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(54) MULTILAYER PRINTED CIRCUIT BOARD INCLUDING AN ANTENNA ELEMENT, AND MANUFACTURING METHOD OF A MULTILAYER PRINTED CIRCUIT BOARD ANTENNA ELEMENT

(57) A multilayer PCB (100, 200) comprises a plurality of layers (101, 102, 103, 104; 201, 202, 203), the plurality of layers being stacked in a stacking direction (S) and extending in a planar direction (P) up to an edge (110, 210) of the PCB (100, 200); an antenna element (150, 250) formed along the edge (110, 210); an RF feeding structure (155, 255) electrically connected to the antenna element (150, 250); and a metallic ground structure (160, 260), wherein the antenna element (150, 250) is electrically connected to the ground structure (160, 260), wherein the antenna element (150, 250) is formed as a single resonant structure.

A method of manufacturing the antenna element (150, 250) on an edge (110, 210) of the PCB (100, 200).

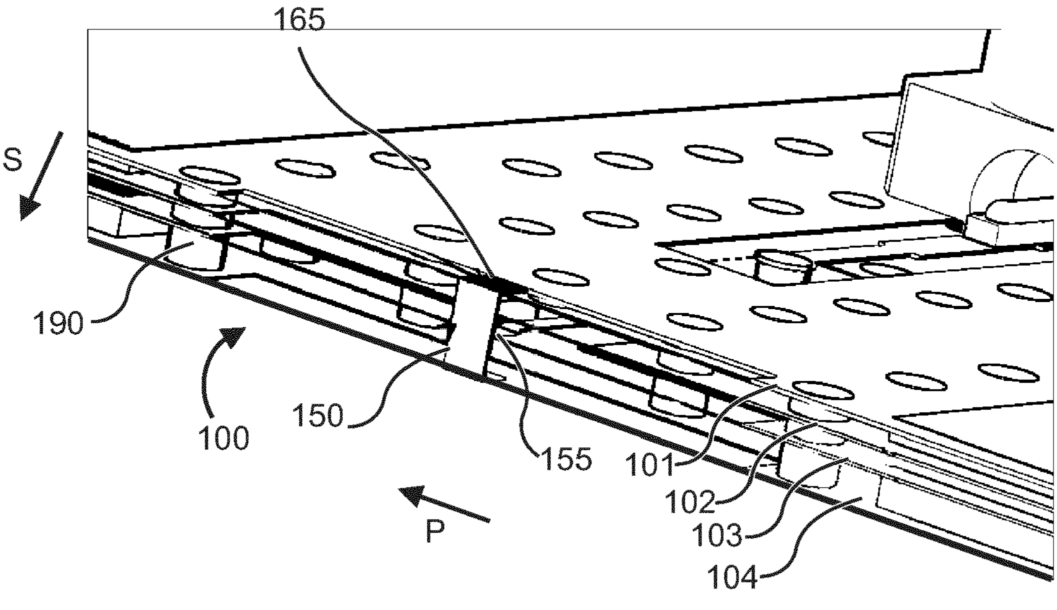

Fig. 2

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a multilayer printed circuit board, PCB, having an antenna element, and to a manufacturing method of a multilayer PCB antenna element.

BACKGROUND ART

[0002] Printed circuit boards (PCBs) having multiple layers and including one or more antenna elements for transmitting and receiving an RF signal are known in the art. A PCB having RF functions, for example a PCB of a mobile device such as a mobile phone, smartphone etc., typically has severe space constrictions due to a high demand for miniaturization. That is, a typical PCB with RF functions is already crowded. The PCB components such as surface mounted device components (SMD) and the like are typically arranged on a planar surface, i.e. on the topmost layer or in between the layers. Providing an antenna element at such a location reduces the space available for the other PCB components.

[0003] Conventionally, mobile antennas up to resonance frequencies or usable frequencies of around 6 GHz had been integrated on a surface of the PCB, such as an outer surface of a topmost or bottommost layer of the multilayer PCB or - rarely - in between the layers. For example, such conventional antennas in the range of up to 6 GHz were directly printed onto the layer surface. With the advent of the fifth generation mobile communication standards (5G), millimeter wave antennas have to be integrated into the already crowded device PCB.

[0004] While in the case of higher communication frequency such as 30 GHz (corresponding to a wavelength of the transmitted or received electromagnetic wave of about 10 mm in free space) such a millimeter wave antenna tends to be smaller, the radiation properties (transmitting/receiving efficiencies) are comparatively poor when the millimeter wave antenna is arranged on the PCB layer. Also, as frequency increases, it is advantageous or even required that some RF PCB components other than the antenna are shielded on the PCB layers and at the PCB edge.

[0005] Document WO 2017/194096 A1 describes an antenna formed on a multilayer PCB edge, the antenna comprising an antenna patch and a feeding patch. In this conventional technique, the antenna patch is formed of multiple conductive strips each arranged on a different layer of the multilayer PCB, which requires a high amount of work for obtaining this conventional structure and is prone to undesired variations of the radiation properties due to the multi-element configuration.

[0006] In an alternative configuration, document WO 2017/194096 A1 also describes a dipole structure formed on an edge of the multilayer PCB. A dipole needs to be fed through a matching network such as a balun, which requires additional space.

[0007] Document EP 3 051 628 A1 describes a multilayer circuit board having a plurality of vertical interconnect access (VIA) holes formed in the multiple layers and arranged in a horizontal direction. The VIA holes line up with a plurality of VIA holes in another layer, whereby a grid-type radiation member is formed. In other words: The VIA hole antenna elements that form the resulting grid-type radiation member are disposed as a grid-array that, as a whole, act as an RF patch. That is, a plurality of VIA hole antenna elements act together in transmitting or receiving an electromagnetic wave by means of the grid-array. Due to the fact that this conventional technique uses a plurality of VIA holes, a large amount of space is required.

[0008] Moreover, in the conventional technology of e.g. documents WO 2017/194096 A1 or EP 3 051 628 A1, a large amount of structure elements are provided that participate in the radiation of an electromagnetic wave. These approaches need a comparatively exact positioning during the manufacturing process. Even if the corresponding manufacturing process satisfies the accuracy demands, there is still a high risk of a development of defects, such as cracks or other damages, in the PCB because the structure elements are located extremely near to one another.

[0009] There is a demand for a PCB having an antenna structure or antenna element in which the above drawbacks are at least partially addressed. In particular, there is a need for a PCB having an antenna structure or antenna element that is comparatively simple and small.

SUMMARY OF THE INVENTION

[0010] According to an aspect of the present disclosure, a multilayer printed circuit board (PCB) according to claim 1 is provided. The PCB comprises a plurality of layers. The plurality of layers are stacked in a stacking direction and extending in a planar direction up to an edge of the PCB. The PCB further comprises an antenna element formed along the edge. The PCB further comprises an RF feeding structure electrically connected to the antenna element. The PCB further comprises a metallic ground structure, wherein the antenna element is electrically connected to the ground structure. The antenna element is formed as a resonant structure. In embodiments, the antenna element is formed as a single resonant structure. In other embodiments, the antenna element is formed as a multi-element resonant structure.

[0011] Typically, feeding is made by a galvanic connection between the RF feeding structure and the antenna element. In an alternative embodiment, feeding is made by capacitive coupling between the RF feeding structure and the antenna element. According to another aspect of the present disclosure, a manufacturing method of an antenna element of or for a multilayer printed circuit board (PCB) according to claim 10 is disclosed. The method comprises providing a PCB having a plurality of layers, the plurality of layers being stacked in a stacking direction and extending in a planar direction up to an edge of the PCB, wherein the layers comprise an RF feeding structure extending up to the edge and a short-circuit conductor extending up to the edge. The method further comprises metallizing at least a part of the edge to obtain a metallization. The method further comprises removing parts of the metallization to obtain the antenna element such that the antenna element is connected to the RF feeding line and such that the antenna element is connected, via the short-circuit conductor, to a metallic ground structure to affect an RF input impedance of the antenna element. Typically, in the method, the antenna element is obtained as a single resonant structure.

[0012] In embodiments, the PCB, as described herein, is used in a fixed, or stationary, RF communications device. Examples of a fixed RF communications device include, without limitation, a computer such as a personal computer, an industrial robot etc. In alternative embodiments, the PCB, as described herein, is used in a mobile RF communications device. Examples of a mobile RF communications device include, without limitation, a mobile phone or smartphone, an automotive control unit (car ICU) etc.

[0013] A single resonant structure, as used herein, is considered a structure that is different from e.g. an antenna array. In more detail, an antenna array comprises a plurality of emitting elements whose emitted electromagnetic waves interact with each other, e.g. in a way that a constructive or destructive interference occurs. In this connection, a single resonant structure is considered to emit an electromagnetic wave substantially without any electromagnetic interaction such as constructive interference or destructive interference with neighboring like structures. Particularly, a single resonant structure is, as to its RF usage or configuration, a non-periodical structure or a non-array structure.

[0014] A single-resonant structure may prove advantageous in that it occupies a comparatively small amount of space, even in the edge area of the PCB. As the single-resonant structure is comparatively narrow, a reasonable amount of space is available on the edge, e.g. for a shielding metallization or the like on the edge in areas other than that of the antenna element.

[0015] A multi-element resonant structure, as used herein, may be formed of a plurality of such single-resonant structures. In other words: The single resonant structure may be replicated, in or on the PCB, to create an array of antenna elements. Further motivation for replication of the single resonant structure may be to implement antenna diversity structures and/or MIMO structures.

[0016] Further aspects and features are apparent from the dependent claims.

[0017] In embodiments, the antenna element of the multilayer PCB extends substantially over the entirety of layers in the stacking direction of the layers. For example, when a PCB is formed of a plurality of layers including a topmost layer and a bottommost layer, each layer being a substantially flat, sheet-like element, and the stacking direction is defined as substantially orthogonal to the respective mounting surfaces of the sheet-like elements, the antenna element may extend from substantially the topmost layer to substantially the bottommost layer in a uniform manner, i.e. one-piece configuration, or - in other words - without any interruptions in the stacking direction.

[0018] In embodiments, the antenna element is a monopole sheet element, or monopole patch element. The monopole sheet element is formed in a substantially uniform manner. For example, the monopole sheet element has a uniform one-piece configuration, i.e. it extends substantially devoid of any interruptions or variations in the stacking direction.

[0019] In embodiments, the antenna element is a monopole vertical interconnect access (VIA). The VIA antenna element is electromagnetically exposed on the edge, i.e. it is free from any shielding material such as metal, at least in an intended, or predetermined, direction of radiation. Typically, the VIA antenna element is obtained by providing a VIA through the plurality of layers, preferably through the entirety of layers, and cutting the PCB along the stacking direction and penetrating the VIA. In this way, the VIA is given a semitubular shape that extends substantially in the stacking direction. In other words: According to this embodiment, the VIA is cut open such that the inner structure of the resultant semitube is exposed on the edge.

[0020] In embodiments, the antenna element further comprises a tuning structure. The tuning structure is electrically connected to the antenna element. For example, the tuning structure is part of the antenna element. In particular, the tuning structure is effective when used with a VIA serving as the antenna element, as described herein. The tuning structure has a width in a width variation direction. The width variation direction is substantially perpendicular to the stacking direction, and the width variation direction is substantially perpendicular to the planar direction. The width of the tuning structure is different from the width of the antenna element, particularly the VIA. Particularly, the tuning structure is broader than the semitubular via such as to allow for an impedance matching and/or frequency tuning of the antenna element. The tuning structure may be formed as a tuning ring.

[0021] In embodiments, the antenna element is electrically connected to the ground structure via a short-circuit conductor. The short-circuit conductor and the ground structure are configured such that they affect an RF input impedance of the antenna element. In particular, the RF input impedance of the antenna element can be tuned, or affected, by proper dimensioning of the short-circuit conductor and the ground structure. In an example, the ground structure is at least partially arranged on the same edge as the antenna element, yet sufficiently spaced apart from the antenna element to allow for an appropriate radiation of electromagnetic waves by the antenna element.

[0022] In embodiments pertaining to the manufacturing method, in the removing of parts of the metallization, the method further comprises a tuning of the antenna element to a desired resonance frequency. For example, the parts of the metallization to be removed may be chosen such that the resulting (remaining) antenna element has predetermined dimensions depending on the desired operating frequency or resonance frequency, e.g. dimensions in the width direction. Additionally or alternatively, in embodiments pertaining to the manufacturing method, in the removing of parts of the metallization, the method further comprises an adaption of an RF input impedance of the antenna element. For example, the parts of the metallization to be removed may be chosen such that a resulting short-circuit conductor or parts thereof, connecting the antenna element to the ground structure, has predetermined dimensions depending on the RF input impedance.

[0023] In embodiments pertaining to the manufacturing method, in the removing of parts of the metallization, the method further comprises a shaping of a monopole sheet element that extends in a substantially uniform manner in the stacking direction.

[0024] In embodiments pertaining to the manufacturing method, in the removing of parts of the metallization, the method further comprises exposing a VIA at the edge. Exposing the VIA, as used herein, relates to electromagnetically exposing the VIA, such that it is substantially free from any shielding material such as metal, at least in an intended, or predetermined, direction of radiation.

[0025] In embodiments pertaining to the manufacturing method in which the VIA is exposed at the edge, the method further comprises cutting the VIA open such that it has a substantially semitubular shape in the stacking direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] In the following, embodiments of the present disclosure are described with reference to the drawings in which:

Fig. 1 shows a schematic perspective view of a multilayer printed circuit board, PCB, according to an embodiment;

Fig. 2 shows a partial schematic perspective view of a PCB according to an embodiment that is cut open on parts of the edge thereof for illustration purposes;

Fig. 3 shows another partial schematic perspective view of a PCB according to an embodiment;

Fig. 4 shows a partial schematic perspective view of a PCB according to an embodiment;

Fig. 5 shows another partial schematic perspective view of a PCB according to an embodiment; and

Fig. 6 shows yet another partial schematic perspective view of a PCB according to an embodiment.

DETAILED DESCRIPTION

[0027] Fig. 1 is a schematic perspective illustration of a multilayer printed circuit board, PCB, according to an embodiment. The PCB of the first embodiment is designated with reference numeral 100. Fig. 2 is a partial schematic perspective illustration of the PCB 100 that is shown in a cut-open manner for illustration and the ease of explanation. Fig. 3 shows a part of the PCB 100 in a perspective illustration. It is noted that throughout Figs. 1-3, single particular elements may be disposed at different locations, such as a feeding structure 155 (to be described later in detail) being disposed in an intermediate layer in Fig. 2, and disposed on a top layer in Fig. 3. Yet, the views of Figs. 1-3 are comparable in principle, and thus, the first embodiment is described in the following with common reference to Figs. 1-3.

[0028] The PCB 100 comprises a plurality of metallic layers, or sheets, 101, 102, 103, 104 that are stacked in a stacking direction S and separated by layers of non-conducting (dielectric) material. It is noted that the number of layers is not limited to four as in the present example, and that it may be a number different from four. The layers 101, 102, 103, 104 are substantially planar sheets that extend in a planar direction P.

[0029] The PCB 100 further comprises an antenna element 150 that is formed along an edge 110 of the PCB 100, i.e. an edge - or front surface - that is formed by some or all of the layers 101, 102, 103, 104. The edge or front surface is typically a real surface or virtual surface that is formed on a narrow side of the PCB 100, i.e. substantially perpendicular to the planes that are formed by each of the layers 101, 102, 103, 104. The antenna element 150 can be fed with an electromagnetic signal to be emitted via an RF feeding structure 155. The RF feeding structure 155 is electrically connected to the antenna element. For example, a resonating circuit such as a transmitting circuit (not shown) is mounted in or on the PCB 100 and has an RF output thereof connected to the RF feeding structure 155.

[0030] An electromagnetically effective dimension of the antenna element 150 is configured such that the antenna element 150 resonates at or in the range of a predetermined frequency, or operating frequency. The operating frequency is for example a frequency above 15 GHz, typically above 20 GHz and preferably at about 30 GHz.

[0031] The PCB 100 further comprises a metallic ground structure 160. The metallic ground structure 160 is electrically connected to the antenna element 150 via a short-circuit conductor 165. The short-circuit conductor 165, and the metallic ground structure 160, help to tune an RF impedance of the antenna element 150 to a desired value. Typically, the short-circuit conductor has a length less than an effective wavelength of the antenna element 150, such as a length shorter than a quarter wavelength of the operating frequency.

[0032] The antenna element 150 is configured as a single resonant structure, i.e. a non-periodical structure. In other words: The PCB is devoid of another antenna element that is to be fed with an RF signal related to an RF signal used on the RF feeding structure 155 such that the another antenna element and the antenna element 150 act together such that a constructive or destructive interference occurs. In yet another way: The antenna element 150 is not necessarily part of any antenna array.

[0033] In further embodiments, multiple antenna elements 150 along the (same) edge 110 can be connected with one another to form different RF structures such as an array. In yet further embodiments, multiple antenna elements 150 along the same edge 110 or on the edge 110 and on edges different from the edge 110 can be connected with one another to form a diversity structure and/or a MIMO structure.

[0034] Typically, the antenna element 150 is a sheet-like element formed of a single physical structure, such as a single metallization. In particular, the antenna element 150 is typically formed as one piece, unlike a mesh arrangement of antenna parts.

[0035] In a corresponding manufacturing method of producing the antenna element 150 of the embodiment shown in Figs. 1-3, a multilayer PCB 100 is provided that has an arbitrary number of dielectric and/or metallic layers 101, 102, 103, 104. A side surface on the edge 101, typically the whole contour, of the PCB 100 is metallized. A conducting patch is milled out of the side metallization, the conducting patch to become the antenna element 150. The patch size is tuned, at least in width and preferably in width and length, to resonate at a predetermined frequency, or operating frequency. The operating frequency is for example a frequency above 15 GHz, typically above 20 GHz and preferably at about 30 GHz. In other words: The patch is tuned to become a millimeter-wave antenna.

[0036] The RF feeding structure 155 is present in or on any of the layers 101, 102, 103, 104. For example and without limitation, as shown in Fig. 2, the RF feeding structure 155 is printed in layer 102 of the PCB 100. The RF feeding structure 155 extends up to the edge 110 to be electrically connected to a region of the antenna element 150 (a feeding region), e.g. by means of the contour metallization process and the subsequent partial removal of the metallization.

[0037] Likewise, the short-circuit conductor 165 is present in or on any of the layers 101, 102, 103, 104. For example and without limitation, as shown in Fig. 2, the short-circuit conductor 165 is printed on layer 101 of the PCB 100. The short-circuit conductor 165 extends up to the edge 110 to be electrically connected to a region of the antenna element 150 (a tuning region), e.g. by means of the contour metallization process and the subsequent partial removal of the metallization.

[0038] The short-circuit conductor 165, or shorting strip, and the RF feeding structure 155, or feeding line, are provided for electrically coupling the antenna element 150, or antenna patch, to components of the PCB 100. The antenna element 150 itself is electromagnetically exposed from the edge 110, i.e. the PCB 100 is configured and the antenna element 150 is arranged such that a transmission or a reception of an electromagnetic wave from/to the antenna element 150 in a direction away from the edge 110 or towards the edge 110 is possible. As apparent e.g. from Fig. 1 or Fig. 3, the antenna element 150 being electromagnetically exposed from the edge 110 does not exclude the presence of any material that is comparatively uncritical for any such transmission or reception, such as a substrate material 180 disposed on or along the edge 110.

[0039] The metallic ground structure 160 may e.g. be a groundplane formed on one of the layers, such as, without limitation, a topmost layer 101 or a bottommost layer 104 of the PCB 100. In Fig. 1, a groundplane is formed on the topmost layer 101 without any limitation intended. In Fig. 3, a metallic ground structure 160 that may have an electrical connection to the groundplane is formed on the edge 110 side of the PCB, while a clearance or distance is kept from the antenna element 150 in order to suppress a negative impact on the radiation characteristics of the antenna element 150.

[0040] As apparent e.g. from Figs. 2 and 3, one or more vertical interconnect access elements 190, VIAs, may be present that allow for a signal interconnection between the layers 101, 102, 103, 104. However, none of the VIAs 190 in the embodiment of Figs. 1-3 is specifically designed to participate in a transmission or reception of an electromagnetic wave by the antenna element 150.

[0041] Fig. 4 is a schematic perspective illustration of a multilayer printed circuit board, PCB, according to another embodiment. The PCB of the second embodiment is designated with reference numeral 200. Fig. 5 is a partial schematic perspective illustration of an alternative configuration of the PCB 200 in the embodiment of Fig.4. The alternative configuration shown in Fig. 5 differs in that the RF feeding structure 255 and the short-circuit conductor 265 are disposed in a layer of the PCB 200 different from that in Fig. 5. Fig. 6 shows a part of the PCB 200 of Figs. 5 in a different perspective illustration. The second embodiment in the configuration of Fig. 4 and in the alternative configuration of Figs. 5 and 6 is described in the following commonly with reference to Figs. 4-6.

[0042] The PCB 200 comprises a plurality of layers, or sheets, 201, 202, 203 that are stacked in a stacking direction S. It is noted that the number of layers is not limited to three as in the present example, and that it may be a number different from three. The layers 201, 202, 203 are substantially planar sheets that extend in a planar direction P, and may be dielectric or metallic sheets, or a combination thereof.

[0043] The PCB 200 further comprises an antenna element 250 that is formed along an edge 210 of the PCB

200, i.e. an edge - or front surface - that is formed by some or all of the layers 201, 202, 203. The edge 210 or front surface is typically a real surface or virtual surface that is formed on a narrow side of the PCB 200, i.e. substantially perpendicular to the planes that are formed by each of the layers 201, 202, 203. The antenna element 250 can be fed with an electromagnetic signal to be emitted via an RF feeding structure 255. The RF feeding structure 255 is electrically connected to the antenna element 250. For example, a resonating circuit such as a transmitting circuit (not shown) is mounted in or on the PCB 200 and has an RF output thereof connected to the RF feeding structure 255.

[0044] An electromagnetically effective dimension of the antenna element 250 is configured such that the antenna element 250 resonates at or in the range of a predetermined frequency, or operating frequency. The operating frequency is for example a frequency above 15 GHz, typically above 20 GHz and preferably at about 30 GHz.

[0045] The PCB 200 further comprises a metallic ground structure 260. The metallic ground structure 260 is electrically connected to the antenna element 250 via a short-circuit conductor 265. The short-circuit conductor 265, and the metallic ground structure 260, help to tune an RF impedance of the antenna element 250 to a desired value.

[0046] The antenna element 250 is configured as s single resonant structure, i.e. a non-periodical structure. In other words: The PCB 200 is devoid of another antenna element that is to be fed with an RF signal related to an RF signal used on the RF feeding structure 255 such that the another antenna element and the antenna element 250 act together such that a constructive or destructive interference occurs. In yet another way: The antenna element 250 is not part of any antenna array.

[0047] In further embodiments, multiple antenna elements 250 along the (same) edge 210 can be connected with one another to form different RF structures such as an array. In yet further embodiments, multiple antenna elements 250 along the same edge 210 or on the edge 210 and on edges different from the edge 210 can be connected with one another to form a diversity structure and/or a MIMO structure.

[0048] In the present embodiment, the antenna element 250 is formed of a vertical interconnect access, VIA, that is cut open such that it exhibits a semitubular shape which is electromagnetically exposed on the edge 210. In other words: The antenna element 250, or radiating element, has the shape of a part of a cylinder on the edge 210 of the PCB 200.

[0049] In a corresponding manufacturing method of producing the antenna element 250 of the embodiment shown in Figs. 4-6, a multilayer PCB 200 is provided that has an arbitrary number of dielectric and/or metallic layers 201, 202, 203. A side surface on the edge 201, typically the whole contour, of the PCB 200 is metallized. In the present embodiment, the VIA for the antenna element 250 is manufactured according to a commonly known process; subsequently, the PCB 200 is cut open crossing the VIA such that the antenna element 250 is obtained.

[0050] The RF feeding structure 255 is present in or on any of the layers 201, 202, 203. For example and without limitation, as shown in Fig. 5 or 6, the RF feeding structure 255 is printed in layer 202 of the PCB 200. The RF feeding structure 255 extends up to the edge 210 to be electrically connected to a region of the antenna element 250 (a feeding region), e.g. by means of the contour metallization process and the subsequent partial removal of the metallization.

[0051] Likewise, the short-circuit conductor 265 is present in or on any of the layers 201, 202, 203. For example and without limitation, as shown in Fig. 5, the short-circuit conductor 265 is printed on layer 201 of the PCB 200. In another example and without limitation, as shown in Fig. 4, the short-circuit conductor 265 is printed in layer 202 of the PCB 200. In yet another example and without limitation, as shown in Fig. 6, the short-circuit conductor 265 is formed as a part of metallic layer 203 of the PCB 200. The short-circuit conductor 265 extends up to the edge 210 to be electrically connected to a region of the antenna element 250 (a tuning region), e.g. by means of the contour metallization process and the subsequent partial removal of the metallization.

[0052] In the embodiment of Figs. 4-6, one or more tuning elements (tuning rings) 270-1, 270-2 are provided. These tuning elements, or metallic catch pads, may e.g. be added in different layers of the PCB for impedance matching and frequency tuning purposes.

[0053] The tuning elements 270-1, 270-2 are tuned such that the antenna element 250 resonates at a predetermined frequency, or operating frequency. The operating frequency is for example a frequency above 15 GHz, typically above 20 GHz and preferably at about 30 GHz. In other words: The VIA antenna element 250 is tuned to become a millimeter-wave antenna resonating at a predetermined (desired) frequency.

[0054] When manufacturing the VIAs 250, 290, including the VIA antenna element 250, the width thereof is typically limited due to restraints in the manufacturing process. By providing the tuning elements 270-1, 270-2 in addition to the VIA antenna element 250, the capacity thereof can be altered to become a desired value. In other words: The VIA antenna element 250 is artificially reduced in electrically active length, which allows for an effective tuning of the resonance frequency thereof.

[0055] The antenna element 250 itself is electromagnetically exposed from the edge 210, i.e. the PCB 200 is configured and the antenna element 250 is arranged such that a transmission or a reception of an electromagnetic wave from/to the antenna element 250 in a direction away from the edge 210 or towards the edge 210 is possible. As apparent e.g. from Fig. 4, the antenna element 250 being electromagnetically exposed from the edge 210 does not exclude the presence of any material that is comparatively uncritical for any such transmission or reception, such as a substrate material 280 disposed on or along the edge 210.

[0056] As apparent e.g. from Figs. 5 or 6, one or more further vertical interconnect access elements 290, VIAs, may be present that allow for a signal interconnection between the layers 101, 102, 103, 104. However, none of the VIAs 290 in the embodiment of Figs. 4-6 is specifically designed to participate in a transmission or reception of an electromagnetic wave by the VIA antenna element 250. In other words: Signal transmission and/or reception via willfully created electromagnetic radiation is performed by the VIA antenna element 250, whereas the further VIAs 290 serve the purpose of a signal interconnection between the layers 201, 202, 203 without any particular involvement in a willful, or intended, radiation process.

[0057] It is noted that while the above description refers to specific embodiments, the skilled person will recognize that the features described therein may be combined as appropriate, and/or that one or more features thereof may be altered or omitted as appropriate, without departing from the gist of the present application whose scope is defined by the claims.

Claims

1. A multilayer printed circuit board (100, 200), PCB, comprising:

a plurality of layers, the plurality of layers (101, 102, 103, 104; 201, 202, 203) being stacked in a stacking direction (S) and extending in a planar direction (P) up to an edge (110, 210) of the PCB (100, 200);
an antenna element (150, 250) formed along the edge (110, 210);
an RF feeding structure (155, 255) electrically connected to the antenna element (150, 250); and
a metallic ground structure (160, 260), wherein the antenna element (150, 250) is electrically connected to the ground structure (160, 260),
wherein the antenna element (150, 250) is formed as a single resonant structure or as a multi-element resonant structure.

2. The multilayer PCB (100, 200) according to claim 1, wherein the antenna element (150, 250) is formed as a single resonant structure.

3. The multilayer PCB (100, 200) according to any one of the preceding claims, wherein the antenna element (150, 250) extends, in the stacking direction (S), substantially over the entirety of layers (101, 102, 103, 104; 201, 202, 203).

4. The multilayer PCB (100) according to any one of the preceding claims, wherein the antenna element (150) is a monopole sheet element formed in a substantially uniform manner in the stacking direction (S).

5. The multilayer PCB (200) according to any one of claims 1 through 3, wherein the antenna element (250) is a monopole vertical interconnect access, VIA.

6. The multilayer PCB (200) according to claim 5, wherein the monopole VIA antenna element (250) has a semitubular shape extending substantially in the stacking direction (S).

7. The multilayer PCB (200) according to any one of claims 5 or 6, wherein the antenna element (250) further comprises a tuning structure (270-1, 270-2) having a width in a direction substantially perpendicular to the stacking direction (S) and substantially perpendicular to the planar direction (P) that is different from a width of the monopole VIA antenna element (250), particularly broader than the width of the monopole VIA antenna element (250).

8. The multilayer PCB (100, 200) according to any one of the preceding claims, wherein the antenna element (150, 250) is electrically connected to the ground structure (160, 260) via a short-circuit conductor (165, 265), the ground structure (160, 260) and the short-circuit conductor being (165, 265) configured to affect an RF input impedance of the antenna element (150, 250).

9. The multilayer PCB (100, 200) according to any one of the preceding claims, wherein the antenna element (150, 250) is configured such as to be resonant at a frequency above 15 GHz, typically above 20 GHz and preferably at about 30 GHz.

10. A manufacturing method of a multilayer printed circuit board, PCB, antenna element (150, 250), the method comprising:

providing a PCB (100, 200) having a plurality of layers (101, 102, 103, 104; 201, 202, 203), the plurality of layers being stacked in a stacking direction (S) and extending in a planar direction (P) up to an edge (110, 210) of the PCB (100, 200), wherein the layers comprise an RF feeding structure (155, 255) extending at least up to the edge (110, 210) and a short-circuit conductor (165, 265) extending at least up to the edge (110, 210);
metallizing at least a part of the edge (110, 210) to obtain a metallization; and
removing parts of the metallization to obtain the antenna element (150, 250) such that the an-

tenna element (150, 250) is connected to the RF feeding line (155, 255) and such that the antenna element (150, 250) is connected, via the short-circuit conductor (165, 265), to a metallic ground structure (160, 260) of the PCB (100) to affect an RF input impedance of the antenna element (150, 250).

11. The manufacturing method of claim 10, further comprising, in the removing of parts of the metallization, a tuning of the antenna element to a desired resonance frequency and/or an adaption of an RF input impedance of the antenna element (150, 250).

12. The manufacturing method of any one of claims 10 or 11, wherein removing parts of the metallization to obtain the antenna element (150) includes shaping a monopole sheet element extending in a substantially uniform manner in the stacking direction (S).

13. The manufacturing method of claim 10, wherein removing parts of the metallization to obtain the antenna element (250) includes exposing a vertical interconnect access, VIA, at the edge (210).

14. The manufacturing method of claim 11, wherein the VIA is cut open such as to have a semitubular shape extending substantially in the stacking direction.

15. Use of a multilayer PCB (100, 200) according to any one of claims 1 through 9 in an RF device, such as a mobile RF communications device or a fixed RF communications device.

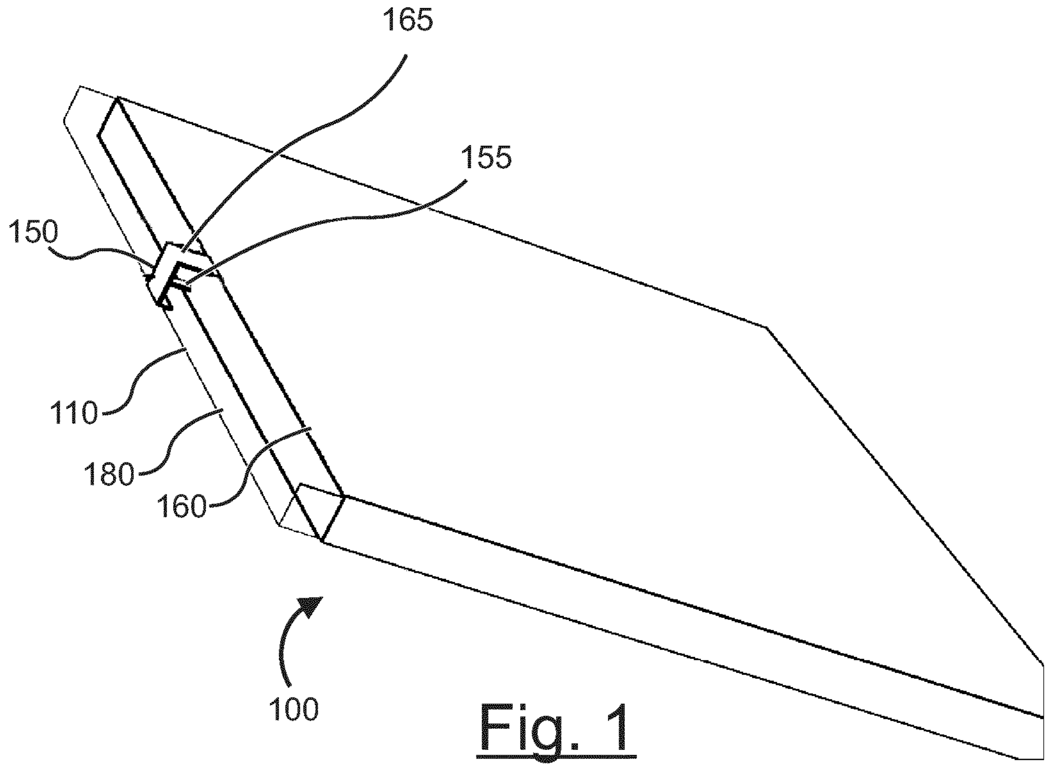
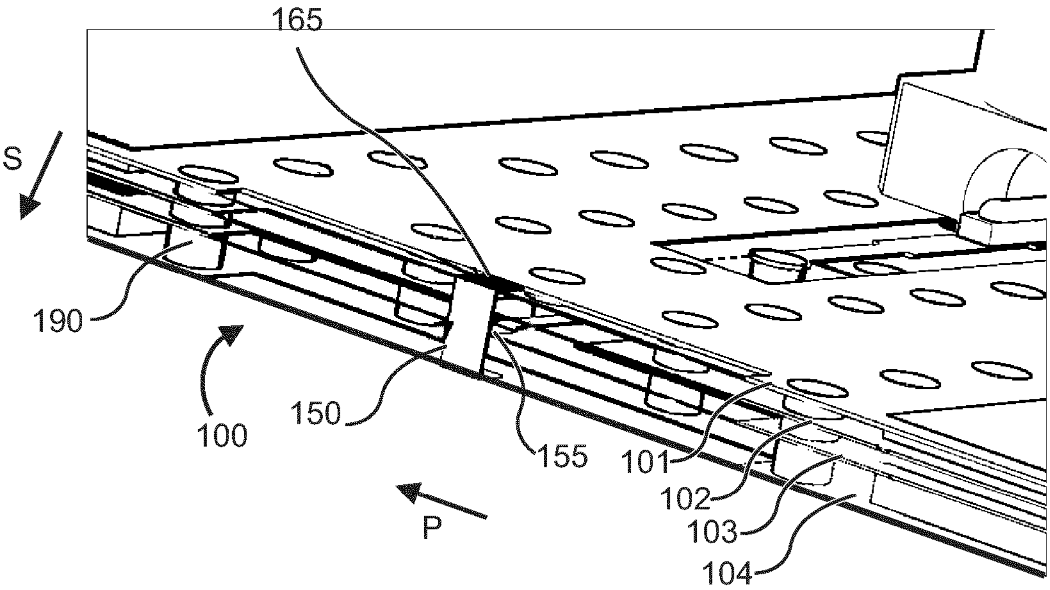

165
155
150
110
180
160
100

Fig. 1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S
190
100
150
155
101
102
103
104
P

Fig. 2

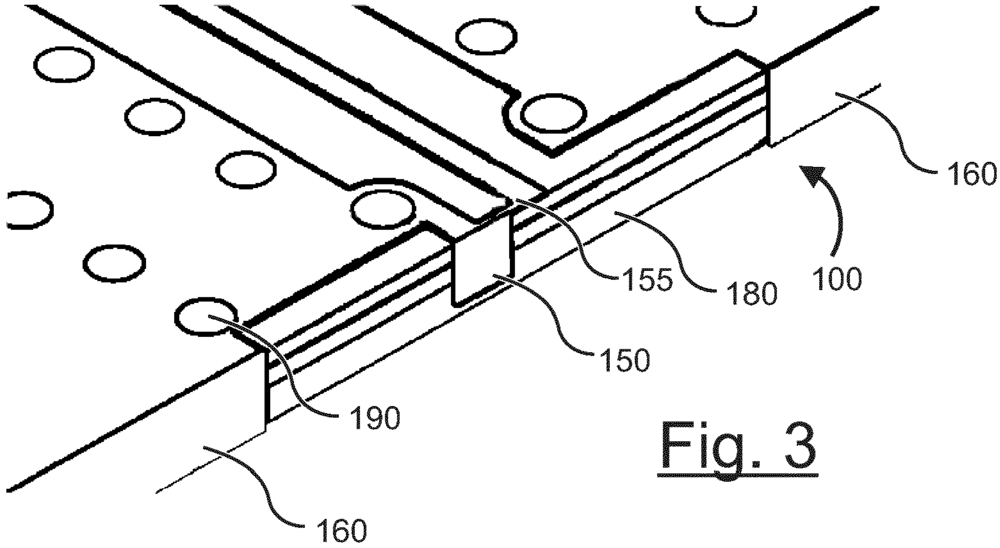
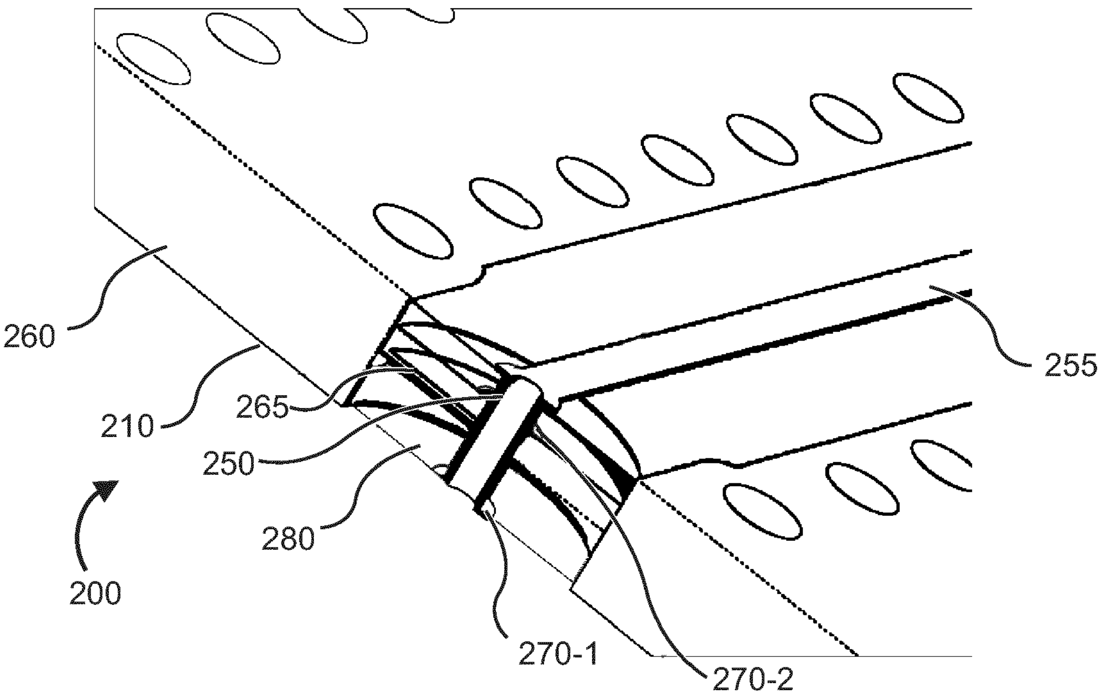

160
155
180
100
150
190
160

Fig. 3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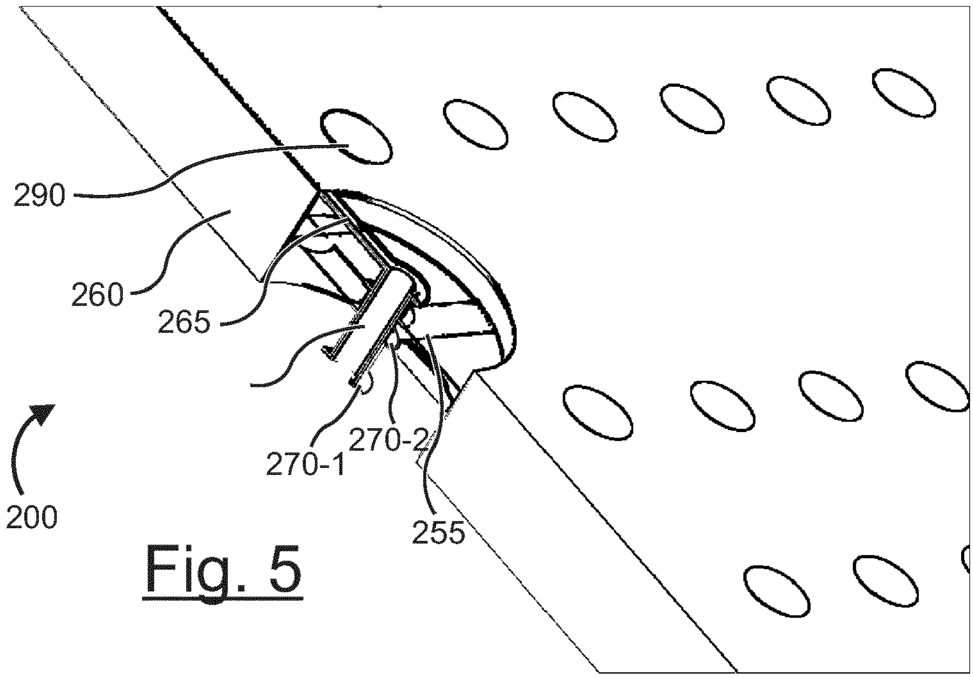
255
210
265
250
280
200
270-1
270-2

Fig. 4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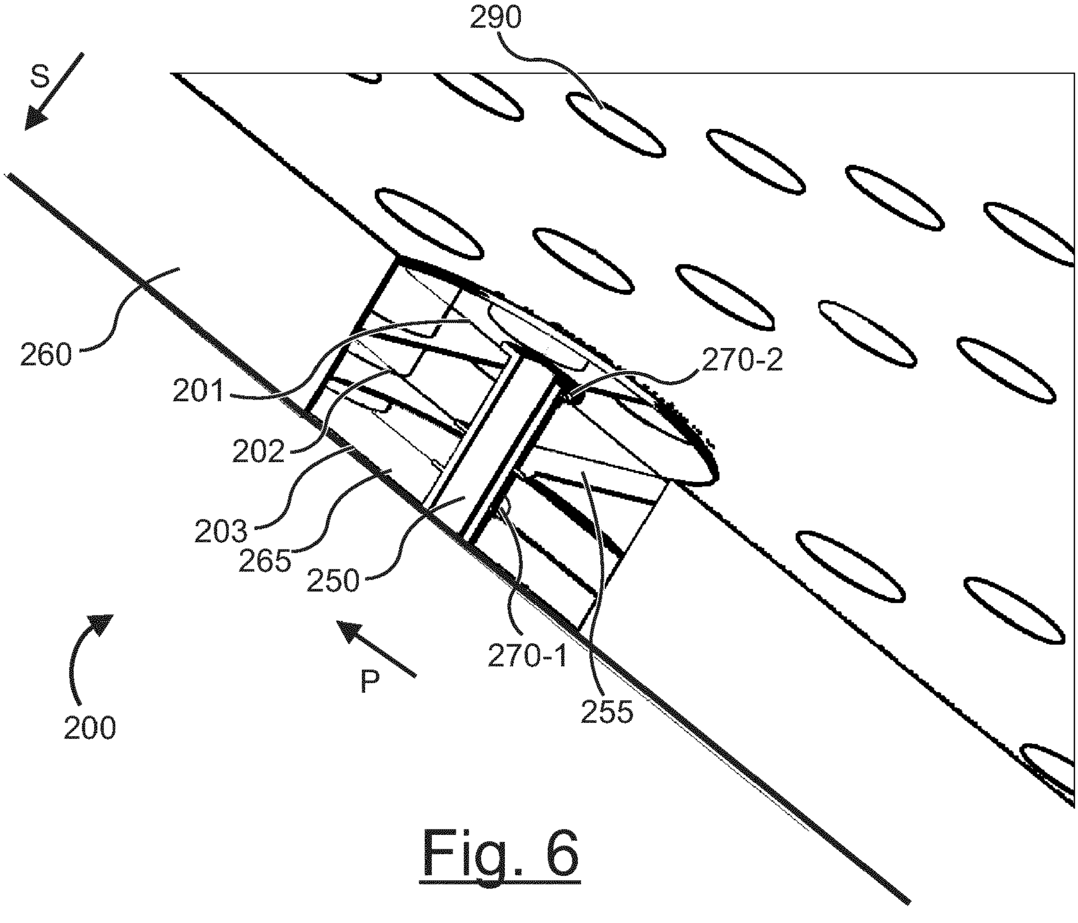
265
270-1
270-2
255
200

Fig. 5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P
200

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 19 19 6697

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	6 February 2020	Culhaoglu, Ali

CATEGORY OF CITED DOCUMENTS

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06-02-2020

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