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(54) Slot array antenna with waiveguide feeding and process for producing said antenna

(57) Slot array antenna (10) with waveguide feed comprising at least one radiating waveguide (20) comprising a radiating slot array (21) and at least one coupling slot (31) adapted for feeding the at least one radiating waveguide (20) with a radiofrequency electromagnetic radiation, the antenna (10) having a multi-layer structure and comprising:

- a first plate-shaped substrate (11) made from dielectric material comprising a first metalized layer (1) and a second metalized layer (2) respectively arranged on a first face and an opposite second face of the first plate-shaped substrate (11), the first (1) and the second (2) metalized layer respectively representing a first confinement wall and a second opposite confinement wall of said radiating waveguide (20), the radiating slots (21) being openings made in the first metalized layer (1) and the at least one coupling slot (31) being an opening made in the second metalized layer (2);
- a second plate-shaped substrate (11) made from dielectric material having a third face coupled with the second metalized layer, the antenna also comprising at least one feeding waveguide (40-43) of said radiating guide (20) operatively coupled with the latter through said coupling slot (31), the feeding waveguide (40-43) being made in the thickness of the second plate-shaped substrate (2).

In the aforementioned antenna the second metalized layer (2) represents an upper confinement wall of the at least one feeding waveguide, which is a shared confinement wall between said radiating waveguide and said feeding waveguide.

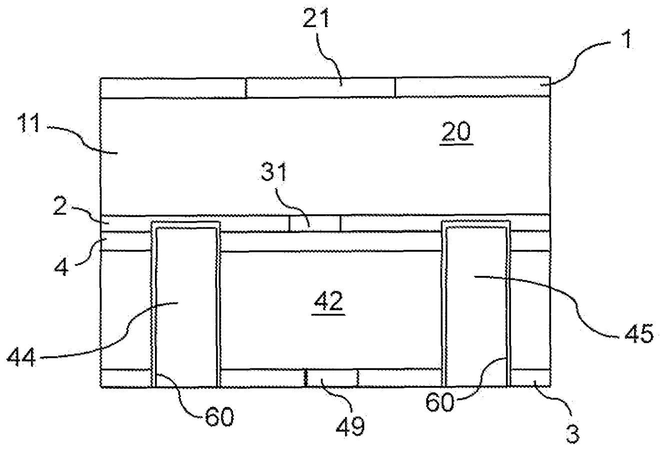

FIG. 6

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Description

[0001] The present invention concerns the technical field of antennas for telecommunication systems and in particular it refers to a slot array antenna with waveguide feed and to a process for making said antenna.

[0002] The slot array antennas with waveguide feed are currently widely used in navigation systems, in radar systems and in other telecommunications applications, for example in aeronautical and missile-related applications. Such antennas generally comprise one or more radiating waveguides having a plurality of radiating slots, provided for irradiating electromagnetic radiation, and each having at least one coupling slot provided for operatively coupling the radiating waveguide with a feeding waveguide, so as to be able to feed the radiating waveguide, and therefore the radiating slots, with electromagnetic radiation. Of course, in radar systems, the same antenna is used both to transmit and to receive, for which reason when receiving, by exploiting the reciprocity of the antenna, the radiating slots are used to receive electromagnetic radiation reflected from a target.

[0003] Slot array antennas with waveguide feed for aeronautical, radar and missile-related applications are generally made using radiating waveguides having a structure made from aluminium, in which the radiating slots and the coupling slots are through openings made respectively in the upper and lower walls of the guide and obtained through electro-erosion techniques or through laser or mechanical processing.

[0004] The state of the art also includes a way of making slot array antennas with waveguide feed in accordance with which it is foreseen for the radiating slot array to be made on a sheet of copper, making through openings on such a sheet through photolithographic techniques. The radiating waveguides are made as blocks of copper or aluminium with an essentially U-shaped section that are fixedly connected to the sheet through relatively expensive and complicated techniques, like for example dip brazing.

[0005] These manufacturing techniques described above allow processing that is able to satisfy the precision generally required by the applications, but also have the drawback of requiring relatively high manufacturing costs.

[0006] The article "Compact Two-Layer Slot Array Antenna with SIW for 60 Ghz Wireless Applications", by Ahmad Bakhtafrouz et Al., Antennas and Propagation Society International Symposium, Apsursi, 2009, describes a slot array antenna comprising a plurality of radiating guides made in un first substrate and a feeding waveguide of said radiating guides made in a second substrate. The two substrates, apparently after having made the aforementioned guides, are coupled together through a layer of epoxy resin containing silver and therefore electrically conductive. Such a layer of epoxy resin in practice represents the upper confinement wall of the feeding guide that is therefore different from the lower confinement wall of the radiating waveguides. The process for manufacturing the antenna described in the aforementioned article is therefore relatively complex, because it is clearly necessary to take into account a delicate alignment and because the layer of resin must be shaped so as to follow the profile of the coupling slots (indicated in the aforementioned article as "feed slots") made on the lower face of the first substrate. Moreover, it is practically impossible to deterministically establish the shape of the layer of conductive resin after polymerisation since it is different to the initial one of the resin in plastic state. For this reason, it may be the case that the coupling slots are partially covered by such a resin, which means possible losses and mismatching. In fact, in the final part of the aforementioned article the authors hypothesise that a part of the losses measured with respect to a simulated theoretical situation can be attributed to the conductive resin, without however clearly specifying the reasons why, to quote the article, "such a resin can increase the loss in the feeding guide".

[0007] Patent application FR 2 778 024 describes a connection structure for dielectric waveguides. It is considered that this document is unable to give a man skilled in the art any suggestion on improving the problem of coupling present in the antenna described in the aforementioned article, also because the described connection structure would require the coupling slots to be made inclined both on the lower substrate and on the upper one and would require such substrates to be aligned very accurately before coupling them so as to match up corresponding pairs of coupling slots, which would make the manufacturing process relatively more complex. Whenever the alignment is not accurate, there will be losses similar to those of the antenna described in the aforementioned article.

[0008] The purpose of the present invention is to provide a slot array antenna with waveguide feed that is able to be made through a process that is able to overcome the drawbacks indicated above with reference to the manufacturing techniques of the state of the art described above.

[0009] Such a purpose is accomplished through a slot array antenna as defined in general in the attached claim 1.

[0010] Advantageous embodiments of a slot array antenna according to the present invention are defined in the attached dependent claims.

[0011] An object of the present invention is also a process for making a slot array antenna with waveguide feed as defined in claim 8 in its general form and in the subsequent claims in particular embodiments.

[0012] An object of the present invention is also a double-band antenna as described in claim 15.

[0013] Further characteristics and advantages of the invention will become clear from the following detailed description, given purely as a non-limiting example, with reference to the attached drawings, in which:

- figure 1 is a schematic side view of a first embodiment of a slot array multi-layer antenna with waveguide feed;
- figure 2 is a plan view in which a first layer of the antenna of figure 1 is represented;
- figure 3 is a plan view in which a second layer of the antenna of figure 1 is represented;
- figure 4 is a plan view in which a third layer of

the antenna of figure 1 is represented;

- figure 5 is a plan view that shows a part of figure 2 is greater detail;
- figure 6 is a side section view of a portion of the antenna of figure 1;
- figure 7 is an example block diagram of a process for making a slot array antenna with waveguide feed;
- figure 8 shows a side section view of a slot array antenna in accordance with a first variant embodiment; and
- figure 9 schematically shows a part of a slot array antenna in accordance with a second variant embodiment.

[0014] With reference to the attached figures, reference numeral 10 globally indicates a slot array antenna with waveguide feed. The antenna 10 is for example part of a telecommunications system, like for example an automatic guidance system or a radar system comprising a transmission and/or reception system operatively connected to such an antenna, not shown in the figures. In accordance with a non-limiting embodiment, the antenna 10 is an antenna operating in KA band.

[0015] As can be seen in figure 1, the antenna 10 represented in the attached figures has a multi-layer structure and comprises:

- a first layer 1 made from an electrically conductive metal (in short "first metalized layer 1");
- a first plate-shaped substrate 11 made from dielectric material;
- a second layer 2 made from an electrically conductive metal (in short "second metalized layer 2");
- an adhesive layer 4;
- a second plate-shaped substrate 12 made from dielectric material; and
- a third layer 3 made from an electrically conductive metal (in short "third metalized layer 3").

[0016] In the particular example represented, the antenna 10 also comprises four feeding connectors 13, for example in waveguide, only two of which can be seen in figure 1.

[0017] Preferably, the metalized layers 1, 2 are two layers that are laminated/plated and more preferably electrodeposited on the two opposite faces of the first dielectric substrate 11. Preferably, the metalized layers 1, 2 are made from copper and have, for example, a thickness equal to about 8-20 micron and more preferably equal to about 8 micron. The first dielectric substrate 11 is, for example, a commercial substrate made from reinforced glass microfibre with a relatively low dielectric constant, for example within the range 2 - 3 and more preferably equal to about 2.2. For example, the first substrate 11 has a thickness equal to about 1mm. A substrate 11 of the aforementioned type is, for example, currently produced by Taconic™ and marketed with the name "TLY - 5A" and it is supplied by the aforementioned producer with the copper layers 1 and 2 already electrodeposited. Preferably, the second dielectric substrate 12 is also of the type described above with reference to the first dielectric substrate 11, with the sole difference that the second dielectric substrate 12, instead of having a metallisation layer on both faces, has a free face, i.e. a face on which no metallisation is foreseen. On the opposite face of the second dielectric substrate 12, on the other hand, there is the metallisation layer 3, which is for example a laminated/plated layer and more preferably a layer of electrodeposited copper of the type already described with reference to the metalized layers 1 and 2. The second substrate 12 is also currently produced by Taconic™ and marketed with the name "TLY - 5A" and it is supplied by the aforementioned producer with the copper layer 3 electrodeposited and with a free face, i.e. without a metallisation layer. Alternatively, the second dielectric substrate 12 with the electrodeposited copper layer 3 can be obtained from a substrate with two opposite metallisation layers (like the substrate 11) by removing one of said layers.

[0018] In a further embodiment, the first 11 and the second 12 dielectric substrate are laminated dielectric substrates with surface metallization as described above but produced and marketed by Rogers Corporation with the trade name Duroid™ 5880.

[0019] The layer 4, on the other hand, is a thin adhesive layer used to keep together the two laminated dielectric substrates 11 and 12 and in particular used to glue the free face of the second substrate 12 to the free face of the metallisation layer 2. For example, the adhesive layer 4 is a thin dielectric film, therefore electrically insulating, for example like the one currently marketed with the name "Neltec™ 6700". The dielectric properties of such an adhesive layer 4 are advantageously as similar as possible to those of the second dielectric substrate 12. As an alternative to the adhesive layer 4, it is possible to use any suitable electrically insulating layer or film, or any other suitable medium, capable of connecting/fixing the dielectric substrate 12 to the second metalized layer 2 and that has dielectric characteristics compatible with the application.

[0020] With reference to figures 2 and 3, the slot array antenna 10 comprises at least one radiating waveguide 20 comprising a plurality, or an array, of radiating slots 21. In the particular example represented, the slot array antenna 10 comprises, without for this reason introducing any limitation, forty radiating waveguides 20, of different lengths and having a variable number of slots based on the respective length. It should be observed that the particular example described is in the form of a planar antenna having slot array with symmetry in quadrants and more specifically a monopulse antenna.

[0021] Henceforth in the present description we shall refer to a slot array antenna 10 comprising a plurality of radiating waveguides 20.

[0022] Advantageously, the radiating waveguides 20 are made in the first dielectric substrate 11, which therefore houses them, and the first 1 and the second 2 metalized layer represent opposite confinement walls, upper and lower respectively, of the radiating waveguides 20.

[0023] Advantageously, the radiating slots 21 are openings, in the example substantially rectangular in shape, made in the first metalized layer 1, preferably through photolithographic techniques of selective removal of the metallisation layer 1 at the points in which it is wished to make the radiating slots 21. Photolithographic techniques are commonly used in making printed circuits and they are part of the background knowledge of a man skilled in the art, and for this reason they will not be detailed any further in the present description. In an alternative embodiment that is less preferred, because it is currently more expensive, the aforementioned selective removal of the metallization is carried out using a laser device. It should be noted that the free face of the metalized layer 1 in practice represents the radiating surface of the antenna.

[0024] We shall now refer to figure 3, which shows the section A-A of the multi-layer structure of figure 1 seen from the side of the arrow IV. It should be noted that in practice in figure 3 it is possible to see the face of the metalized layer 2 distal from the first dielectric substrate 11. As can be seen, each of the radiating waveguides 20 comprises at least one coupling slot 31, provided for operatively coupling the radiating waveguide 20 with a feeding waveguide, so as to be adapted to feed the radiating waveguide 20, and therefore the radiating slots 21, with electromagnetic radiation. Advantageously, the coupling slots 31 are also openings, in the example substantially rectangular in shape, made in the second metalized layer 2, preferably through photolithographic techniques that adopt a selective removal of the metallization 2 at the points in which it is wished to make the coupling slots 31. As can be seen in figure 3, the coupling slots 31 are openings that are substantially rectangular in shape, and the inclination of which varies among the different radiating waveguides 20. Also in this case, in an alternative embodiment that is less preferred, because it is currently more expensive, the aforementioned selective removal of the metallization is carried out using a laser device or through mechanical processing.

[0025] With reference to figure 5, in accordance with a particularly advantageous embodiment, inside the dielectric substrate 11 a plurality of through channels 22 are defined, in sets of two relatively close to one another and aligned in arrays of channels, that extend in the thickness of the dielectric substrate 11 between the first 1 and the second 2 metallisation layer. Such through channels 22, preferably having a circular section, are internally surface coated, or alternatively entirely filled, with an electrically conductive material, like for example copper. Again with reference to figure 5, it should be noted that each radiating guide 20, comprises side confinement walls 23, 24. Such side confinement walls 23, 24 are each formed by a respective array of through channels 22. It should be noted that if the minimum distance between two adjacent through channels 22 is relatively small with respect to the working wavelength of the antenna 10 (for example equal to about 1/20 thereof), the confinement walls 23, 24, although consisting of discreet and spaced elements 22, can be considered as approximately continuous side confinement walls.

[0026] The through channels 22 are for example obtained by perforating, for example drilling, the first metalized layer 1, the first dielectric substrate 11 and the second metalized layer 2. The channels 22 thus made are then preferably plated with a copper inner surface coating.

[0027] For example, the diameter of the channels 22 is equal to about 0.4 mm and the processing tolerance of the perforation is advantageously equal to +/- 0.005mm. On the position of the channel holes 22, the tolerance is advantageously equal to +/- 0.03 mm. Obviously, these processing parameters can be varied based upon the working frequency for which the slot array antenna 10 is designed.

[0028] The processing steps described above with reference to the formation of the radiating waveguides 20, of the radiating slots 21 and of the coupling slot are carried out on a first dielectric substrate 11 laminated/plated on both faces, before coupling such a first dielectric substrate 11, through an electrically insulating adhesive layer 4, with the dielectric substrate 12 laminated/plated just on one of the two faces. Thereafter, indeed, the first 11 and the second 12 dielectric substrate are coupled, through the electrically insulating adhesive layer 4, so that the non-plated face of the second dielectric substrate 12 faces the metallisation layer 2.

[0029] In accordance with an embodiment, the slot array antenna 10 comprises at least one feeding waveguide 40, 41, 42, 43 of the radiating guides 20 operatively coupled with them through the coupling slots 31. In the particular example represented in the figures, four feeding waveguides 40, 41, 42, 43 are provided each intended to independently feed a respective group of ten radiating waveguides 20. As can be seen, the feeding waveguides 40, 41, 42, 43 are oriented transversally with respect to the radiating waveguides 20. Henceforth we shall refer, without for this reason introducing any limitation, to the case in which the slot array antenna 10 comprises a plurality of feeding waveguides 40, 41, 42, 43.

[0030] The feeding waveguides 40, 41, 42, 43 are advantageously made in the second dielectric substrate 12, which therefore houses them, preferably making blind grooves 44-48, preferably through mechanical processing and alternatively through laser processing, advantageously in parallel sets of two, in the second dielectric substrate 12, preferably going from the metallisation layer 3, entirely crossing such a layer 3, also entirely crossing the second dielectric substrate 12, the dielectric adhesive layer 4 and coming to partially cover (i.e. partially cross) also the second metalized layer 2. This explains why the feeding waveguides 40, 41, 42, 43 are (partially) visible in figure 3, since the blind grooves 44-48 that partially cross the metallisation layer 2 are indeed visible.

[0031] As can be seen in figure 6, which shows a side section of the portion of the antenna 10 defined by the dashed square 35 in figure 3 (section along the axis Y-Y), in which it is in practice possible to see a cross section of the feeding waveguide 42, the blind grooves 44-48 thus obtained are surface coated, i.e. plated, with a conductive metallization 60 to form the side confinement walls of the feeding waveguides 40-43. As can be seen in figure 6, it is clear that the upper and lower confinement walls of the feeding waveguides 40-43 will consist of the metalized layers 2 and 3.

[0032] It should be observed that the upper confinement wall of the feeding waveguides coincides with the metallisation layer 2, which represents the lower confinement wall of the radiating waveguides 20. Such a wall is therefore a confinement wall, or layer, shared among the radiating waveguides and the feeding waveguides. In practice, the lower face of such a wall represents the upper conductive confinement surface of the feeding waveguides and the upper face of such a wall represents the lower conductive confinement surface of the radiating waveguides 20. For this reason, having made the coupling slots 31 in advance in the metallisation layer 2, the alignment problems quoted with reference to the prior art are overcome and there is no risk of even partial or minimal blockage of such coupling slots 31, the shape of which, after the coupling between the two substrates, perfectly preserves the precise profile desired that can be obtained with the operation for making such slots. It should also be observed that in practice the adhesive layer 4, at the feeding waveguides, is incorporated in them.

[0033] In accordance with an embodiment, the slot array antenna 10 also comprises at least one input slot 49 for each feeding waveguide 40-43. It should be observed that in figure 6 the input slot 49 has been represented purely as an example, since from the joint viewing of figures 3 and 4 it can be seen how in the section along the axis Y-Y there isn't any input slot 49.

[0034] Preferably, the input slots 49 are openings, for example substantially rectangular in shape, made in the third metalized layer 3, preferably through photolithographic techniques that foresee a selective removal of the metallisation layer 3 at the points in which it is wished to make the input slots 49.

[0035] As can be seen from the joint viewing of figures 2-4, the slot array antenna also includes a plurality of through channels 50 that extend from the free face of the metalized layer 1 to the free face of the metalized layer 3. Such through channels 50 are aligned in arrays of channels, arranged in sets of two, a relatively small distance apart with respect to the wavelength, and they are coated or filled with conductive material, such as copper, to separate two or more feeding waveguides 40-43 from one another. With reference to figure 4, it can be seen how an array 50 of through channels divides the feeding waveguide defined by the blind plated grooves 46, 47 in two feeding waveguides 40, 41 and how, in an analogous manner, an array 50 of through channels divides the feeding waveguide defined by the blind and plated grooves 44, 45 in the two feeding waveguides 42, 43. It should be observed how in the described example, such through channels 50 are arranged, exploiting the available space, between adjacent waveguides, so as not to interfere with them, therefore avoiding influencing the propagative characteristics.

[0036] As can be seen in figures 3 and 4, the slot array antenna 10 also comprises a plurality of blind holes 51, to allow the same antenna to have connectors fixed to it, for example in waveguide, adapted for feeding the feeding waveguides 40-43. Such blind holes, advantageously, are not plated and extend from the metallisation layer 2 to the metallisation layer 3. In the specific example represented in the figures, four groups are provided comprising four holes 51 each to allow each of the feeding waveguides 40-43 to be coupled with a respective connector.

[0037] With reference to figure 7, an example of a process for making a slot array antenna 10 as described above will be described hereafter.

[0038] The process, globally indicated with 100, comprises a first step 101 of providing the first plate-shaped dielectric substrate 11 having two opposite metalized faces, i.e. equipped with two surface metallisation layers 1, 2. A dielectric substrate 11 of the type indicated above has already been described with reference to figures 1-6 and therefore it will not be detailed any further. Similarly, the first step 101 comprises an operation of providing the second plate-shaped dielectric substrate 12, as already described earlier, equipped with a free face and with an opposite metalized face, i.e. coupled with the metallisation layer 3.

[0039] The process 100 also comprises a step 102 including an operation of making at least one radiating slot array 21 by selectively removing, preferably photolithographically, said portions of the first metalized layer 1 and an operation of making at least one coupling slot 31 by selectively removing, preferably photolithographically at least one portion of the second metalized layer 2. As already stated earlier, in an alternative embodiment, the selective removal of portions of the metalized layers 1 and 2 takes place through laser techniques.

[0040] The process 100 also comprises a step 103 comprising an operation of making a plurality of through channels 22 that extend from the first 1 to the second 2 metalized layer and an operation of surface coating inner walls of said channels 22, or of filling such through channels 22 with an electrically conductive material, so that the through channels 22 thus filled or coated define side confinement walls of at least one radiating waveguide 10, the first 1 and the second 2 metallisation layer representing two further opposite confinement walls of the aforementioned at least one radiating waveguide 20. Preferably, the aforementioned through channels 22 are obtained by perforating the first metalized layer 1, the first dielectric substrate 11 and the second metalized layer 2, for example through a mechanical perforation device.

[0041] In accordance with a currently preferred embodiment, the aforementioned steps or operations are carried out in the aforementioned sequence:

- making and metalizing (through perforation and subsequent coating or filling) the through channels 22;
- making two photolithographic masks, accurately aligning such masks with respect to the through channels 22 and subsequently photo-etching said masks respectively on a free surface of said first layer 1 and of said second metallization layer 2;
- making and metalizing (through perforation and subsequent coating or filling) the through channels 22;
- attachment for selective removal of portions of the first 1 and second 2 metallisation layer based on the aforementioned photolithographic masks to make the radiating and coupling slots.

[0042] The process 100 also comprises:

- a step 104 of coupling the aforementioned second dielectric substrate 12 with the second metalized layer 2 (on the side of the face that is not metalized of the second dielectric substrate 12) by interposition of a layer 4 of dielectric and therefore electrically insulating adhesive;
- a step 105 of making blind grooves 44-47 that extend from the third metalized layer 3 until they at least partially cover the second metalized layer 2 and of coating inner walls of such blind grooves with a metallization or alternatively of filling such blind grooves with metallic material to define side confinement walls of one or more feeding guides 40-43.

[0043] In accordance with a particularly advantageous embodiment, after having made the coupling slots 31 and before fixedly connecting the two substrates 11, 12, an operation of selectively increasing the thickness of the second metalized layer 2 is carried out, for example galvanically, in the areas in which it has not been removed to make the coupling slots 41. For example, such an enlargement operation is such as to bring the metalized layer 2 from a thickness of about 8-20 micron to a thickness of about 40-70 micron. In this way, the step 105 of making the blind grooves 44-47 can be carried out in a simple manner, for example with a relatively small precision milling cutter, without running the risk of completely perforating the metalized layer 2. In the absence of such enlargement, if a very accurate milling cutter were not used, given the small thicknesses involved there would indeed be a high risk of completely passing through the metalized layer 2 during cutting. It should be noted that the expedient of the aforementioned enlargement is not equivalent to using a starting metalized layer 2 of greater thickness, because in this case it would be more complicated to make coupling slots 31 in it having a shape with adequate precision for the performance required by the application.

[0044] The process 100 also comprises a step 105 of making at least one input slot 49 by removing, preferably photolithographically, at least one portion of the third metalized layer 3 and preferably also a step of making one or more arrays of through channels 50 that pass through the entire multi-layer structure as made above and of internally metalizing said arrays of through channels 50 to divide at least one feeding waveguide (40-43) into two or more operatively separate feeding waveguides.

[0045] The process 100 also preferably comprises a step 106 of making one or more groups of non-through holes 51 to couple one or more input connecters with the multi-layer structure as obtained above on the side of the third metallisation layer 3.

[0046] The process 100 also preferably comprises a step 107 of selectively plating the exposed metalized parts with a layer of protective material, for example with gold.

[0047] From what has been described above, it is therefore possible to understand how a slot array antenna of the type described above can be made with a less complex or expensive process compared to what currently occurs in the state of the art. It should also be noted that the antenna 10 has a compact structure in terms of vertical dimensions and is relatively light and does not have the problems of losses due to the coupling between the two substrates described with reference to the prior art.

[0048] It should also be observed that since the radiating guides are made from a substrate of dielectric material (i.e. such guides are "loaded"), such guides can have a relatively small width (by width we mean the longer side of the section of the guide) and they make it possible to make distances of positioning of two consecutive slots inside the same guide that for the same working frequency are relatively smaller than those of the air guides of the prior art. For this reason, therefore, for the same planar dimensions of the antenna it is possible to make an antenna having a greater number of guides and/or guides with a greater number of radiating slots therefore obtaining, for the same planar dimensions, an improvement in performance in terms of directivity and gain.

[0049] Without effecting the principle of the invention, the embodiments and the details can be widely varied with respect to what has been described and illustrated purely as a non-limiting example, without for this reason departing from the scope of the invention as defined in the attached claims.

[0050] For example, in accordance with a variant embodiment, schematically represented in figure 8 in a side section, the antenna 10 as described with reference to figures 1-6, in which the connectors 13 are not provided, has a monopulse comparator 80 that is operatively connected to the input slots 49 coupled with it on the side of the metalized layer 3. In accordance with a particularly advantageous embodiment, the monopulse comparator 80 is a waveguide comparator, made on a dielectric substrate 81 analogous to the substrate 11 described above (therefore equipped with two metallisation layers 82 and 83) in which the side guide walls are made with arrays of through channels 22 of the type described with reference to the radiating guides 20. Such a comparator 80 can be coupled with the metalized layer 3 for example through a layer (not represented in figure 8) analogous to the adhesive layer 4 described above. In accordance with an alternative embodiment not shown in the figures, the monopulse comparator is a conventional comparator made in a block of aluminium and has dug out guide walls and it is fixed to the metalized layer 3 that can advantageously in this case be made from aluminium and with a greater thickness so as to allow the stable coupling with the comparator.

[0051] With reference to figure 9, in accordance with a further particularly advantageous variant embodiment, two multi-layer antennas of the type described above with reference to figures 1 and 6, upper and lower antenna respectively, designed and sized to operate in two different frequency bands (for example respectively in bands ka and X), are stacked and coupled with one another face to face. In this way a multi-band antenna and in particular a double band antenna is formed. In order to allow the radiating slots 91 of the lower antenna to have access to the face 1 of the antenna, some through channels 91 are made in advance, internally coated with electrically conductive material, which completely cross the upper antenna and which are arranged, as represented in figure 9, so as not to interfere with the radiating and feeding waveguides 20 of the upper antenna. In practice, such through channels are arranged between adjacent radiating waveguides of the upper antenna. Such through channels therefore represent an outlet on the face 10 of the radiating slots of the lower antenna, and therefore their number is equal to the number of radiating slots of the lower antenna and they are arranged aligned with them. As can be seen, the through channels 91 communicating with the radiating slots of the lower antenna are made exploiting the interspaces present between adjacent radiating waveguides 20 of the upper antenna. For this reason, such through channels 91 can be defined as non-interfering with the radiating waveguides because since they do not pass through them they do not, at least substantially, influence their propagative characteristics. It is also suitable for such through channels not to pass through any feeding waveguide of the upper antenna.

[0052] Similarly, in the lower antenna there are through channels not interfering with the guides of such an antenna, in the same number as and in a corresponding position to the input slots 49 of the upper antenna 10. In order for such channels not to influence the performance of the upper antenna, the thickness of the channel must be advantageously such that the impedance seen from the upper earth plane looking towards the channel is close to zero.

[0053] The embodiment just described above can be implemented thanks to the fact that since the radiating guides are made in the substrate of dielectric material (i.e. such guides are "loaded"), such guides, for the same working frequency, have a lower width than the air guides of the prior art, and therefore, for the same planar dimensions of the antenna, they can be apart from adjacent guides by an amount sufficient to make through channels 91 between adjacent guides without degrading the performance of the antenna due to the grating lobes effect.

Claims

1. Slot array antenna (10) with waveguide feed comprising at least one radiating waveguide (20) comprising a radiating slot array (21) and at least one coupling slot (31) adapted for feeding the at least one radiating waveguide (20) with radiofrequency electromagnetic radiation, the antenna (10) having a multi-layer structure and comprising:

    - a first plate-shaped substrate (11) made from dielectric material comprising a first metalized layer (1) and a second metalized layer (2) respectively arranged on a first face and an opposite second face of the first plate-shaped substrate (11), the first (1) and second (2) metalized layer respectively representing a first confinement wall and a second opposite confinement wall of said radiating waveguide (20), the radiating slots (21) being openings made in the first metalized layer (1) and the at least one coupling slot (31) being an opening made in the second metalized layer (2);
    - a second plate-shaped substrate (11) made from dielectric material having a third face coupled with the second metalized layer, the antenna also comprising at least one feeding waveguide (40-43) of said radiating guide (20) operatively coupled with the latter through said coupling slot (31), the feeding waveguide (40-43) being made in the thickness of the second plate-shaped substrate (2);

    characterised in that

    the second metalized layer (2) represents an upper confinement wall of the at least one feeding waveguide, which is a shared confinement wall between said radiating waveguide and said feeding waveguide.

2. Slot array antenna (10) according to claim 1, wherein the first and the second substrate are coupled together through a dielectric adhesive layer, which, at said feeding waveguide, constitutes part of said feeding waveguide.

3. Slot array antenna (10) according to any one of the previous claims, also comprising a plurality of through channels (22) that extend in said thickness of the first substrate (11) between the first (1) and the second (2) metalized layer, said through channels (22) being internally coated or filled with electrically conductive material, and wherein the radiating waveguide (20) comprises side confinement walls each comprising a respective array of said through channels (22).

4. Slot array antenna (10) according to any one of the previous claims, also comprising a plurality of through channels (91) that extend from the first metalized layer (1) to the third metalized layer (3), internally coated with an electrically conductive material, provided in positions such as to be able to couple a further slot array antenna, intended to operate in a different band, with said antenna (10) on the side of said third metalized layer (3), so as to obtain a multi-band antenna, said through channels being adapted for facing radiating slots of said further antenna and being substantially non-interfering with said radiating guides, being arranged between adjacent radiating guides.

5. Slot array antenna (10) according to claim 1, wherein the second substrate (2) comprises a fourth face opposite to said third face and wherein the antenna (10) also comprises a third metalized layer (3) arranged on said fourth face, the third metalized layer respectively representing a confinement wall of the feeding waveguide (40-43).

6. Slot array antenna (10) according to claim 5, comprising at least a first and a second blind groove (44-47) that extend from a free surface of the third metalized layer (3), through the second substrate (12) until they partially go over said second metalized layer (2), the first and second groove respectively comprising a first wall and a second wall coated with a metalized layer, wherein said first and said second wall represent side confinement walls of the feeding waveguide (40-43).

7. Slot array antenna (10) according to claims 5 or 6, also comprising at least one array of through channels (50), that extend from the first (1) to the third (3) metalized layer, coated or filled with a conductive metallic material, the at least one array of through channels (51) being adapted for dividing said feeding waveguide (40-43) into two or more feeding waveguides.

8. Process (100) for making a slot array antenna (10) comprising:

- a step (101) of providing a first plate-shaped dielectric substrate (11), equipped with two opposite metalized layers (1, 2) and adapted for housing at least one radiating waveguide and a second plate-shaped dielectric substrate (12), having a free face and an opposite face coated with a third metalized layer (3), said second substrate being adapted for housing at least one feeding waveguide of said radiating waveguide;
- a step (102) of making at least one radiating slot array (21) by selectively removing portions of the first metalized layer (1) and an operation of making at least one coupling slot (31) by selectively removing at least one portion of the second metalized layer (2);
- a step (104) of coupling the second substrate (12) with the second metalized layer (2) so that said second metalized layer is suitable for constituting a confinement wall of said feeding waveguide.

9. Process according to claim 8, wherein the coupling step is carried out by interposition of a dielectric adhesive layer (4) between said second metalized layer and the second substrate.

10. Process (100) according to claim 8, also comprising a step (103) including the following operations:

- making a plurality of through channels (22) that extend from the first (1) to the second (2) metalized layer; and
- surface coating inner walls of said channels (22), or filling such through channels (22) with an electrically conductive material, so that the through channels (22) thus filled or coated define side confinement walls of at least one radiating waveguide (20), the first (1) and the second (2) metalized layer representing two further opposite confinement walls of said radiating waveguide.

11. Process (100) according to claim 8, also comprising a step (105) of making blind grooves (44, 47) that extend from the third metalized layer (3) until they at least partially cover the second metalized layer (2) and of coating inner walls of such blind grooves with a metallization, or of filling such grooves with electrically conductive metallic material, to define side confinement walls of one or more feeding waveguides (40-43).

12. Process (100) according to claim 11, also comprising a step of selectively increasing the thickness of said second metalized layer (2) to be carried out before carrying out said coupling step (104) and after having made said coupling slot (31).

13. Process according to claim 8, wherein said antenna comprises a plurality of said radiating guides (20) and wherein the process also comprises a step of making through channels (91) that extend from the first metalized layer (1) to the third metalized layer (3), of internally coating such channels with an electrically conductive material, to couple said antenna (10) on the side of said third metalized layer (3) with a further slot array antenna intended to operate in a different band, said through channels (91) being suitable for facing radiating slots of said further antenna and being substantially non-interfering with said radiating guides, being arranged between adjacent radiating guides (20).

14. Process according to any one of the previous claims 8 to 13, wherein said selective removal is carried out photolithographically.

15. Multi-band antenna comprising a multi-layer antenna according to claim 4 and also comprising said further antenna intended to operate in a different band, said antennas being stacked on top of one another and coupled together.

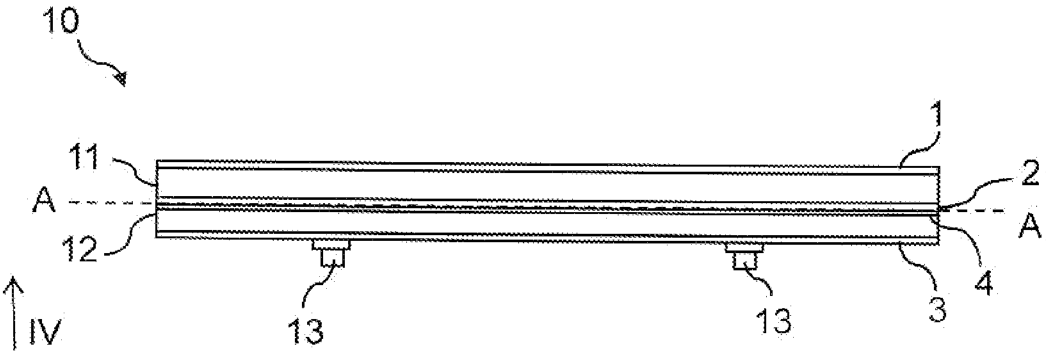


FIG. 1

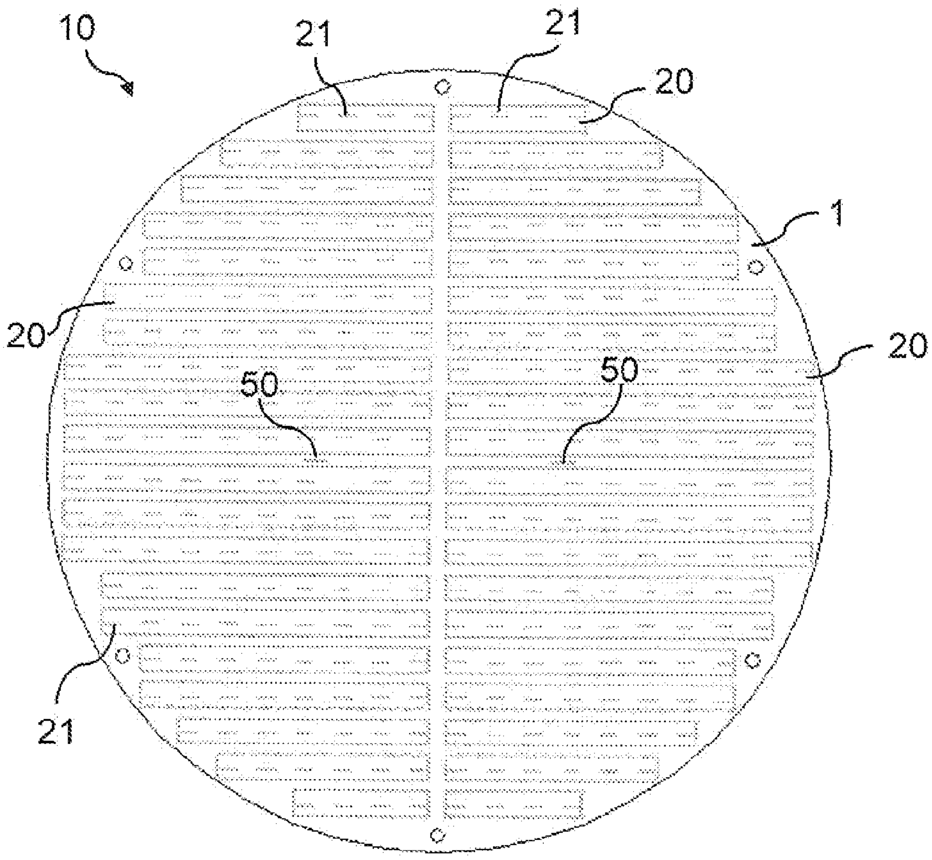
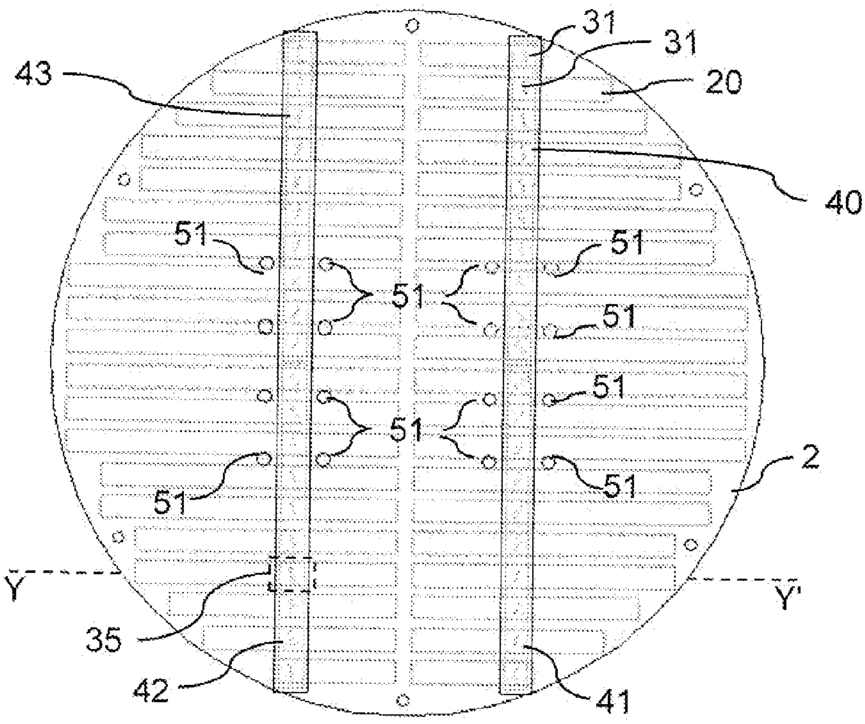


FIG. 2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51
2
51
Y
Y'
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42
41

FIG. 3

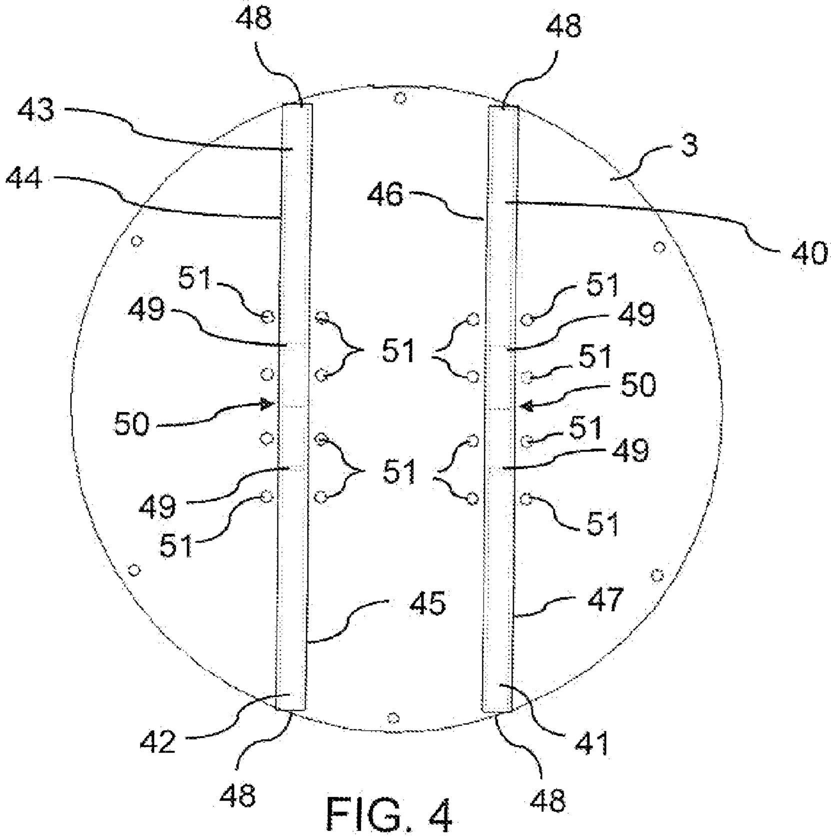
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FIG. 4

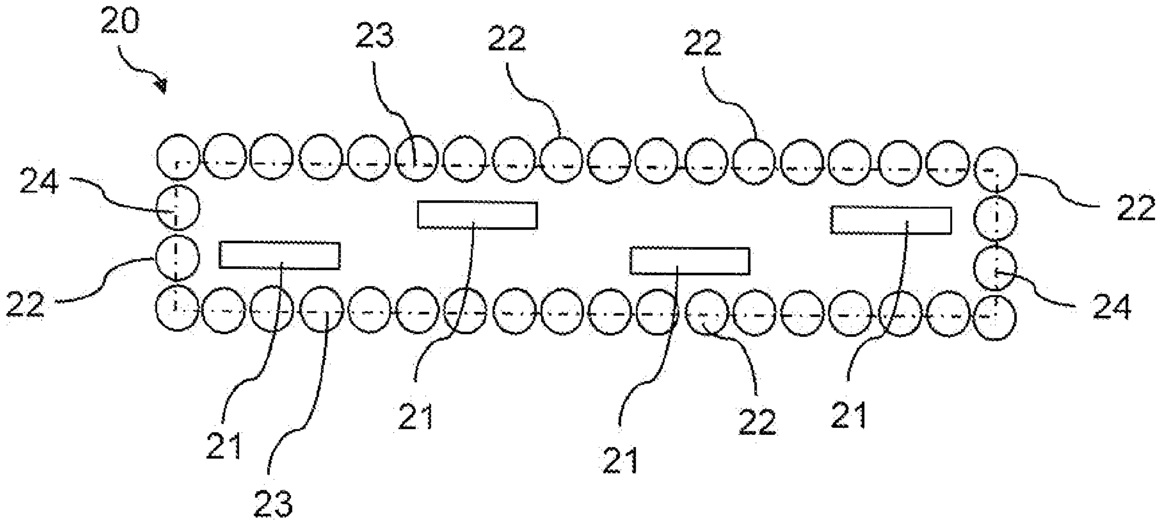
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FIG. 5

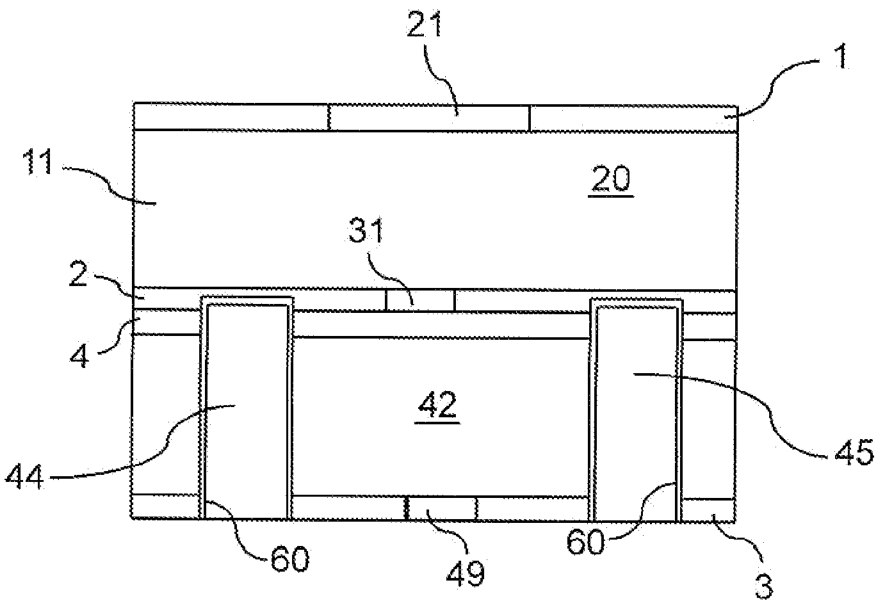
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FIG. 6

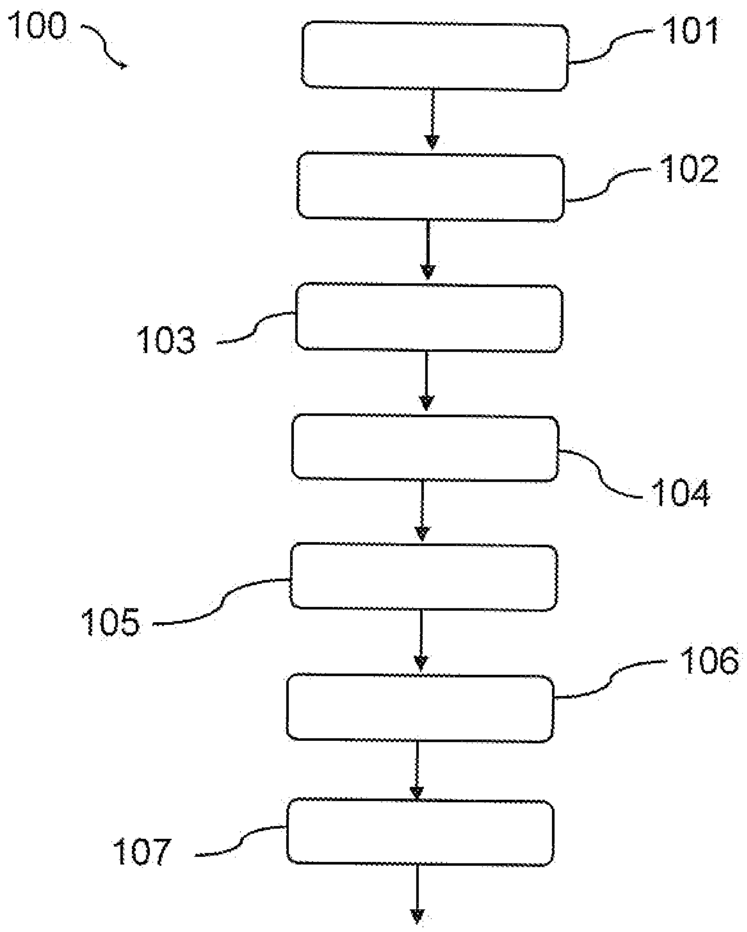
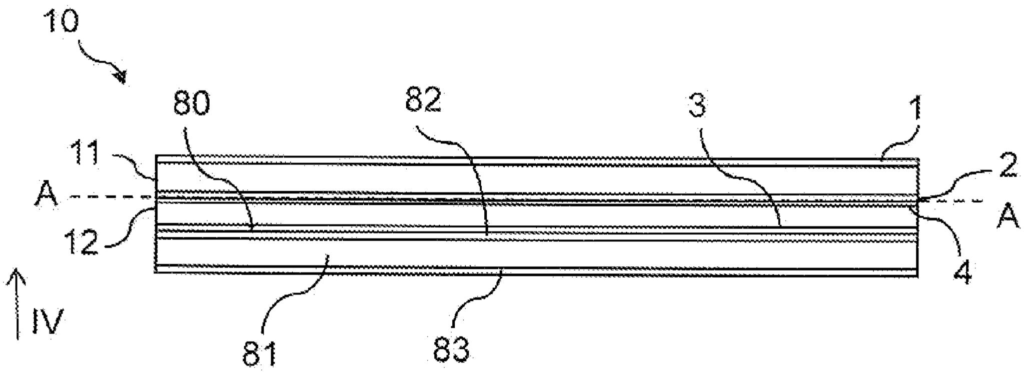


Fig. 7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12
4
IV
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83

FIG. 8

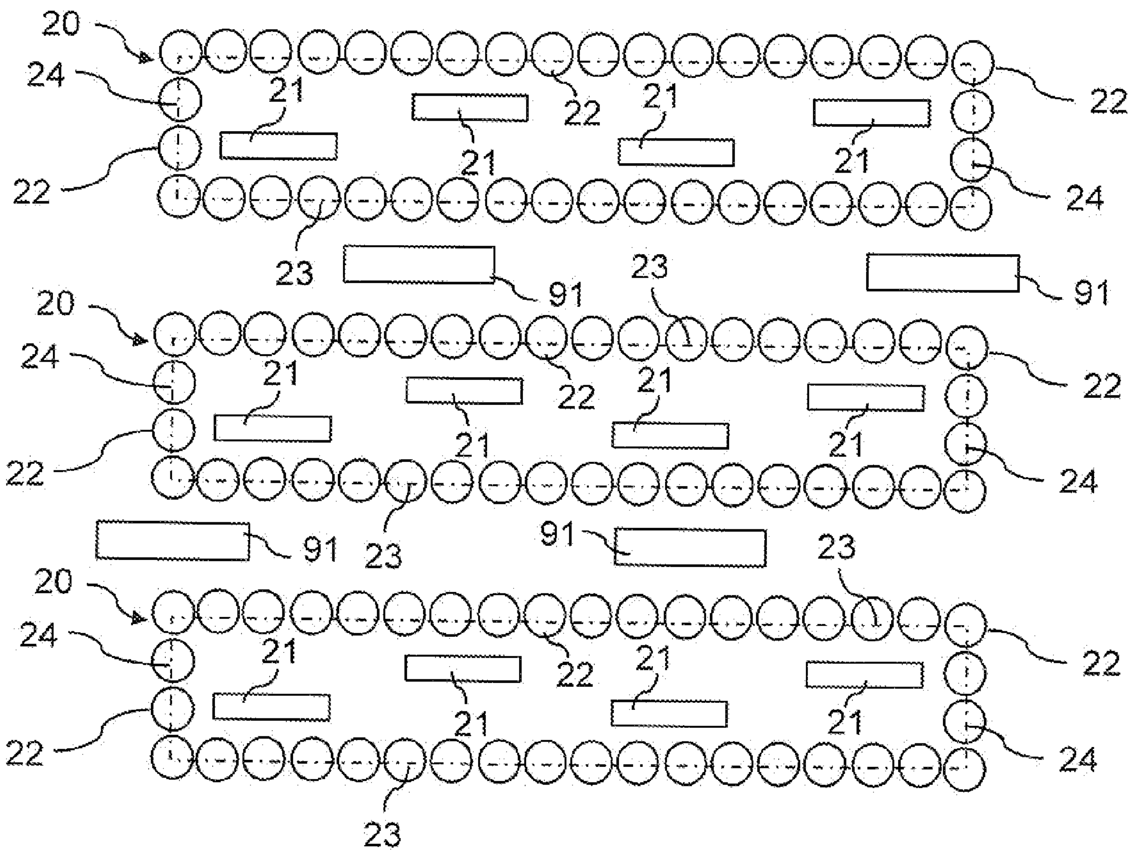
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FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 10 16 5653

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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	23 August 2010	Kruck, Peter

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EPO FORM 1503 03.82 (P04C01)

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