 2B, 2C.

The second layer 20B comprises a central non-conductive surface 26 embedded in a conductive surface 25. In other words, the conductive surface 25 surrounds the central non-conductive surface 26. The second layer 20B further comprises a plurality of slots 24A, 24B, 24C, 24D that are non-conductive and extend from the central non-conductive surface 26 to the edge of the printed circuit board. The central non-conductive surface and the slots are for example etched from a fully conductive layer. In other words, the second layer 20B is fully conductive except the surface 26 and the slots 24A, 24B, 24C, 24D being etched in the conductive layer. According to a specific and non-limiting embodiment of the disclosed principles, one of either the central conductive surface 22 of the first layer 20A or the central non-conductive surface 26 of the second layer 20B is surrounding the other, the central conductive surface 22 and the central non-conductive surface 26 being centred in the plane of the printed circuit board antenna 20. An interval 27 between the central conductive surface 22 of the first layer 20A or the central non-conductive surface 26 of the second layer 20B results from one of either of these surfaces being surrounding the other. By "surrounding" it is meant here and throughout the document that one surface is overlapping the other in the plane of the PCB: when looking at projections of both surfaces in the plane of the PCB, one projected surface is completely included in the other and the difference between both surfaces creates an interval. The interval 27 between the central conductive surface 22 of the first layer 20A or the central non-conductive surface 26 of the second layer 20B of the PCB antenna behaves as a slot antenna by radiating electromagnetic waves. However, although behaving as a slot, the interval 27 differs from a slot since an interval is a hole between conductive surfaces of different layers while a slot is a hole within a conductive surface of same layer.

[0016] In order to benefit from a homogeneous interval, the shapes of the central conductive surface 22 of the first layer 20A and of the central non-conductive surface 26 of the second layer 20B are identical, but only of different sizes. In another embodiment, the shape identity is not required but a shape similarity is sufficient, for example one of the surface being a disc and the other being a (filled) oval.

[0017] The term central utilized herein is an abuse of language since in this context it does not necessarily indicate that the central surface is positioned at the exact center of the printed circuit board but rather indicates that the central surface is positioned away from the edges, although not of the same distance for each of the edge.

[0018] The sizing of the antenna is so that the conductive circular disc 22 of the first layer 20A and the non-conductive circular disc slot 26 of the second layer 20B

are aligned in the (x,y) plane, while the diameter of the second is for example 10 mm larger than the diameter of the first and so that the interval 27 generated between the circular disc etched on one side of the substrate and the circular slot realized on the other side presents almost the same dimensions as the slot of a regular ASA, for example of 5mm.

[0019] Figure 2D, 2E, 2F show a Multiple Input Hybrid Slot (MIHS) antenna according to a non-limiting second exemplary embodiment of the disclosed principles using triangular slots. Figure 2D illustrates a top view, figure 2E a bottom view and figure 2F a combined view in perspective. In this embodiment, four inputs are used. Other embodiments will use less inputs, for example two or three or will use more inputs such a six or eight to adapt to other kind of applications. The second embodiment is very similar to the first embodiment and uses almost the same elements arranged identically. The difference is the shape of slot. While antenna of the first embodiment used straight slots on its second layer, the antenna 27 of second embodiment uses slots 28A, 28B, 28C, 28D that have a triangular shape whose base are located on the edge of the printed circuit board and that are directed to the circular central non-conductive surface 28. This shape provides better decorrelation between the radiation patterns corresponding to the different inputs and better antenna efficiency.

[0020] Figure 2G shows a Multiple Input Hybrid Slot (MIHS) antenna according to a non-limiting second exemplary embodiment of the disclosed principles in a perspective view with size information. In this embodiment, the overall size of the printed circuit board is 280mm by 280mm. The central conductive surface of the top layer is circular and has a diameter of 160mm while the central non-conductive surface of the bottom layer is also circular and has a diameter of 170mm thus creating an interval that is 5mm wide. The conductive tracks of the top layer are 2.375mm wide. The triangular slots of the bottom layer have a base of 30mm and are 2.25mm wide at the area where they meet the circular central non-conductive surface. Figure 2G also show the positioning of the main printed circuit board under the antenna. This board is 80mm wide and is spaced at 40mm below the antenna.

[0021] Figure 3A shows the radiation directivity of the MIHS antenna of second exemplary embodiment without main board. Figure 3B shows the radiation directivity of the MIHS antenna of second exemplary embodiment with main board. The diagrams correspond to simulations of horizontal plane total directivity radiation pattern at different frequencies and highlight the impact of using the main board within the antenna system design. From top left to bottom right, the frequencies correspond to 200, 500, 550, 600, 650 and 700MHz. These frequencies are chosen since they correspond to the frequencies used for broadcast television and particularly ATSC. It can be noticed that the antenna without the main board has highly correlated radiation patterns, for example the bottom left diagram of figure 3A corresponding to the 600MHz

frequency shows only two patterns for the four inputs, meaning that two of them have the same radiation diagrams and thus are highly correlated. In the corresponding diagram of figure 3B for the same frequency, with the main board, the four patterns are clearly separated thus significantly reducing this correlation. These simulations show that adding the main board improves the decorrelation between the inputs.

[0022] Figure 3C shows the achieved directivity for the antenna of the second embodiment in the azimuth plane when switching between the four radiation patterns without the main board. Figure 3D shows the achieved directivity for the antenna of the second embodiment in the azimuth plane when switching between the four radiation patterns with the main board. When comparing these diagrams, it can be seen that thanks to the improved decorrelation between the radiation patterns in presence of the main board, fairly better directivity is obtained in the azimuth plane when switching between the different inputs.

[0023] Figure 4 shows an example of antenna according to a specific and non-limiting embodiment of the disclosed principles wherein the feeding points are modified. Indeed, instead of distributing the feeding points symmetrically towards the corners of the board like proposed in the first and second embodiments, the feeding points and corresponding conductive tracks are moved to other locations, for example towards a point between the center of an edge of the board and the closest corner. Simulations showed that the performances of the antenna regarding its wide band behavior, the relatively low coupling and the good efficiency of the antenna are still correct. In addition, this modification further enhances its patterns diversity.

[0024] Figure 5 shows an example of antenna according to a specific and non-limiting embodiment of the disclosed principles using an asymmetric setup. In this embodiment, some slots of the bottom layer are straight while others are using a triangular shape. This asymmetry of the slot shapes further enhances the diversity.

[0025] Figure 6 shows an example of antenna according to a specific and non-limiting embodiment of the disclosed principles using single stub tuning. It should be noticed that these antennas can easily be matched in the VHF band with an acceptable bandwidth using any matching technique, for example using single stub tuning. This is done by extending the conductive tracks of the first layer parallel to the edge of the printed circuit board. In such setup, the antenna is well matched in the Hi-VHF band without degrading its matching in the UHF band. Furthermore, the antenna still presents a very interesting radiation efficiency in both bands.

[0026] Figure 7 shows six examples of antenna according to specific and non-limiting embodiments of the disclosed principles with different number of inputs. From top left to bottom right, the antennas respectively use three, four, five, six, seven or eight inputs, illustrating the adaptability of the principles to different configurations.

[0027] Figure 8 shows an example of antenna accord-

ing to specific and non-limiting embodiments of the disclosed principles with eight inputs. In this embodiment, the central conductive surface of the first layer and the central non-conductive surface of the second layer present a particular shape adapted to receive eight conductive tracks instead of the circular shape used in former embodiments. This antenna provides a very good coverage in the horizontal plane without any low directivity zone.

[0028] Figure 9 shows six examples of positioning of the main board regarding the antenna, according to specific and non-limiting embodiments of the disclosed principles. When varying the position of the main board relatively to the antenna, the radiation diagram varies. Thus, the position should be chosen according to simulations in order to achieve the desired result. As illustrated in Figure 9, in some situations it might be interesting to use more than one board (or an additional metallic plate) for improved flexibility in the control of the radiation patterns.

[0029] In all embodiments described herein, the antenna is printed on a FR4 (Flame Resistant 4) substrate ($\epsilon_r = 4.2$, $\tan(\delta) = 0.02$) with a thickness of 1.041 mm. The PCB is a square of 280mm by 280mm.

[0030] According to another embodiment, the shape of both the central conductive surface of top layer and central non-conductive surface of the bottom layer are not circular but are in the shape of a triangle, a square, a polygon, a star, an oval, an ovoid or other quirlier forms.

[0031] According to a specific and non-limiting embodiment, the antenna is designed for a central frequency around 600MHz, corresponding for example to a digital terrestrial transmission frequency band. The PCB antenna, according to any corresponding embodiment and/or variant previously described is a square of 280mm by 280mm, the diameter of the conductive disc (conductive surface) is for example 160 mm, and the diameter of the non-conductive disc is 170 mm. This antenna design is for example well suited for being integrated in digital TV receivers so that the TV receivers, with integrated MHIS antenna are adapted for an indoor TV reception without requiring any external or outdoor antenna. The integration a MIHS antenna directly in a digital TV receiver allows for easier deployment of digital TV receivers by avoiding the need of any external outdoor antenna solution. The MIHS antenna is further compatible with other frequency bands and suited for being integrated in other communications devices such as cell phones, Wi-Fi devices, and wireless access points of any wireless standard. According to another specific and non-limiting embodiment, the antenna is designed for a central frequency around 5GHz, for example corresponding to Wi-Fi devices. To a first approximation, the dimensions of antenna are adapted to another frequency band by applying a ratio on its dimensions corresponding to the ratio of the central frequencies (here for example 600/5000). According to this specific and non-limiting embodiment, a MIHS antenna designed for the 5GHz band would fit in a PCB square of 36 mm by 36 mm and the diameters of the

conductive disc and non-conductive discs being respectively of 19 mm and 20.5 mm, resulting in an interval of 1.5mm. Such an antenna device can be integrated in wireless devices such a cell phones, tablets, set-top-boxes, Wi-Fi cards or Wi-Fi access points. Any MIHS antenna design with dimensions adapted to a targeted frequency is compatible with the disclosed principles.

[0032] While not explicitly described, the present embodiments may be employed in any combination or sub-combination. This is particularly true as each of the embodiment may individually provide an improvement of the decorrelation between the radiation patterns corresponding to the different inputs. Combining them carefully will allow the improvements to be cumulated. Moreover, the present principles are not limited to the described shape examples for the central conductive surface and any other type of shape is compatible with the disclosed principles. The present principles are not further limited to the described numbers of layers of the printed circuit board antenna and are applicable to any arrangement of any number of layers of a printed circuit board antenna. The present principles are further not limited to the described shape, number, position and length of the slots extending the central non-conductive surface towards the edges of the printed circuit board antenna, and are applicable to any other shape, number, position and length of the slots.

Claims

1. A printed circuit board antenna (20, 29) having multiple inputs, the antenna comprising a first layer (20A) and a second layer (20B), the first layer comprising a plurality of conductive tracks (21A, 21B, 21C, 21D) feeding a central conductive surface (22), the second layer comprising a central non-conductive surface (26) within a conductive area and a plurality of slots (24A, 24B, 24C, 24D) extending the non-conductive surface towards an edge of the printed circuit board, wherein the central conductive surface (22) of first layer and the central non-conductive surface (26) of the second layer have similar shape with different sizes to create an interval between the surfaces that behaves as a slot antenna and radiates electromagnetic waves.
2. The antenna according to claim 1 wherein at least one of slots (28A, 28B, 28C, 28D) of the second layer is triangular, whose base is located on the edge of the printed circuit board and directed to the circular slot.
3. The antenna according to claim 1 or 2 wherein the central conductive surface of first layer (22) and the central non-conductive surface (26) of the second layer are shaped in the form of a disc.
4. The antenna according to any of claims 1 to 3 where

the number of conductive tracks is one among two, three, four, five, six, seven and eight.

5. The antenna according to any of claims 1 to 4 wherein the outer extremities of the conductive tracks are located in the corners of the printed circuit board. 5
6. The antenna according to any of claims 1 to 5 wherein, for at least one conductive track, the outer extremity of the at least one conductive track is located at the edge of the printed circuit board between the corners and the center of the edge of the printed circuit board. 10
7. The antenna according to any of claims 1 to 6 wherein at least one conductive track is using single stub tuning to be matched in the VHF band. 15
8. The antenna according to any of claims 1 to 7 wherein the shape of the central conductive surface of first layer and the non-conductive central of the second layer is one among a triangle, a square, a polygon, a star, an oval and an ovoid. 20
9. The antenna according to any of claims 1 to 8 wherein the conductive surfaces are printed on the printed circuit board. 25
10. The antenna according to any of claims 1 to 9 wherein the non-conductive surfaces are etched into the printed circuit board. 30
11. The antenna according to any of claims 1 to 10 wherein the size of the interval is 5mm for broadcast television reception or 1.5mm for WiFi reception. 35
12. A device for receiving communications, the device comprising the antenna according any one of the claims 1 to 11 and a main board, wherein the main board is positioned to improve the decorrelation between the inputs of the antenna. 40

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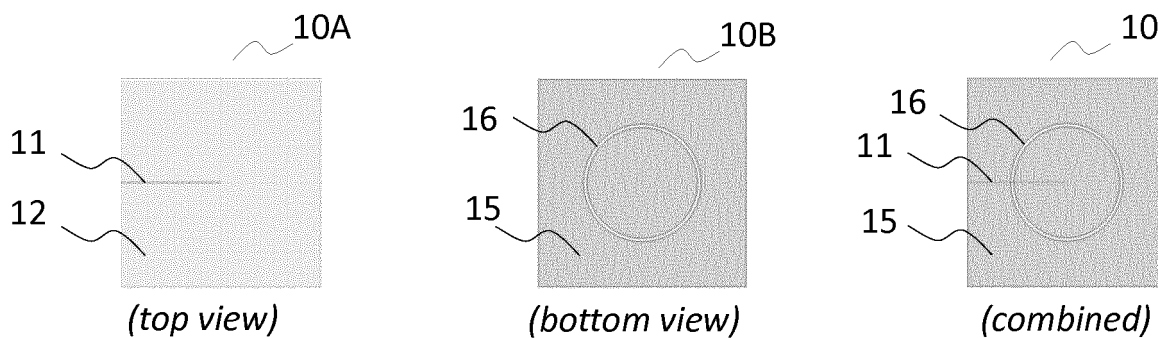


Figure 1
(prior art)

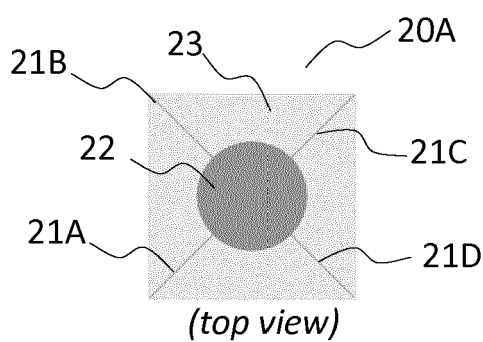


Figure 2A

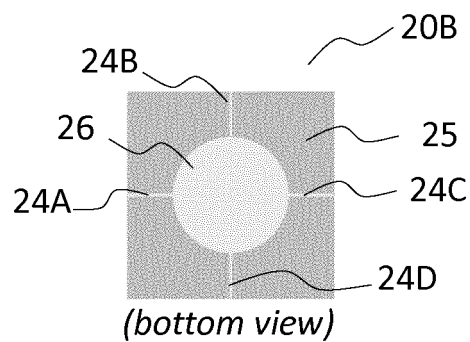


Figure 2B

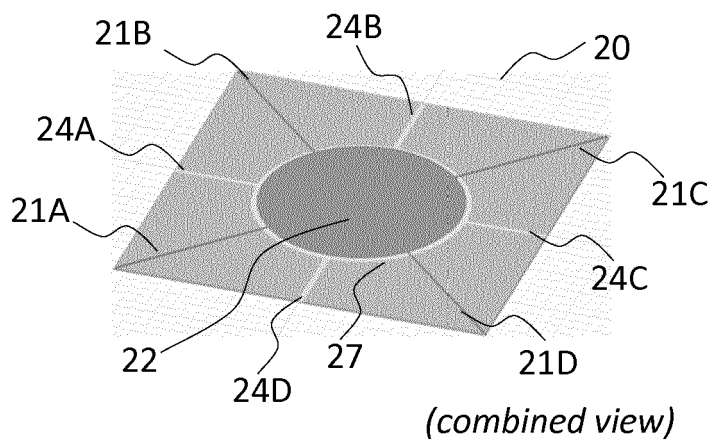
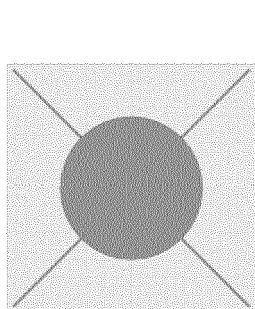
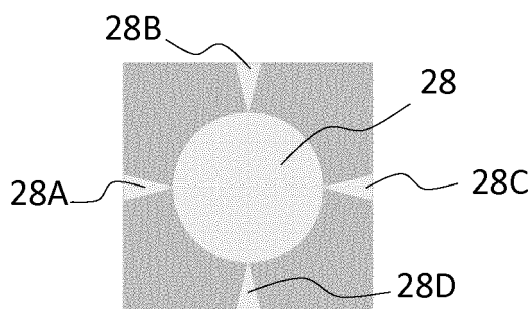


Figure 2C



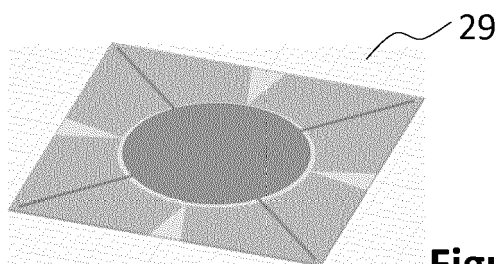
(top view)

Figure 2D



(bottom view)

Figure 2E



(combined view)

Figure 2F

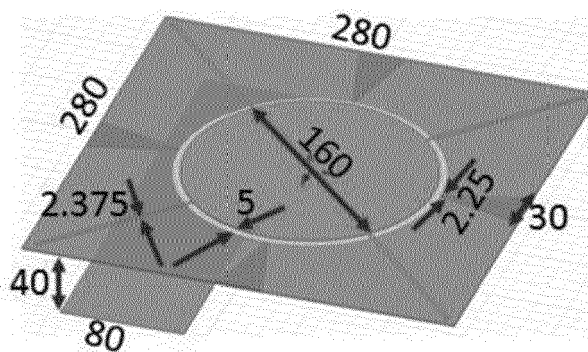


Figure 2G

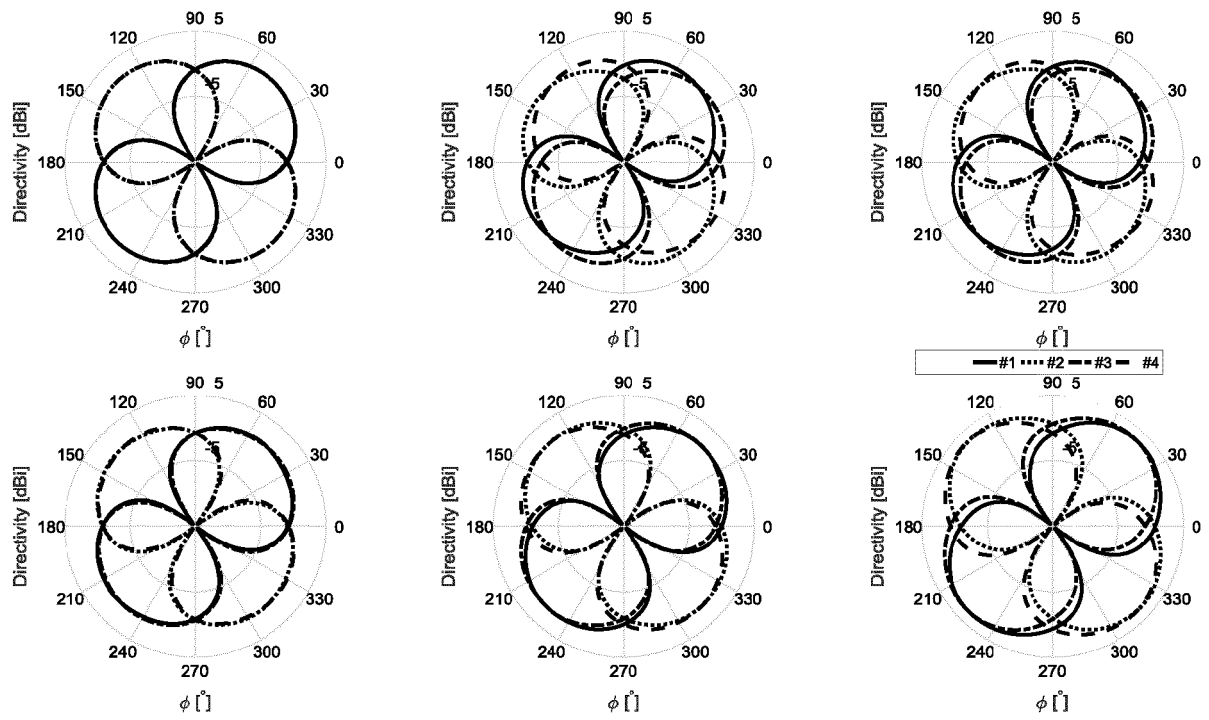


Figure 3A

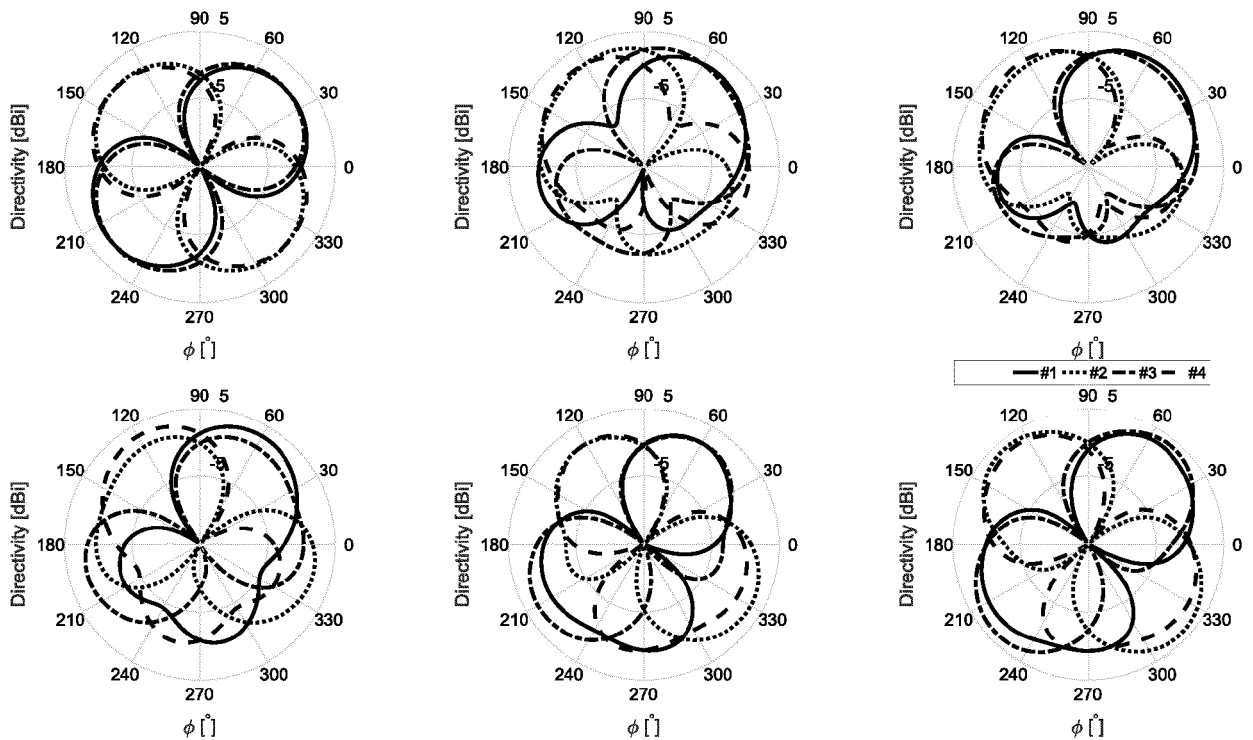


Figure 3B

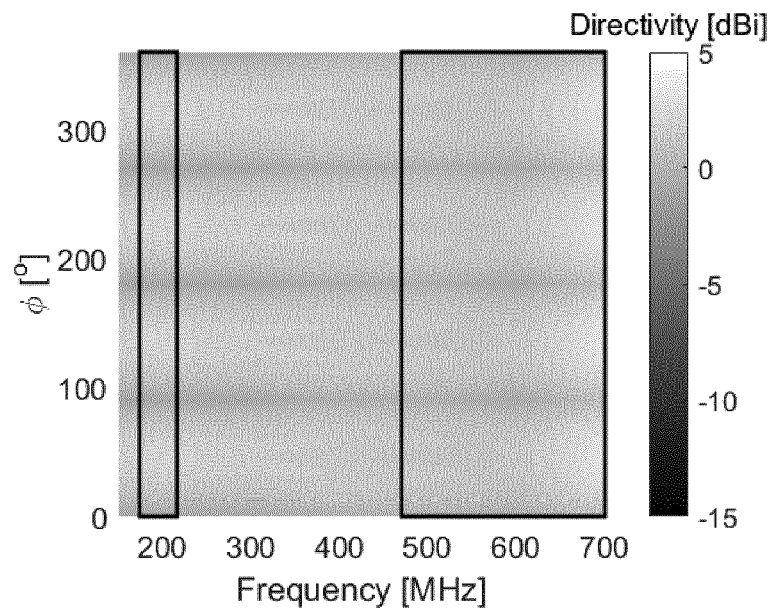


Figure 3C

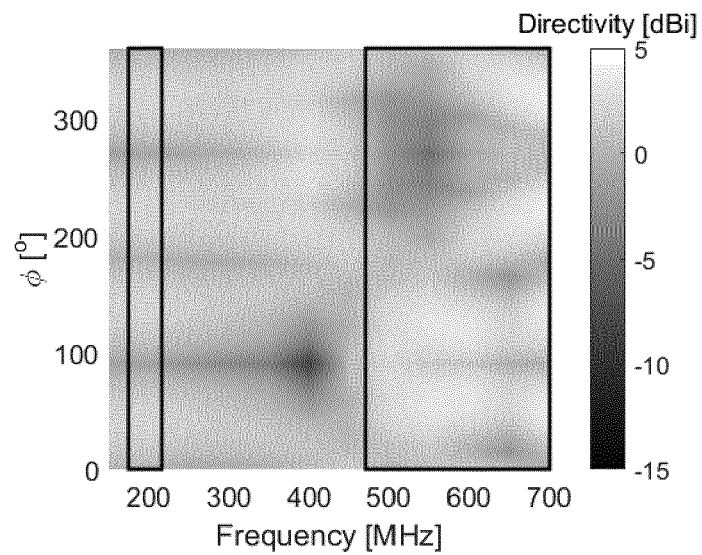


Figure 3D

Figure 4

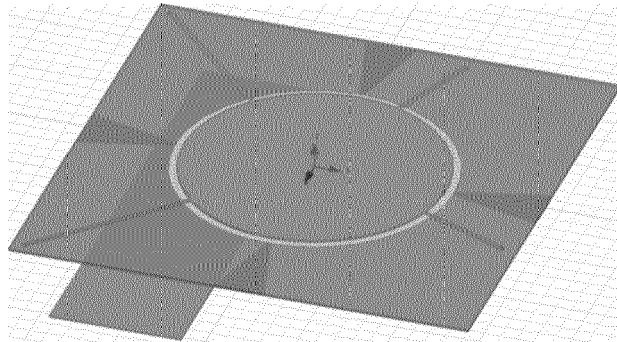


Figure 5

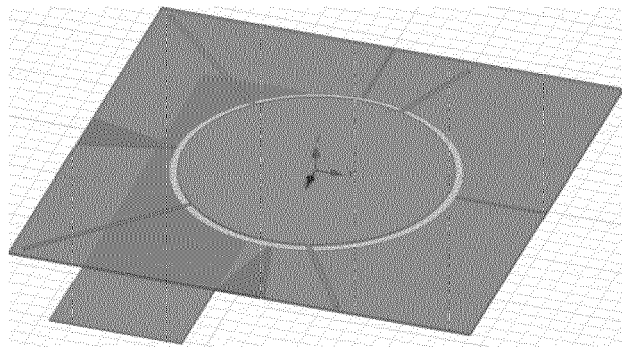
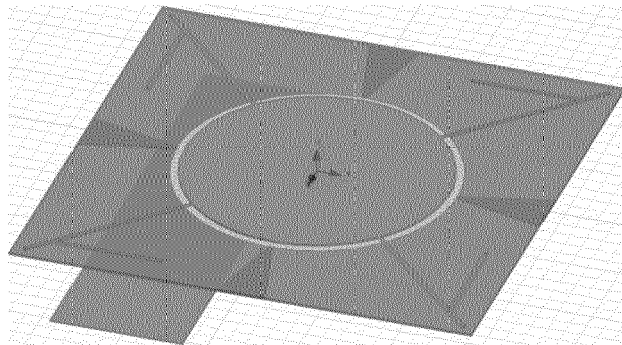


Figure 6



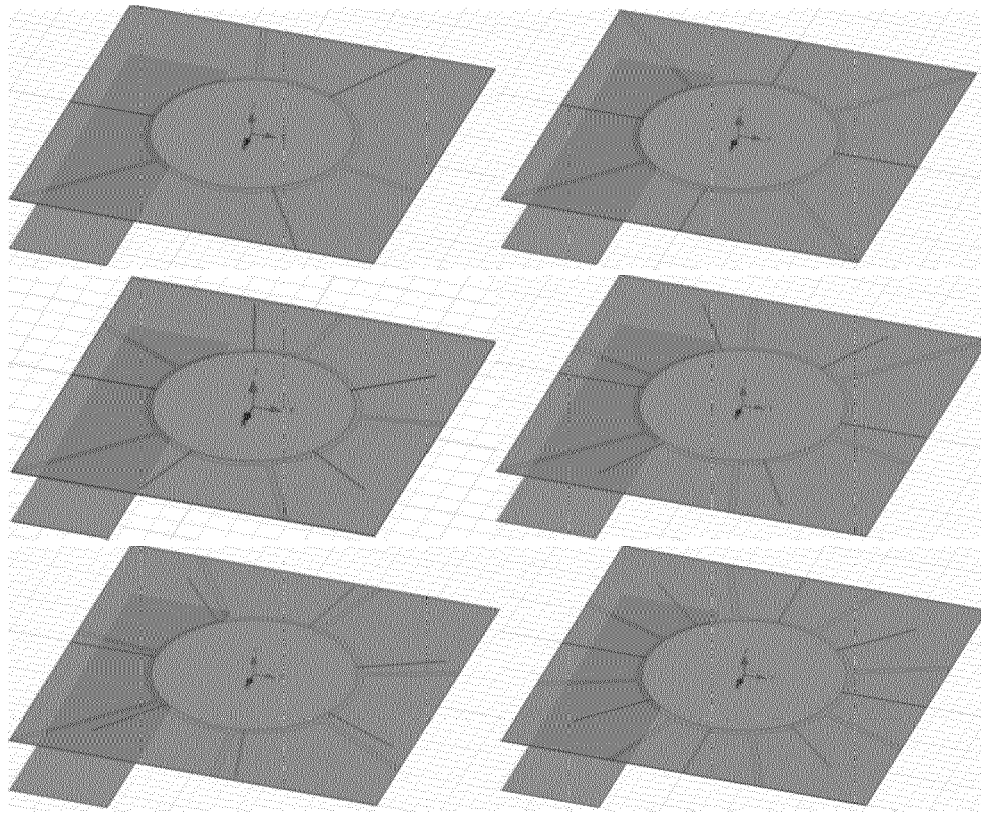


Figure 7

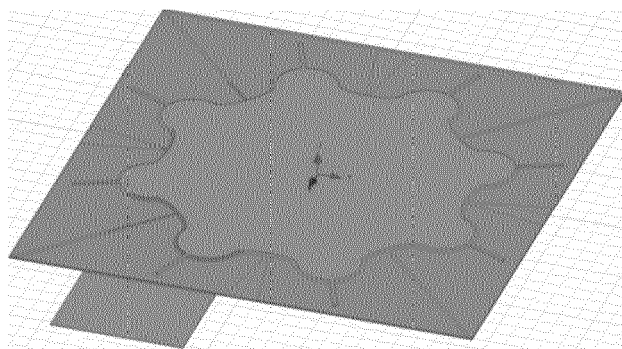


Figure 8

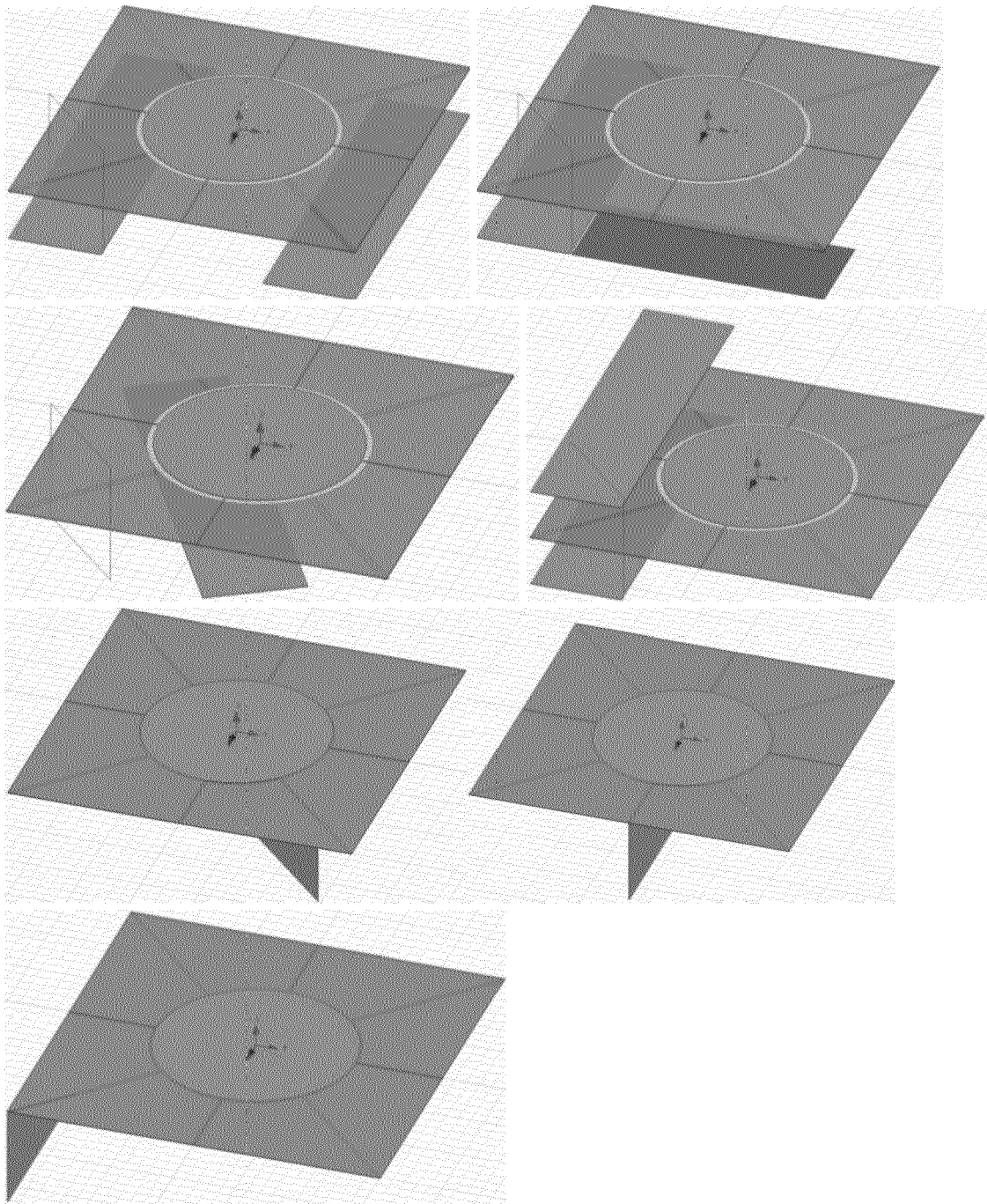


Figure 9



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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 12 June 2018	Examiner Hüschelrath, Jens
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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