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(54) **STACKED PATCH ANTENNA ARRAY**

SCHICHTARTIG AUFGEBAUTE PATCH-GRUPPENANTENNE

RÉSEAU D'ANTENNES À PLAQUES EMPLIÉES

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Description

[0001] This invention relates to an antenna that can be used with multiple satellite-based global positioning and navigation systems, such as both the NAVSTAR GPS and Galileo GNSS.

[0002] A number of satellite-based global positioning and navigation systems currently exist, such as the above-mentioned United States NAVSTAR Global Positioning System (GPS), which was developed by the U.S. military in the 1970's. Each system is based on the transmission of ranging signals in particular frequency bands.

[0003] Currently, in the NAVSTAR GPS, there are in excess of 30 GPS satellites orbiting the Earth. However, at any one time there are at least 24 functional GPS satellites orbiting the Earth in 12-hour orbits; four satellites in each of six orbit planes, each transmitting a ranging signal. A typical GPS receiver requires ranging signals from at least four GPS satellites to determine its position using geometry and trilateration.

[0004] The NAVSTAR GPS is based on transmission of ranging signals in frequency bands including L1 (1575 MHz), L2 (1227 MHz), L3 (1381 MHz) and L5 (1176. MHz), all having a bandwidth of 20 MHz. Other satellite navigation systems use different, wider, frequency bands. For example, the new GNSS called Galileo, which is to be deployed by the European Union, operates at frequency bands that are different to those used by the NAVSTAR GPS, including E5a (1166.45 to 1186.45 MHz) and E5b (1197.14 to 1211.14 MHz). Since the two E5 bands (E5a and E5b) are very close together, it can be assumed that both bands will be combined and have a combined bandwidth of 45 MHz.

[0005] There is therefore a need for an antenna, which can receive signals emitted in the multiple frequency bands of either system, whilst utilising existing GPS installations. This requirement is particularly relevant in airborne applications where a retrofit to legacy installation is needed to reduce cost without compromising airworthiness. Furthermore, a multi-standard antenna for both NAVSTAR GPS and Galileo GNSS would effectively be dual-band, with the upper frequency band from 1565 to 1585 MHz (L1) an the lower frequency band from 1166 to 1211 MHz (E5).

[0006] However, a problem exists in that, with antenna systems, the physical size of the antenna is related to the bandwidth of the system and as the bandwidth of the Galileo GNSS is more than double that of the NAVSTAR GPS, the size of the respective antennas differs.

[0007] In addition, the radiation pattern for the multi-standard airborne GNSS antenna is expected to have advanced characteristics in terms of coverage and more stringent requirements on its polarisation purity as compared to single band GPS antennas of today.

[0008] EP-A-0270209 discloses a dual band antenna and US5245745 discloses a method of making a thick-film patch antenna structure.

[0009] Accordingly, an object of the present invention is to provide a multi-standard radiator for a GNSS antenna, which can receive ranging signals transmitted in multiple frequency bands from different GNSS, whilst remaining an overall physical size that ensures that the antenna assembly can be backwards compatible with existing GPS fixtures/docketing stations and installations onboard a vehicle where it is to be used.

[0010] According to the present invention there is provided a radiating element board for use in a passive antenna, the radiating element board comprising a plurality of multi-layer radiating elements, each of which comprises:

a first patch provided on a first layer for receiving signals within a first frequency band; and
a second patch provided on a second layer for receiving signals within a second frequency band,
wherein the plurality of radiating elements are arranged on the radiating element board such that each radiating element is sequentially rotated a predetermined angle from its neighbouring element, all elements being rotated in the same direction and in the same plane, wherein each patch is short-circuited to ground along an edge of the patch so that multi-band radiation can only escape from a virtual slot provided substantially along the opposite edge of the corresponding patches; characterised in that each patch has serrated teeth provided along a first edge opposite the edge short-circuited to ground for broadband and tuning purposes.

An example of the present invention will now be described with reference to the following figures, in which:

Figure 1 is an exploded view of a multi-standard radiator comprising a radiating element board according to the present invention;
Figure 2 shows an array of radiating elements comprising a radiating element board;
Figure 3 shows the patches of the radiating elements;
Figure 4 is a cross-sectional view of Figure 3 taken between two of the patches;
Figures 5(a) to (d) show examples of different feeding structures for the patches;
Figure 6 is a schematic of a polarization forming network;
Tables 7(a) and 7(b) show minimum and maximum gain, respectively, above the horizon;
Figures 8(a) and 8(b) show an antenna radiation pattern template and close-up of the details along the horizon, respectively; and

Figure 9 is a cross section illustration of a radiating element, showing the relative distances between the short circuit and feeding lines.

[0011] Figure 1 is an exploded view of a multi-standard radiator 1, comprising a radiating element board 2 according to the present invention. The radiating element board 2 is attached to a polarization forming network circuit board 3 and enclosed within a radome 4, which seals against a base-plate 5 that has grooves to accommodate components of the polarization forming network circuit board 3. The radome 4 may be made from "PTFE", "Nylon" or a similar material, approximately 2.5mm thick. The radome (4) is bonded, using an epoxy resin bond film, to the base-plate 5, which is ideally aluminium. A gasket 7, preferably neoprene or plastic, may be provided to ensure a good seal between the radome 4 and the base-plate 5. Alternatively the radome can be directly glued on the base plate with structural adhesive. An output 9 to the multi-standard radiator 1 is provided on the underside of the base-plate 5.

[0012] Alternatively, the radome may be a foam-filled radome, which is formed around the elements to keep the weight of the antenna low whilst ensuring high mechanical stability, at the same time preventing humidity ingress as well as mitigating adverse differential pressure effects.

[0013] Figure 2 shows an array of four passive radiating elements 10, which form a radiating element board 2 according to the present invention. The elements 10 are arranged to form a substantially square radiating element board 2, wherein each element 10 is rotated 90 degrees from its neighbour and all elements 10 are rotated in the same direction. The arrangement shown in Figure 2 provides right-hand circular polarisation although it will be appreciated that lefthand polarisation could also be achieved were the elements orientated in the other direction.

[0014] Each passive radiating element 10 comprises two patches 11,12 separated by dielectric material 13, which is ideally an RF quality plastic material. The dielectric material is, preferably, in a stratified dielectric form, based on dissimilar properties that are important in terms of electrical permittivity and which are determined both by the required frequency of operation of the corresponding patch plus limitations imposed on the maximum overall space the patch can occupy plus the minimum required bandwidth for the corresponding operation.

[0015] Stratified dielectric material has been found to provide superior performance when compared with dielectric material in single form, as will be explained in more detail later on. However, a skilled person will recognise that, although stratified dielectric material is preferred, for the case of GPS/Galileo antenna there are many dielectric materials that can enable adequate operation in single form to satisfy reduced antenna specifications at a lower cost.

[0016] The dielectric material 13 provided in the radiating elements 10 of the present invention is substantially in the form of dielectric plates 13. As an alternative, the space between the patches 11,12 could be filled with air or foam, as mentioned above.

[0017] The construction of the antenna therefore offers potential in terms of controlling the volume of the antenna while at the same time allows the capability of operation the antenna on substantially separated frequency bands. This stems from the fact that a predefined maximum volumetric envelope can be made compatible with diverse frequency operation by ensuring that the electrical size of the antenna is suitable for the prescribed frequencies using common location for the feed and the short circuit position. Such choice allows also the flexibility of introducing geometrical features required for the efficient and precise manufacturing and tuning using only widely available commercial quality RF materials without resorting to the need of specialised variants or sophisticated production methods.

[0018] The first patch 11, provided for the NAVSTAR GPS and Galileo (L1), (L2), (L3) or (L5) frequency band, is arranged to be on the outside of each radiating element 10. A second, physically larger, patch 12 is provided on an inner layer of each element 10, with a dielectric plate 13 provided either side of it, and covers the GPS and Galileo (both E5A and E5B) frequency bands simultaneously. The passive radiating elements 10 are constructed using standard multi-layer printed circuit board (PCB) technology, i.e. several substrate layers bonded together to create a thick multi-layer assembly.

[0019] The dielectric material 13, provided on the radiating element 10 between the patches 11,12 and on either side of the inner patch 12, ensures that proper operation in terms of antenna voltage standing wave ratio (VSWR) is achieved by causing the antenna to resonate to the bands of interest. In addition, this ensures that the overall physical size of the antenna 1 is backwards compatible with existing GPS fixtures/docking stations and installations onboard vehicles, such as commercial aircraft, where it is to be used.

[0020] For instance, currently many aircraft employ GPS only antennas with fixings that suit the particular form as dictated by the ARINC743A standard. Any deviation from the details outlined in this standard is likely to be unacceptable in terms of installation cost and overall airframe performance. The increased height is necessary so that, besides the bandwidth, the group delay of the antenna is overall acceptable. It is well known that the Q factor of an antenna is inversely related to the volume it occupies. It is also well known that the Group delay response of the antenna and its variation across the band is proportional to the Q of the underlying antenna cavity. Therefore the bandwidth response of the antenna is crucial in maintaining the required group delay performance.

[0021] Figure 3 shows the arrangement of radiating elements 10 in a radiating element board 2 according to the present invention without the dielectric material 13 shown. Both the outer patches 11 and inner patches 12 of each

radiating element 10 are short circuited by wires 14 passing through one of their edges, the wires 14 connecting both patches 11,12 to ground in order that a quarter-wave operation is achieved and to make sure that the overall mechanical size is physically controlled.

[0022] The short circuits 14 are collocated on the edges of each outer patch 11 and inner patch 12. This alignment is very useful when manufacturing the overall antenna assembly because the short circuit positioning can act as an alignment guide when aligning the patches 11,12. The alignment of the short circuit 14 is also useful for tuning the antenna, especially the inner patch 12, as it enables the radiating edge of the inner patch 12 to be exposed.

[0023] In stratified dielectric form, the dielectric plates 13 provide an enhanced flexibility over dielectric plates 13 in single form, which allows the electrical distances from feed points to the short circuit 14 at two different bands for the patches 11,12 to be equalised, while maintaining the same mechanical distance. The electrical distance between the feed wire and short circuit 14 has to be the same for both the outer patch 11 and the inner patch 12. This can be achieved when the effective dielectric properties of the patches 11,12 is appropriate and finely tuned taking into account the different frequencies and bands that the two patches 11,12 can operate.

[0024] This can be further explained with reference to Figure 9. If one assumes that the outer patch 11 needs to be tuned in band with center frequency f1 (for instance the GPS or Galileo L1) and the inner patch 12 at frequency band with centre value f2 (for instance the GPS L5 or Galileo E5). In order that the desired resonance is achieved, it is required to tune out the reactive part of the driving impedance Z1 or Z2 for the respective patches at the centre of the respective frequencies.

[0025] Within the preferred configuration this resonance operation is achieved when the feed is loaded by an additional effective reactance X1 and X2 respectively. The part of the antenna offering this resonance reactance is that formed between the feeding point and the short circuit formation. In fact, this section behaves as two stacked short transmission line of common length ds loaded in the other end by inductances La and Lb representing in a realistic electrical way the metal plated short circuit via holes or any other alternative realisation.

[0026] The transmission line equations can be written as follows:

$$X1 = j\frac{(2\pi\, La\ f1 + Za\tan(\beta_1\ ds))}{(Za - 2\pi\, La\ f1\ \tan(\beta_1\ ds))}$$

$$X2 = j\frac{(2\pi\, Lb\ f2 + Zb\tan(\beta_2\ ds))}{(Zb - 2\pi\, Lb\ f2\ \tan(\beta_2\ ds))}$$

with

$$\beta_1 = \left(\frac{2\pi\, f1}{c}\right)\sqrt{\varepsilon a} \quad and \quad \beta_s = \left(\frac{2\pi\, f2}{c}\right)\sqrt{\varepsilon b}$$

[0027] The way of synthesizing the required resonance reactances within the disclosed antenna is through control of the characteristic impedances Za and Zb as well as propagation constants $\beta 1$ and $\beta 2$ of the effective transmission lines offered by the section of the antenna to the short circuit location. Inspecting the corresponding transmission line equations shown above, we can see that the short circuit inductances La, Lb can be transformed to resonance impedance X1, X2 at the centre of the two different *operational* bands with a suitable choice of the two bulk electric permittivity's εa, εb and a common value *ds* for the separation of the feed point and the short circuit location for both upper and lower patch.

[0028] The precise determination for the values of the of εa, εb and ds is the outcome of mathematical optimisation based on a detailed electromagnetic modelling. The optimisation objective of the design is the bandwidth required per band as well as the maximum Return loss (or VSWR) that can be tolerated at the band edges.

[0029] The practical approximation of the corresponding slabs with the bulk dielectric contents εa, εb is based on the stratification process where the bulk average value is approximately the average of the materials used weighted by the corresponding thickness.

[0030] In addition the mathematical process can also yield a solution for the εa, εb and ds under the constrain that the upper and lower patches offer a gap between their edges of a given size g suitable for the accommodation of tuning teeth on the bottom patch practically accessible from above. A typical value for g is of the order of 5mm.

[0031] Accordingly, the dielectric plates 13 may be formed from stratifying regular commercial dielectric materials,

found in most material manufacturer's standard product ranges, which offer a distinct but limited range of dielectric constants to synthesize the desired dielectric properties. This synthesis is achieved by using one or more regular commercial materials with a suitable thickness, which is dictated by the bulk dielectric constant that is to be synthesized, as outlined above.

[0032] The shorting wires are preferably formed using plated through-holes, or vias. Of course, it will be appreciated that alternative means of short circuiting the patches 11,12 to ground can also be used and specifically engineered for a particular application. For example, plating the edge of the PCB with a solid metal layer, or using a series of flat metal strips instead of wires. The number of wires 14 and their diameters also need to be accurately controlled. The wires can be thought as a series additional inductive loading of an otherwise resonant cavity formation. Therefore a suitable choice for their number and diameter can affect both the precise resonant frequencies for a given antenna element size and arrangement as well as its bandwidth at resonance. In addition other means of short circuiting can be used in terms of strips of metal.

[0033] The use of plated vias, however, avoids the problems that can be encountered with other short circuit means such as metallic pins, which can be cumbersome as short circuit enablers. In particular, for thicker patches, it is difficult to achieve the required soldering, especially on the inner patch 12 and even then such process is imperfect for a smooth assembly desired of the antenna with adverse effect on the tuning and performance. By using plated vias, there is no need for soldering as the formation of the via holes takes place using standard printed circuit techniques in parallel with the patches within the same manufacturing framework. Therefore no finishing process, as for soldering metallic pins, is required.

[0034] In Figure 3 it can also be seen that each of the patches 11,12 also has a serrated edge, preferably provided on the side opposite to the side that is short circuited. These serrated edges form tuning teeth, which enable fine tuning of the antenna after assembly where, in a controlled fashion, some teeth 15 can be physically removed up to the point that the frequency operation fits the required frequency bands. By arranging the tuning teeth 15 along the same side of each of the patches 11, 12, when multiple radiating assembly boards are arranged to form an antenna, tuning is possible by modifying and/or removing teeth 15 with no negative effect on the quality of circular polarisation. Preferably, the dielectric plates 13 do not extend over the teeth 15 of the inner patch 12, which allows them to be adjusted assembly of the antenna.

[0035] Typically, 10-20 teeth are regularly distributed over the length of the single radiating edges of both the upper and lower patches. With typical teeth lengths of the order of 5mm it is possible to precisely tune the antenna to within a fraction of a MHz. The regularity of teeth distribution allows us easily to apply the same tuning modification to all the corresponding patches of the array formation maintaining thus the symmetry which is essential for good circular polarisation performance. Of course, different numbers of teeth and teeth lengths are possible depending on the configuration required.

[0036] Figure 4 is a cross-sectional view of Figure 3, showing each element 10 having a feeding structure comprising an individual feed pin 16 passing through it. In this example, the feed pin 16 originates at the outer patch 11, passes through a hole 17 provided in the inner patch 12 and then out through the base of the radiation element board 2. The feed pins 16 therefore connect each individual element 10 to the circuit board 3.

[0037] A number of other feeding structures are possible, as illustrated in Figures 5(a) - (d). For example as shown in Figure 5(a), a feed signal may be fed into the element via a cylinder 18 provided in the lower portion of an element 10, with a feed pin 16 passing through the cylinder to connect it to the lower portion of the element and hence inner patch 12, as the feed pin 16 passes up through the hole 17 provided in the inner patch 12 to connect with the outer patch 11. In this example, the inserted metallic coaxial cylinder 18 loading the feeding wire serves to offer an incremental transmission line in series enabling a degree of freedom in terms of a conventional impedance transformation with cascading lines of different characteristic impedance. It can also be used as an additional mainly shunt capacitive element loading of the feeding point

[0038] Alternatively, as shown in Figure 5(b), one or two discs 19 may be provided in the upper and lower portions, respectively, of the element 10 that the feed pin 16 passes through, thereby connecting the outer patch 11 and the inner patch 12 to the circuit board 3. This disc 19 loaded feeding 16 allows mainly a distributed loading of the line which can resemble a loaded LC - inductor capacitance low pass section

[0039] Another option, shown in Figure 5(c), is to feed a signal through feed pin 16 in the proximity of to one or more parasitically excited tuning posts 20 provided at the base of an element 10, at the side of the hole 8 that the feed pin 16 passes through to enter the element 10. Also referred to as parasitic stub 20 loading of the feeding point 16, this arrangement, though mainly of capacitive nature, can also be envisaged in general as a series LC inductor-capacitance section loading in parallel the driving point impedance.

[0040] Yet another option is to provide a slot 21 in the base of an element 10, as shown in Figure 5(d). The slot 21 is substantially perpendicular to a metallic strip 22 provided in the circuit board 3 that the element is mounted on. In this example, when a feed signal is fed into the metallic strip 22 in the circuit board 3, electromagnetic radiation 23 excites element 10 to the inner and outer patches 12, 11. Coupling through a slot 21 is useful as such an arrangement requires

neither a feed wire nor soldering, although it does add another layer. Using this feedings structure, antennas can demonstrate better axial ratio performance over wider elevation angular ranges and enhanced bandwidth performance. Essentially the combination of the slot 21 and the open circuited (in one of its ends after the slot) feeding line 22 provide equivalent higher order circuit loading to the feeding line 22. The slot acts as a series transformer and the open circuited termination of the feeding line 22 acts as a series Inductor and parallel capacitance loading. All these extra degrees of freedom allow enhanced flexibility in matching the structure.

[0041] An advantage of the alternative feeding arrangements is that they offer additional degrees of freedom and act in effectively building higher order matching network features that can help compensate the off resonance equivalent feeding reactance over an increased bandwidth as compared to the simple single feeding feature disclosed. The additional matching features are precisely determined as part of the same mathematical electromagnetic optimisation design methodology previously described.

[0042] The particular arrangement of the radiating elements 10 on the board 3, according to the present invention, creates the effect of circular polarization. Accordingly, an antenna 1 incorporating the radiating element board 2 of the present invention will operate through circular polarization. The example shown in the accompanying figures provides for right hand circular polarization, although a skilled person will recognise that a simple rearrangement of the elements 10 will provide left hand polarization.

[0043] When the radiating element board 2 is in use in a GNSS antenna 1, the individual feed pins 16 connect each of the elements 10 to a circuit board 3, which is part of a circular polarization-forming network such as the one shown in Figure 6. The network combines the input from each of the elements 10 which is rotated 90 degrees from its neighbour, to provide a common output of the antenna 1, preferably via a TNC connector 9 provided on the antenna base 5, as shown in Figure 1. The antenna 1 can be connected to an external pre-amplifier box (not shown) by means of a short RF quality cable which is ideally, but not essentially, less than 300mm in length. Alternatively, the pre-amplifier can be directly integrated with the structure, preferably with the polarization-forming network board.

[0044] Many physical implementations are possible but any network compatible with that shown in Figure 6 will suffice, provided it can cover the necessary frequency bands.

[0045] Low dispersion implementations are always important for ensuring the group delay of the antenna 1 is not compromised. The intimate connection of a suitable network with the radiating element board 2 is important for proper function.

[0046] The advantages of forming the radiating element board 2 as described above are two-fold. Firstly, it allows a single feed per element 10 yet a good quality RHCP is produced when the elements 10 are fed with signals with a progressive phase sequence; and, secondly, a radiation pattern with significant coverage can result for directions close to the horizon, as shown in Tables 7(a) and 7(b). The good coverage at directions close to the horizon is in addition to the outcome of the precise sequential array arrangement of the elements 10 and the fact that the effective points where radiation is emanating is confined only in the space between adjacent elements 10 and not through both opposite edges for each elements 10 as in conventional GNSS patch antennas.

[0047] Figure 8(a), and also Figure 8(b) which shows the circled area of Figure 8(a) in more detail, show the measured radiation patterns performance in relation to the EUROCAE template for future multi-standard GNSS antennas. These templates on one hand ensure that the antenna is sensitive over a broad angular range in the upper radiation hemisphere and on the other hand the radiation is not stronger than required in order to minimise the susceptibility of the GNSS system to unwanted strong emissions from external interference sources. As can be seen, the present arrangement performs well on both aspects. However the antenna 1 is expected to conform to other GNSS system pattern templates in present or evolved forms.

[0048] The radiating elements 10 of the present invention are required to have a thickness that depends on the desired frequency and bandwidth requirements for an antenna. However, for many applications, the elements 10 are required to be of a thickness that cannot be manufactured as a single block by conventional methods. Therefore, two separate blocks are manufactured to provide an upper layer with a patch 11 provided on it and a lower layer with a patch 12 provided on it. These layers can then be fixed together preferably using conductive adhesive, although other suitable conductive joining means could be used, to form a radiating element 10 having the necessary thickness.

[0049] When conductive adhesive is used it is important that it has substantially the same thermal expansion properties as the radiating element 10 material. The upper layer, although having substantially the same width as the lower layer, has a shorter length than the lower layer, thereby providing a step on which a portion of the inner patch 12 can be exposed when the two layers are connected to form the radiating element 10. Furthermore, in addition to having the outer patch 11 printed on its top surface, the upper layer also has a dummy lower patch printed on its underside, which is used to match the upper layer up with the inner patch 12 provided on the lower layer when fixing the two layers together. In this way the short circuit vias forms a continuous low resistance path conductively connecting the upper patch 11, the lower patch 12 and the base plate 2. Similar effects are ensured for the feed via or wires.

[0050] As explained above, the elements 10 are arranged on the circuit board 3 with each element 10 being rotated 90 degrees from its neighbour, with all elements 10 being rotated in the same direction. In addition, there is a gap

between each element 10, which enables teeth 15 on the outer and outer patches 11,12 to be easily removed to fine tune the apparatus. An additional benefit of these gaps is that they allow radiation to escape between the elements 10, rather than only from around the outer edges, and this results in the formation of good radiation patterns.

[0051] The antenna 1 is fabricated using several multi-layer PCB elements. Since the bandwidth requirement is very large, the PCB is, in this instance, created from three PCBs that are bonded together using a patterned conductive bond film. The PCB is made as one complete block, but with slots machined to separate the four radiating elements and to expose the tuning teeth 15 on the lower patch.

[0052] An alternative construction approach would be to make the whole element board 2 from a single multi-layer PCB with plated via holes through the entire element board 2. This depends on the capability of the PCB manufacturer and is dependent on factors such as the specific thickness of the PCB and the aspect ratio of the plated via holes.

[0053] The antenna described herein is designed to operate at GPS band L1 and Galileo bands E5a and E5b. However, a person skilled in the art would understand that simple tuning of the antenna design would allow it to operate at alternative GNSS bands, for example L1/L2 or L1/L3.

Claims

1. A radiating element board (2) for use in a passive antenna, the radiating element board comprising a plurality of multi-layer radiating elements (10), each of which comprises:

   a first patch (11) provided on a first layer for receiving signals within a first frequency band; and
   a second patch (12) provided on a second layer for receiving signals within a second frequency band,
   wherein the plurality of radiating elements are arranged on the radiating element board such that each radiating element is sequentially rotated a predetermined angle from its neighbouring element, all elements being rotated in the same direction and in the same plane, wherein each patch is short-circuited to ground along an edge of the patch so that multi-band radiation can only escape from a virtual slot provided substantially along the opposite edge of the corresponding patches; **characterised in that** each patch (11,12) has serrated teeth (15) provided along a first edge opposite the edge short-circuited to ground for broadband and tuning purposes.

2. The radiating element board (2) according to claim 1, wherein the first and second patches (11,12) on each radiating element are separated by dielectric material (13).

3. The radiating element board (2) according to claim 1 or 2, wherein the dielectric material (13) is in stratified form.

4. The radiating element board (2) according to any preceding claim, wherein the predetermined angle that each element is rotated from its neighbouring element is 90 degrees.

5. The radiating element board (2) according to any preceding claim, wherein each patch (11,12) is short-circuited to the ground by a plurality of plated through-holes provided along the edge of the patch.

6. The radiating element board (2) according to claim 5, wherein the short-circuits in each of the patches (11,12) comprising a radiating element (10) are aligned.

7. The radiating element board (2) according to any preceding claim, wherein each radiating element further comprises a feed structure connecting it, in use, to a polarization-forming network circuit board.

8. The radiating element (2) according to claim 7, wherein the feeding structure comprises a substantially coaxial cylinder which a feeding pin can pass through, or comprises one or more discs which a feeding pin can pass through, or comprises one or more posts provided at the base of the element, or comprises a slot in the base of the element through which electromagnetic radiation propagates.

9. The radiating element board (2) according to any preceding claim, wherein the first patch (11) receives NAVSTAR GPS signals, and/or the second patch (12) receives Galileo GPS signals.

10. The radiating element board (2) according to any preceding claim, wherein the first frequency band is L1 (1565-1585 MHz), L2 (1227 MHz), L3 (1381 MHz) or L5 (1176 MHz).

11. The radiating element board (2) according to any preceding claim, wherein the second frequency band is 1166-1211

MHz (E5).

12. The radiating element board (2) according to any preceding claim, further comprising a pre-amplifier connected to the polarization forming network.

13. The radiating element board (2) according to any preceding claim, which is sealed inside a radome (4).

14. A radiating element board (2) according to claim 13, wherein the radome (4) is foam-filled around the elements (10).

15. A radiator element board (2) according to any preceding claim, wherein each radiator element (10) is constructed from an upper layer with an outer patch (11) provided on it and a lower layer with an inner patch (12) provided on it, the two layers being provided separately before being joined together to form the radiating element using a suitable conducting means.

16. A radiator element board (2) according to claim 15, wherein a dummy metallisation surface is formed on the underside of the upper layer and this is joined to an upper surface of the lower layer to join the two layers together.

17. A radiator element board (2) according to claim 15 or 16, wherein the upper layer and lower layer of each radiator element are joined together using a conductive adhesive.

18. A radiator comprising a radiating element board (2) according to any preceding claim.

Patentansprüche

1. Eine Leiterplatte (2) mit abstrahlendem Element zur Verwendung in einer passiven Antenne, wobei die Leiterplatte mit abstrahlendem Element eine Vielzahl von vielschichtigen abstrahlenden Elementen (10) umfasst, wovon jedes umfasst:

   einen ersten Patch (11), der auf einer ersten Schicht zum Empfangen von Signalen innerhalb eines ersten Frequenzbandes vorgesehen ist; und
   einen zweiten Patch (12), der auf einer zweiten Schicht zum Empfangen von Signalen innerhalb eines zweiten Frequenzbandes vorgesehen ist,
   wobei die Vielzahl von abstrahlenden Elementen auf der Leiterplatte mit abstrahlenden Elementen derartig angeordnet ist, dass jedes abstrahlende Element einen vorbestimmten Winkel von seinem benachbarten Element sequenziell rotiert wird, wobei alle Elemente in der gleichen Richtung und in der gleichen Ebene rotiert werden, wobei jeder Patch entlang eines Randes des Patches Masseschluss hat, sodass Mehrbandstrahlung nur ab einem virtuellen Schlitz austreten kann, der im Wesentlichen entlang des entgegengesetzten Randes der entsprechenden Patches vorgesehen ist; **dadurch gekennzeichnet, dass** jeder Patch (11, 12) sägeartige Zähne (15) aufweist, die entlang eines ersten Randes gegenüber dem Rand mit Masseschluss für Breitband- und Abstimmzwecke vorgesehen sind.

2. Die Leiterplatte (2) mit abstrahlendem Element nach Anspruch 1, wobei die ersten und zweiten Patches (11, 12) auf jedem abstrahlenden Element durch dielektrisches Material (13) getrennt sind.

3. Die Leiterplatte (2) mit abstrahlendem Element nach Anspruch 1 oder 2, wobei das dielektrische Material (13) geschichteter Form ist.

4. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, wobei der vorbestimmte Winkel 90 Grad beträgt, den jedes Element von seinem benachbarten Element rotiert wird.

5. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, wobei jeder Patch (11, 12) durch eine Vielzahl von durchkontaktierten Bohrungen, die entlang des Patch-Randes vorgesehen sind, Masseschluss hat.

6. Die Leiterplatte (2) mit abstrahlendem Element nach Anspruch 5, wobei die Kurzschlüsse in jedem der Patches (11, 12), die ein abstrahlendes Element (10) umfassen, ausgerichtet sind.

7. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, wobei jedes abstrahlende Element ferner eine Speisestruktur umfasst, die es mit einer Polarisation bildenden Netzwerkleiterplatte verbindet.

8. Die Leiterplatte (2) mit abstrahlendem Element nach Anspruch 7, wobei die Speisestruktur einen im Wesentlichen koaxialen Zylinder umfasst, durch den ein einspeisender Stift hindurch passt oder eine oder mehrere Scheiben umfasst, durch welche ein einspeisender Stift hindurch passt oder einen oder mehrere Pfosten umfasst, die an der Basis des Elements vorgesehen sind oder einen Schlitz in der Basis des Elements umfasst, durch den sich elektromagnetische Strahlung ausbreitet.

9. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, wobei der erste Patch (11) NAVSTAR-GPS-Signale empfängt und/oder der zweite Patch (12) Galileo-GPS-Signale empfängt.

10. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, wobei das erste Frequenzband L1 (1565-1585 MHz), L2 (1227 MHz), L3 (1381 MHz) oder L5 (1176 MHz) ist.

11. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, wobei das zweite Frequenzband 1166-1211 MHz (E5) ist.

12. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, die ferner einen Vorverstärker umfasst, der mit dem Polarisation bildenden Netzwerk verbunden ist.

13. Die Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch, die im Innern einer Radarkuppel (4) abgedichtet ist.

14. Die Leiterplatte (2) mit abstrahlendem Element nach Anspruch 13, wobei die Radarkuppel (4) um die Elemente (10) herum mit Schaumstoff gefüllt ist.

15. Eine Leiterplatte (2) mit Strahlerelement nach einem vorhergehenden Anspruch, wobei jedes Strahlerelement (10) aus einer oberen Schicht mit einem darauf vorgesehenen äußeren Patch (11) und einer unteren Schicht mit einem darauf vorgesehenen inneren Patch (12) konstruiert ist, wobei die zwei Schicht separat bereitgestellt sind, bevor sie zusammengefügt werden, um unter Verwendung eines geeigneten leitenden Mittels das abstrahlende Element zu bilden.

16. Eine Leiterplatte (2) mit Strahlerelement nach Anspruch 15, wobei eine Dummy-Metallisationsoberfläche auf der Unterseite der oberen Schicht gebildet und diese mit einer Oberseite der unteren Schicht verbunden wird, um die zwei Schichten zusammenzufügen.

17. Eine Leiterplatte (2) mit Strahlerelement nach Anspruch 15 oder 16, wobei die obere Schicht und die untere Schicht jedes Strahlerelements unter Verwendung eines leitenden Klebstoffs zusammengefügt sind.

18. Strahler, der eine Leiterplatte (2) mit abstrahlendem Element nach einem vorhergehenden Anspruch umfasst.

Revendications

1. Plaque à éléments rayonnants (2) qui va être utilisée dans une antenne passive, la plaque à éléments rayonnants comportant une pluralité d'éléments rayonnants multicouche (10) chacun d'eux comprenant:

   une première plaque (11) prévue sur une première couche et servant à recevoir des signaux dans une première bande de fréquences; et
   une deuxième plaque (12) prévue sur une deuxième couche et servant à recevoir des signaux dans une deuxième bande de fréquences,
   caractérisée en ce que la pluralité d'éléments rayonnants est disposée sur la plaque à éléments rayonnants de manière à ce que chaque élément rayonnant soit tourné séquentiellement d'un angle prédéterminé par rapport à son élément voisin, tous les éléments étant mis en rotation dans le même sens et dans le même plan, **caractérisée en ce que** chaque plaque est court-circuitée à la terre le long de l'un de ses bords de sorte que le rayonnement multi-bande ne peut s'échapper qu'à partir d'une fente virtuelle prévue essentiellement le long du bord opposé des plaques correspondantes; **caractérisée en ce que** chaque plaque (11,12) comporte des

dents crantées (15) qui sont prévues le long d'un premier bord en face du bord court-circuité à la terre pour les besoins de la bande large et de l'accord.

2. Plaque à éléments rayonnants (2) selon la revendication 1, **caractérisée en ce que** les première et deuxième plaques (11,12) de chaque élément rayonnant sont séparées par un diélectrique (13).

3. Plaque à éléments rayonnants (2) selon la revendication 1 ou 2, **caractérisée en ce que** le diélectrique (13) est prévu sous une forme stratifiée.

4. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** l'angle prédéterminé de rotation de chaque élément par rapport à son élément voisin et de 90 degrés.

5. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** chaque plaque (11,12) est court-circuitée à la terre au moyen d'une pluralité de trous traversants plaqués qui sont prévus le long du bord de la plaque.

6. Plaque à éléments rayonnants (2) selon la revendication 5, **caractérisée en ce que** les courts-circuits dans chacune des plaques (11,12) qui comprend un élément rayonnant (10) sont alignés.

7. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** chaque élément rayonnant comporte par ailleurs une structure d'alimentation qui sert à le connecter, en cours d'usage, à un circuit imprimé qui comporte un réseau formant la polarisation.

8. Elément rayonnant (2) selon la revendication 7, **caractérisé en ce que** la structure d'alimentation comprend un cylindre essentiellement coaxial à travers lequel peut passer une broche d'alimentation, ou bien cette même structure comprend un ou plusieurs disques à travers lesquels peut passer une broche d'alimentation, ou bien cette même structure comprend un ou plusieurs montants prévus à la base de l'élément, ou bien cette même structure comprend une fente à la base de l'élément à travers laquelle se propage le rayonnement électromagnétique.

9. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** la première plaque (11) reçoit les signaux NAVSTAR GPS, et/ou la deuxième plaque (12) reçoit les signaux Galileo GPS.

10. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** la première bande de fréquences est L1 (1565-1585 MHz), L2 (1227 MHz), L3 (1381 MHz) ou L5 (1176 MHz).

11. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** la deuxième bande de fréquences est comprise entre 1166 et 1211 MHz (E5).

12. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, comportant par ailleurs un préamplificateur connecté au réseau formant la polarisation.

13. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, qui est scellée à l'intérieur d'un radôme (4).

14. Plaque à éléments rayonnants (2) selon la revendication 13, **caractérisée en ce que** le radôme (4) est rempli de mousse autour des éléments (10).

15. Plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes, **caractérisée en ce que** la réalisation de chaque élément rayonnant (10) comprend une couche supérieure dotée d'une plaque extérieure (11) et une couche inférieure dotée d'une plaque intérieure (12), les deux couches étant prévues séparément avant d'être assemblées, au moyen d'un produit conducteur approprié, pour former l'élément rayonnant.

16. Plaque à éléments rayonnants (2) selon la revendication 15, **caractérisée en ce qu'**une surface de métallisation factice est formée sur le dessous de la couche supérieure et puis elle est réunie à la surface supérieure de la couche inférieure pour assembler les deux couches.

17. Plaque à éléments rayonnants (2) selon la revendication 15 ou 16, **caractérisée en ce que** la couche supérieure

et la couche inférieure de chaque élément rayonnant sont assemblées au moyen d'un adhésif conducteur.

18. Radiateur comportant une plaque à éléments rayonnants (2) selon l'une quelconque des revendications précédentes.

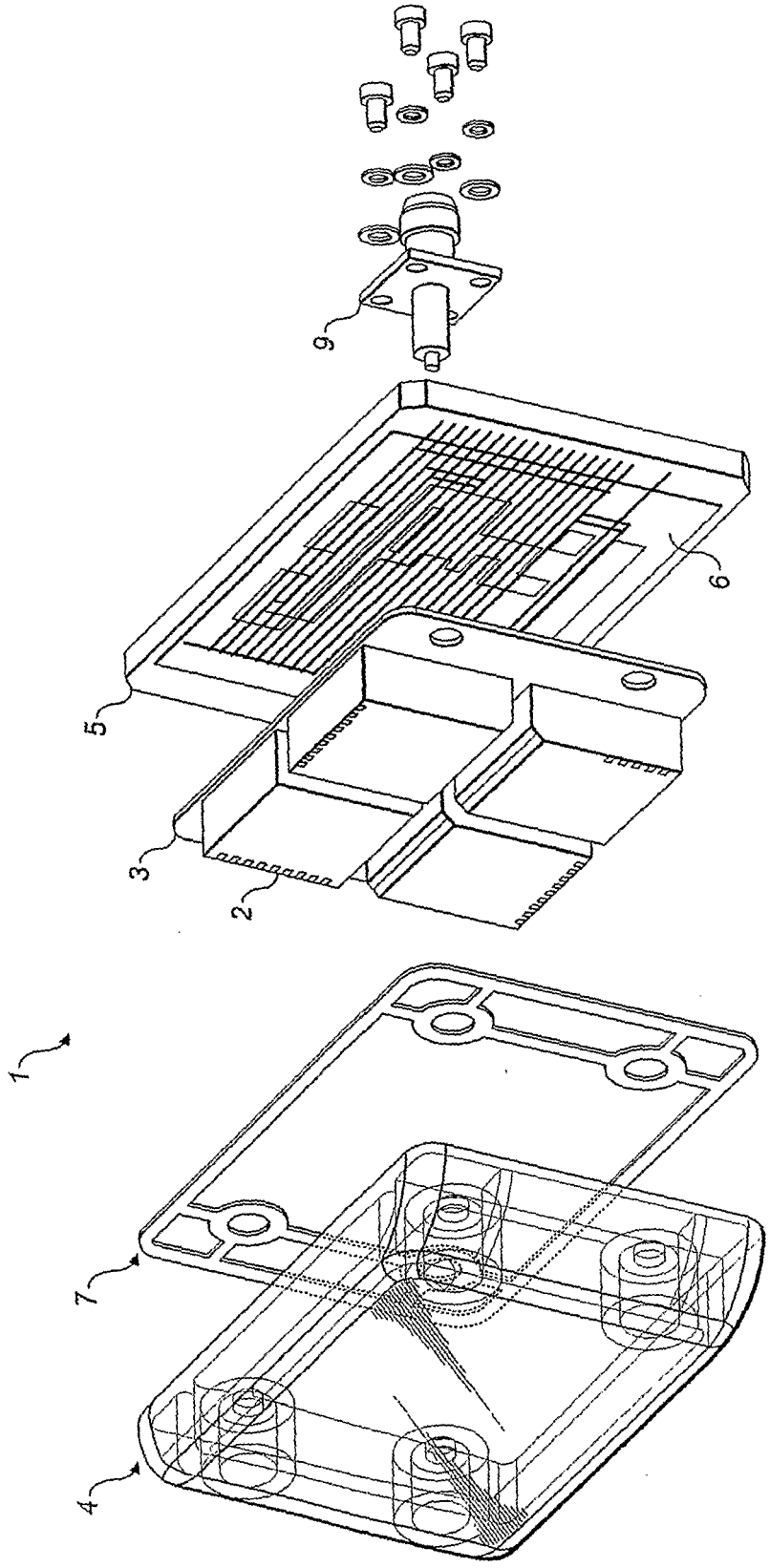


FIG. 1

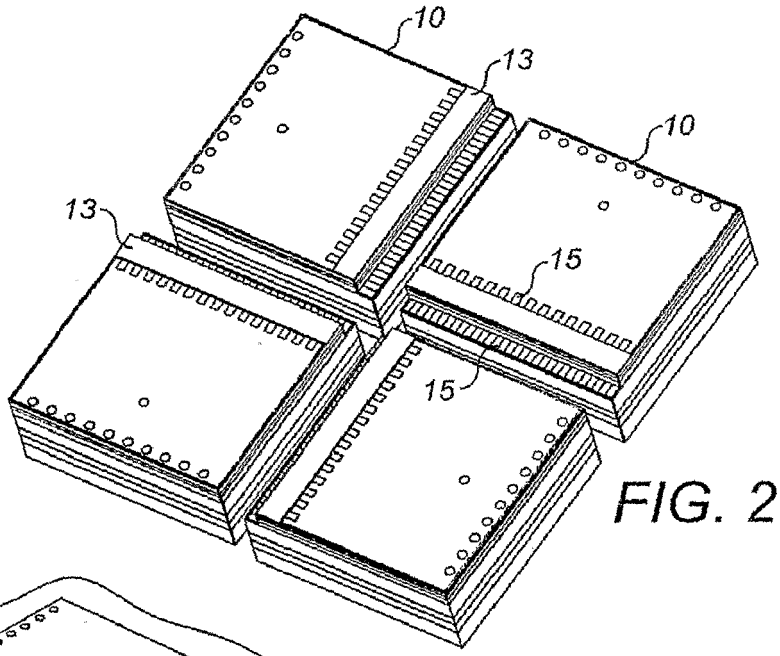


FIG. 2

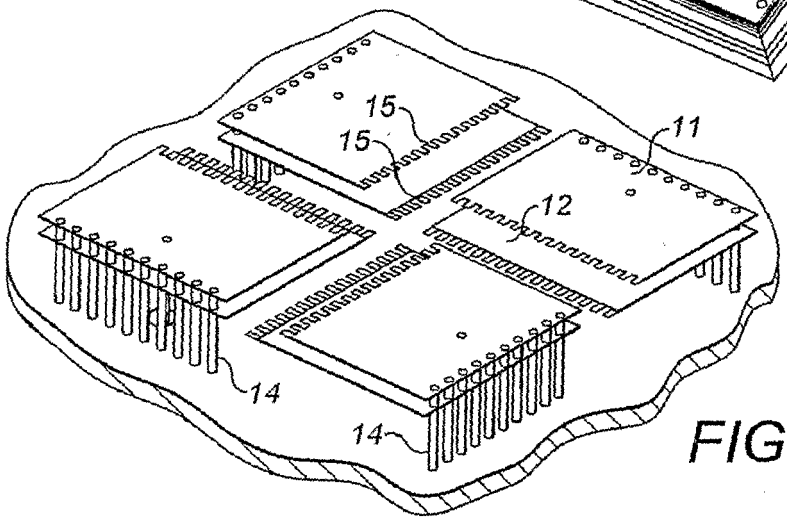


FIG. 3

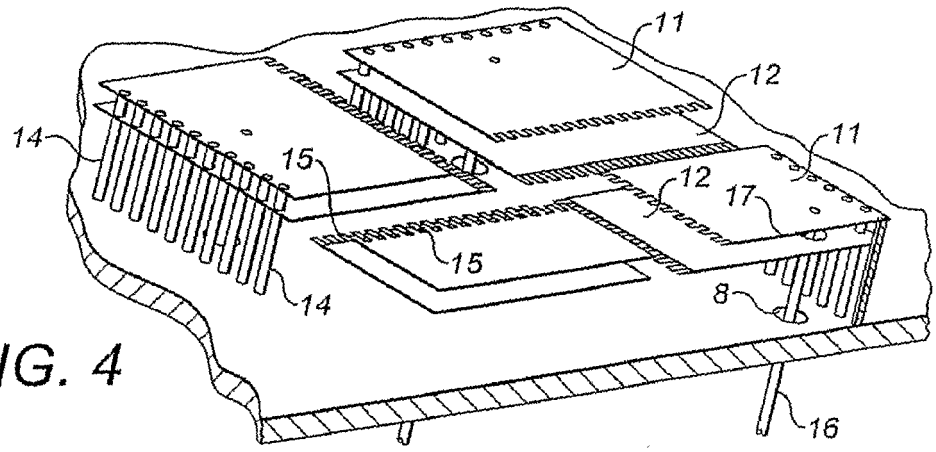


FIG. 4

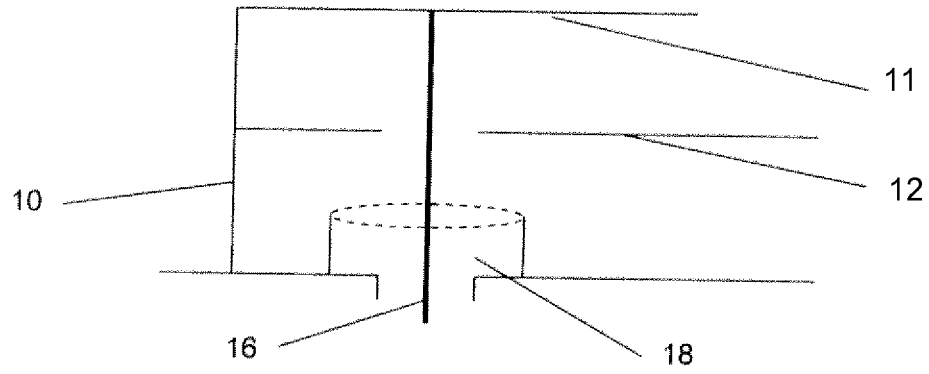


Figure 5(a)

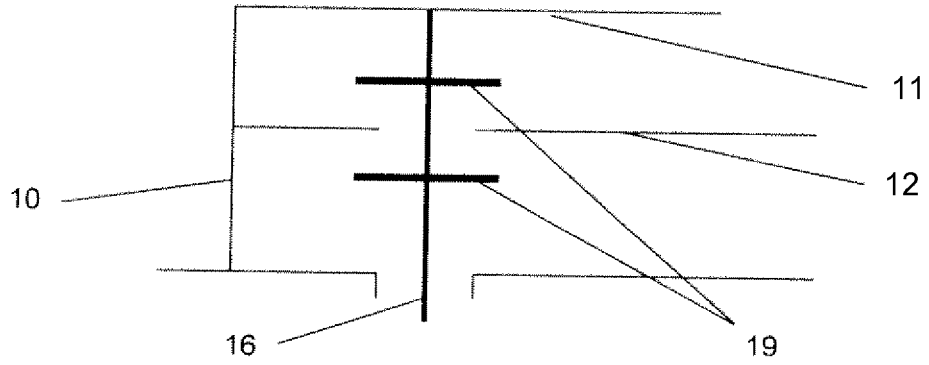
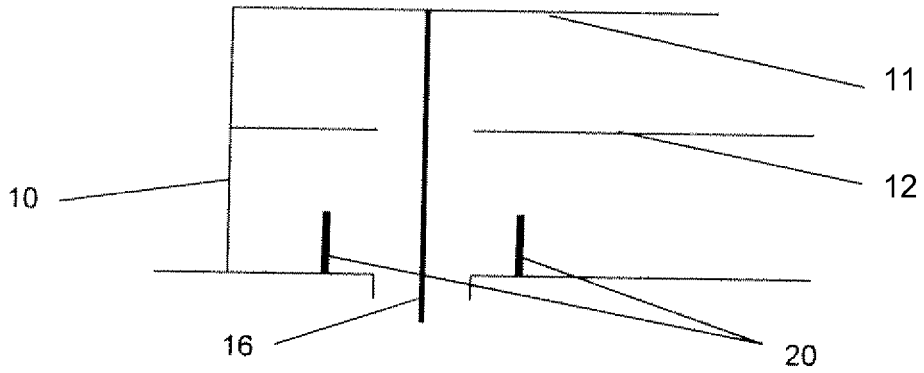


Figure 5(b)



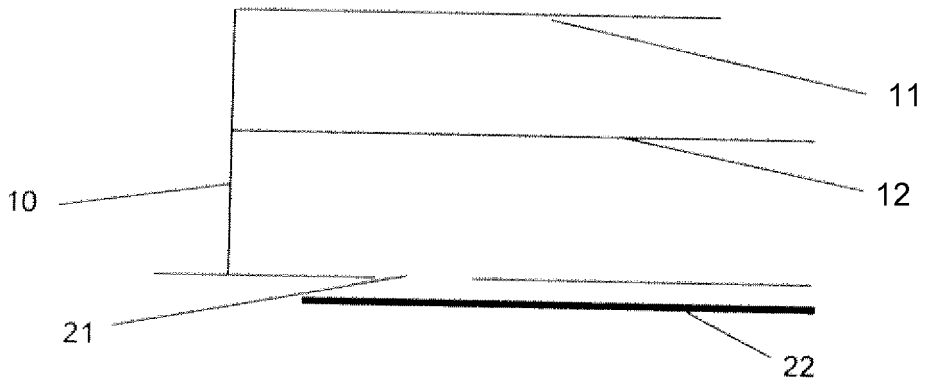


Figure 5(d)(i)

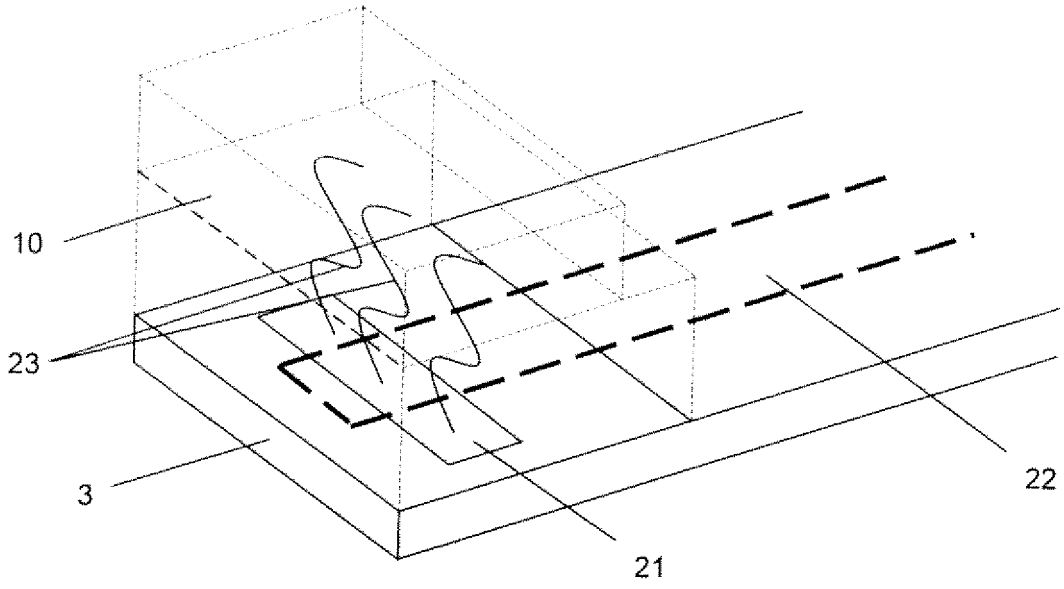


Figure 5(d)(ii)

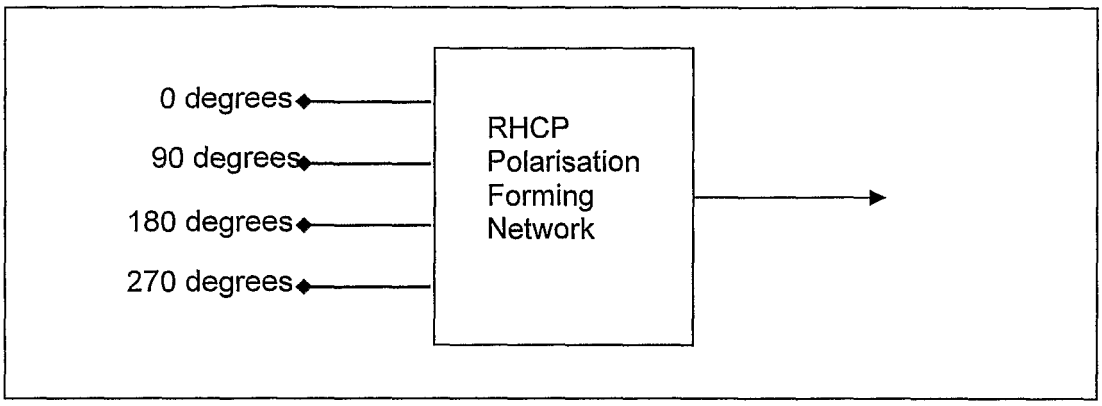


Figure 6

Elevation angle - absolute value	Minimum Gain (L1, L5 & E5 band)
< 75 deg	-2.0 dBic
80 deg	-3.0 dBic
85 deg	-4.5 dBic
90 deg	-7.5 dBic

Table 7(a)

Elevation angle – absolute value	Maximum Gain (L1, L5 & E5 band)
< 85 deg	5.0 dBic
90 deg	-2.0 dBic
Above 120 deg	-10.0 dBic

Table 7(b)

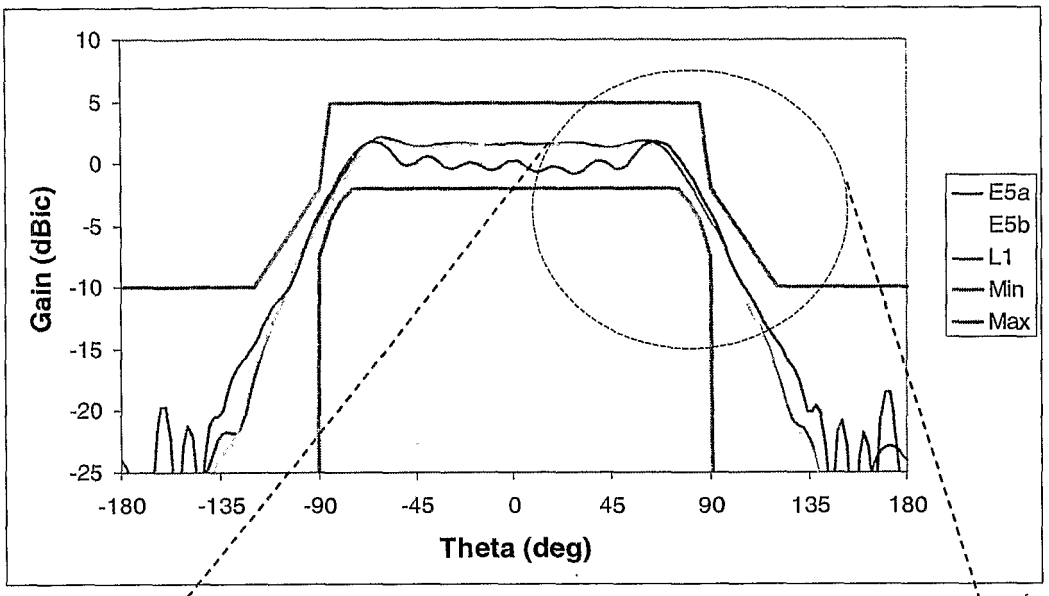


Figure 8(a)

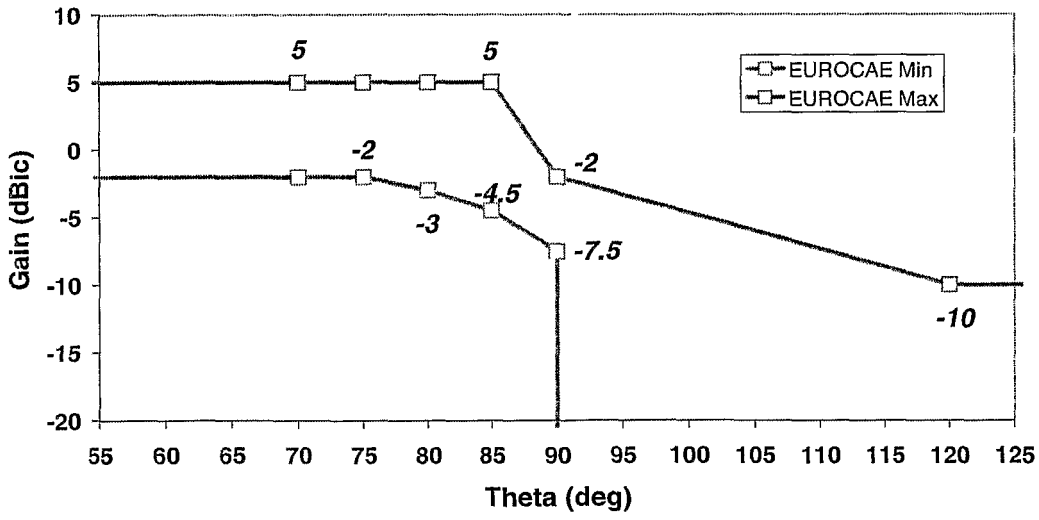


Figure 8(b)

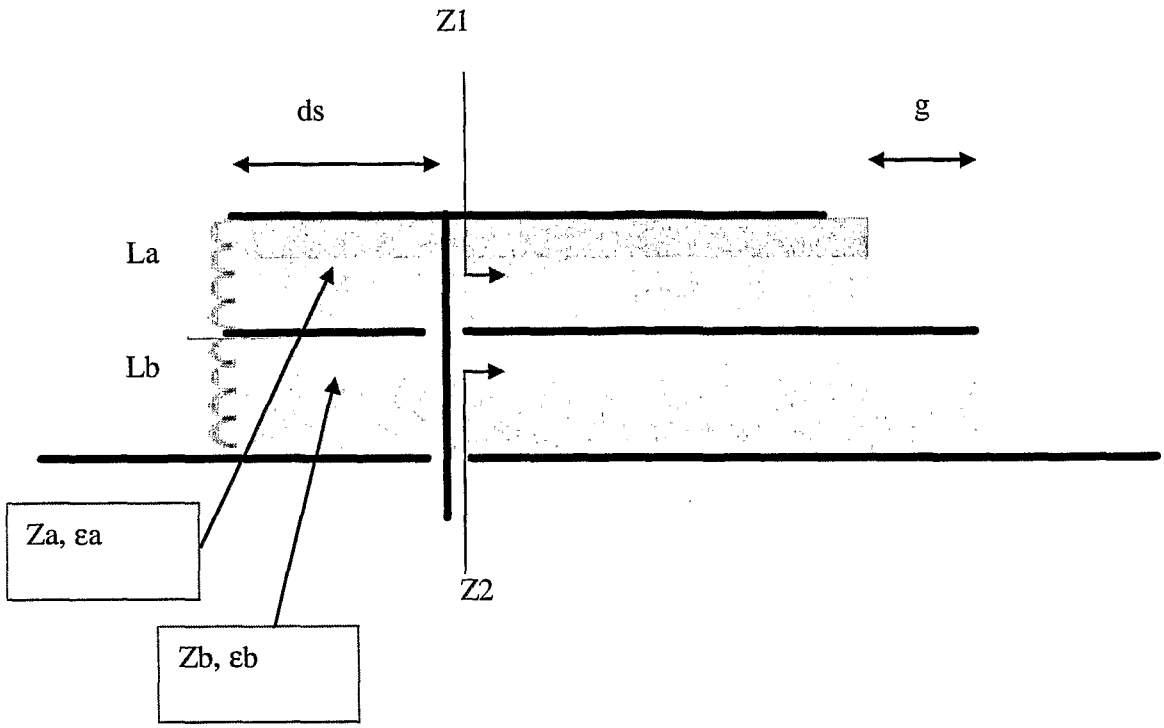


Figure 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 0270209 A **[0008]**
- US 5245745 A **[0008]**