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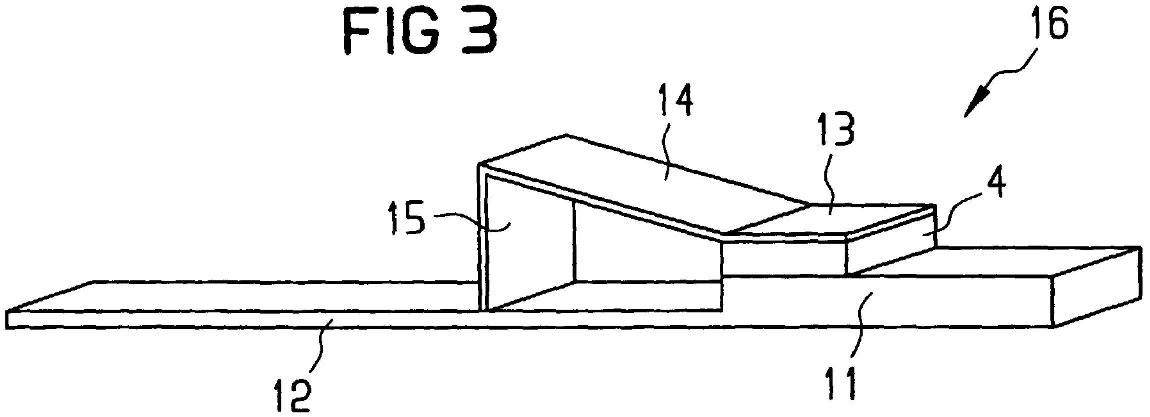
(54) Patch antenna

(57) The present invention relates to a patch antenna comprising a ground element (3; 11, 12) being electrically conductive, a resonator element (2; 8, 9; 13, 14) being electrically conductive, and a solid dielectric element (4) located between the resonator element and the ground element, whereby the ground element (3; 11, 12) and the resonator element (2; 8, 9; 13, 14) are electrically connected at a first end of the resonator element so that a closed end is formed and not electrically connected at a second end of said resonator element so that an open end is formed. The solid dielectric element (4) is only provided in the region of the open end and not in the region of the closed end of the antenna, so that a lightweight antenna producable at low cost is provided. The patch antenna according to the present invention is particularly useful as internal antenna for GSM mobile phones.

FIG 3



EP 1 014 486 A1

Description

[0001] The present invention relates to a patch antenna and particularly to a patch antenna for use inside the housing of a portable device, such as a mobile telephone.

[0002] Many applications require small, lightweight and efficient antennas. Traditionally patch antennas, such as microstrip patch antennas, have been a preferred type for many applications. However, microstrip patch antennas typically are efficient only in a narrow frequency band. Otherwise, the advantage of patch antennas is that they are mountable in a small space, have a high gain and can be constructed in a rugged form.

[0003] There have been a number of efforts in the past to provide an antenna inside a portable communication unit for signal reception and transmission. Such efforts have thought at least to reduce the need to have an external broad or bandwidth antenna because of the inconveniences of handling and carrying such a unit with the external antenna extended. This is particularly true for portable telephone units operating in relatively high frequency ranges, such as the GSM frequency range of 890 MHz to 960 MHz.

[0004] Patch antennas and microstrip patch antennas have been known in the art for applications in which thin and small antennas were required. These kinds of antennas comprise a conductive patch as a resonator element, which is generally parallel to and spaced from a conducting ground element by an insulator consisting of a dielectric material. US 5 777 581 discloses such a microstrip patch antenna, which is designed for use in the UHF band. US 4 980 697 discloses a microstrip type antenna comprising a stack of alternate conductive and dielectric layers, so that the antenna is designed for use in several frequency bands. WO95/24745 discloses an antenna unit for a handheld receiving/transmitting apparatus. The antenna unit comprises a resonator element, a ground element and a connector element, which are formed as conducting layers on a dielectric body. The connector element electrically connects the resonator element and the ground element at one end of the antenna unit, so that a closed end is formed. In the region of the other end of the antenna unit, the resonator element and the ground element are not connected, so that an open end is formed. The distance between the resonator element and the ground element increases from the open end to the closed end. The transmission and reception of radiation mainly takes place at the open end of the antenna unit. Since the entire space of the antenna unit inside the ground element and the resonator element is occupied by the solid dielectric material, this known antenna unit is quite heavy, so that the use of this known antenna unit in portable devices is very inconvenient. Further, the antenna unit is costly to produce, since the entire antenna volume is filled with dielectric material.

[0005] The object of the present invention is therefore to provide a patch antenna according to the preamble of claim 1, which is lightweight and which can be produced at low cost.

[0006] This object is achieved by a patch antenna comprising a ground element being electrically conductive, a resonator element being electrically conductive and a solid dielectrid element located between said resonator element and said ground element. The ground element and the resonator element are electrically connected at a first end of the resonator element so that a closed end is formed and not electrically connected at a second end of said resonator element so that an open end is formed. The patch antenna of the present invention is characterized in that the solid dielectric element is only provided in the region of the open end and not in the region of the closed end of the antenna. Thereby, the patch antenna according to the present invention can be produced at low cost, since not the entire volume between the ground element and the resonator element is filled with solid dielectric material. Further, the patch antenna according to the present invention can be produced having a light weight, since only the part of the antenna in the region of the open end is provided with solid dielectric material, whereas the part at the region of the closed end of the antenna can e. g. comprise air, so that the weight of the antenna is significantly reduced compared to known antennas.

[0007] Although in the state of the art most patch antenna types or microstrip patch antenna types are described as having a very large ground element compared to the resonator element, i. e. the patch, the patch antenna according to the present invention is advantageously of a design, in which the ground element has approximately only the double length of the resonator element, whereby the width of the resonator and the ground element is essentially the same. The ground element and the resonator element of the patch antenna are at least partially parallel to each other.

[0008] The use of the solid dielectric material in the region of the open end of the patch antenna has the further advantage, that the tolerances of the ground element and the resonator element in this very tolerance critical part of the antenna can be set accurately.

[0009] Advantageously, the distance between the resonator element and the ground element in the region of the open end is smaller than in the region of the closed end of the antenna. By this measure, the antenna length, which is defined as the direction extending from the closed end to the open end of the antenna, can be further decreased. This is particularly advantageous if the antenna has to be integrated in mobile devices, in which the valuable space is very refined. Further, increasing the distance between the resonator element and the ground element in the region of the closed end of the antenna as compared to the open end of the antenna increases the frequency bandwidth and the efficiency of the antenna according to the present invention significantly.

[0010] Particularly in comparison to the antenna disclosed in WO95/24745, the increased distance between the resonator element and the ground element in the region of the closed end of the antenna as compared to the open end of the antenna together with the fact, that no solid dielectric material is provided in the region of the closed end of the antenna, where the distance is increased, tremendously lowers the weight of the patch antenna according to the present invention.

[0011] Further advantageously, the ground element has a stepped shape with a first and a second step section, whereby the second step section corresponds to the region of the open end at which the solid dielectric material is provided. And said first step section corresponds to the region of the closed end and has a larger distance to the resonator element than said second step section. Also, said resonator element can have essentially stepped shape with a first and a second step section, whereby the second step section corresponds to the region of the open end at which the solid dielectric material is provided. And said first step section corresponds to the region of the closed end and has a larger distance to the ground element than said second step section. The stepped shapes of the ground element and the resonator element, respectively, provide a simple and at low cost producable design for the patch antenna according to the present invention. The second step sections respectively are located adjacent to the solid dielectric material and the first step sections provide the larger distance between the resonator element and the ground element in the region of the closed end of the antenna, where no solid dielectric material is provided, so that a very light structure is enabled.

[0012] Advantageously, the resonator element and the ground element are parallel in a region of the open end where the solid dielectric material is provided. In the region of the open end of the antenna, the tolerances of the ground element, the resonator element and the dielectric element are critical in view of the resonance frequency and the efficiency of the antenna. Therefore, it is an important feature, that in this region the resonator element and the ground element are essentially parallel to each other. In the region of the closed end, the ground element and the resonator element need not necessarily be parallel to each other, since the tolerances in the region of the closed end are not that critical. This is also the reason why no solid dielectric material needs to be provided in the region of the closed end of the antenna to support the resonator element and the ground element to thereby fix their dimensional relation and reduce their dimensional tolerances.

[0013] Advantageously, the solid dielectric element has a sheetlike shape with a first and a second main surface, which respectively comprise a printed metal layer. The metal layers respectively contact the resonator element and the ground element. In this way, the solid dielectric element can be produced as a printed circuit board, so that a mass production with low cost is possible. Further, by providing the metal layers on the first and second main surface of the dielectric material, the tolerances, e. g. the distance between the resonator element and the ground element can be set accurately, which is very important in the region of the open end of the antenna.

[0014] Further advantageously, the length of the resonator element is essentially half of the length of the ground element. The length direction is thereby the direction between the open end and the closed end of the antenna. Thereby, the length of the resonator element can e. g. correspond to a quarter wavelength of the resonance frequency of the antenna.

[0015] The patch antenna of the present invention is described in more detail in the following description relating to the drawings, in which

figure 1 shows schematically a first embodiment of the patch antenna according to the present invention

figure 2 shows schematically a second embodiment of the patch antenna according to the present invention, and

figure 3 shows schematically a third embodiment of the patch antenna according to the present invention.

[0016] The patch antennas shown in figure 1, 2 and 3 are designed to be used as internal antennas of a GSM mobile phone. However, the proposed antennas can also be used in other applications, in which lightweight, small and low cost antennas are required.

[0017] Generally, applications in portable devices require lightweight and small antennas. However, there are some fundamental limits on how small an antenna can be designed if a special bandwidth and efficiency is required. The so-called Q-value is the ratio between the resonance frequency and the frequency bandwidth of the antenna. The Q-value is a property of the antenna, which depends mainly on the antenna dimensions. Increasing the dimensions of an antenna lowers the Q-value significantly. Thus a good antenna with a large bandwidth is usually a physically large antenna. On the other hand, small antennas to be integrated in a portable device necessarily have a high Q-value and thus a small frequency bandwidth.

[0018] A bandwidth of an antenna with a given Q-value can be increased by proper matching, but only within some limits. The bandwidth that can be matched with a certain matching loss can e. g. be increased by increasing the number of reactive elements in the matching network of the antenna. However, even for an infinite number of reactive elements in the matching network, the bandwidth that can be matched with a certain matching loss is limited for a given Q-value. In reality, a matching section with zero loss does not exist. Therefore, it is usually not a good idea to put more than a single section into the matching network in the case of GSM antennas with high Q-values. An increase of this number of sections will normally give an insertion loss increase larger than the matching loss decrease.

[0019] One possibility to design an antenna for GSM mobile phones is thus to design the antenna to half of the necessary bandwidth and to use a range switching network to switch the antenna resonance frequency between the transmission and the reception band. The second possibility is to use a corresponding matching network to match the antenna to the entire GSM band.

[0020] One problem with an integrated antenna for a GSM mobile phone, as stated above, is that the antenna has got to be relatively small which results in a high Q-value and therefore a small bandwidth. Another even worse problem is that an integrated antenna inherently will be placed much closer to the ground plane than an antenna which is located on top of the phone. Therefore, the distance between the resonator plane and the ground plane for a handportable phone will typically be less than 1 cm for the GSM frequency band. Bending e. g. a monopol so that is in parallel to the ground plane in the distance of about 1 cm transforms it into a kind of microstriplike transmission line which is open in one end. In this case, the capacity to the ground plane is tremendously increased, so that the Q-value also is significantly increased.

[0021] The only way to cope with the ground plane vicinity problem is to use an antenna type which is actually intended to work close to a ground plane. A patch antenna is such an antenna type. Patch antenna theory usually assumes a ground plane with an infinite length compared to the length of the resonator plane. In the patch antenna of the present invention, however, the ground plane can have a length L in the range of the length of the resonator plane, e. g. the double length or the triple length. In the patch antennas shown in figure 1, 2 and 3, the ground plane has a length L, which is approximately the double of the length of the resonator element. Further, in the patch antenna according to the present invention, the width w of the ground plane and the resonator plane are generally the same.

[0022] A patch antenna is an antenna with a narrow frequency bandwidth. The frequency bandwidth can thereby be decreased to some extent by increasing the distance from the resonator plane to the ground plane. Making this distance too large, however, creates surface waves which limit the bandwidth since more energy will be stored.

[0023] One of the main items in view of patch antennas for portable phones is the frequency bandwidth. As stated above, the frequency bandwidth is mainly determined by the dimensions of the antenna. A variation in the dimensional tolerances of the patch antenna leads to tolerances of the resonance frequency of the antenna. If, e. g. the tolerance of the resonance frequency is ± 1 %, this means for GSM applications a resonance frequency tolerance of ± 1 % × 925 MHz = ± 9,25 MHz. 925 MHz is thereby the center frequency of the GSM frequency band of 890 MHz to 960 MHz. The ± 1 % tolerance of the resonance frequency thereby results in an increased bandwidth of (2 × 9,25) MHz + 70 MHz = 88,5 MHz. If the tolerance of the antenna resonance frequency can be lowered, the insertion loss will also be lowered for a given antenna Q-value. The frequency bandwidth of an antenna with a given Q-value can be increased by proper matching, as stated above, but only within some limits. The matching loss thereby increases with an increasing frequency bandwidth to be matched.

[0024] The patch antenna 1 shown in figure 1 is a first simple embodiment of an antenna according to the present invention. The antenna comprises a ground plane 3 of electrically conductive material, e. g. metal, and a resonator plane 2 of electrically conductive material, e. g. metal. The length L of the ground plane 3 has generally the double value of the length of the resonator plane 2. The resonator plane 2 is electrically connected at a first end by means of a connector 5 to the ground plane 3, so that a closed end is formed. The second end of the resonator plane 2 opposite to the first end is not connected to the ground plane 3 so that an open end is formed. A solid dielectric material is provided in the region of the open end between the resonator plane 2 and the ground plane 3.

[0025] The resonator plane 2 thus works essentially as a quarter wave resonator with 0 V at the closed end and a voltage maximum at the open end. This high voltage at the open end creates an E-field to the ground which propagates into space. Therefore the radiation mainly comes from the slot at the open end of the antenna 1.

[0026] The ground plane 3 and the resonator plane 2 have generally the same width w, whereby the width of the resonator plane 2 might be a little smaller than the width of the ground plane 3. The ground plane 3 and the resonator plane 2 are essentially parallel to each other and spaced by a uniform distance h. As stated above, the length of the resonator plane 2 corresponds to a quarter wavelength and the length L of the ground plane 3 is a little bit shorter than one half wavelength. The normal microstrip antenna theories states that the radiation resistance only depends on the width of the resonator plane. The wider the resonator plane is, the lower the radiation resistance is. According to the known theory, the radiation resistance does not really depend on the distance h between the ground plane and the resonator plane or the dielectric constant of the solid dielectric material 4 between the resonator plane 2 and the ground plane 3. As shown in figure 1, the solid dielectric material 4 is only provided in the region of the open end of the resonator plane 2 and not in the region of the closed end.

[0027] In normal microstrip antenna theory the resonator plane is considered to be a very wide microstrip line. This is not a reasonable assumption in the case of a patch antenna as shown in figure 1, where the resonator plane and the ground plane essentially have the same width. For a patch antenna as shown in figure 1, the radiation resistance does not really depend on a distance h between the resonator plane 2 and the ground plane 3. Further, the Q-value of a patch antenna 1 as shown in figure 1 depends on the distance h, whereby a large value for h gives a low value for Q. Thus, the distance h between the resonator plane 2 and the ground plane 3 should be as large as possible to achieve a low Q-value. Further, the Q-value depends on the relative dielectric constant of the solid dielectric material 4 in that a large relative dielectric constant gives a large Q-value. The Q-value of the patch antenna 1 shown in figure 1 further depends on the width of the resonator plane in that a larger width gives a lower Q-value. The efficiency of the patch antenna 1 shown in figure 1 can also be increased by increasing the distance h between the resonator plane 2 and the ground plane 3.

[0028] The patch antenna 1 is fed with a direct probe feeding by means of a coaxial line 6. As shown in figure 1, the feeding line is connected to a side edge of the resonator plane 2 in the region of the closed end of the antenna. The impedance level of the patch antenna 1 can be decreased by moving the feeding point closer towards the closed end. It is further important, that the ground of the coaxial feeding line 6, i. e. the outer line of the coaxial line 6 is connected to the ground plane 3 as close as possible to the feeding point at the side edge of the resonator plane 2. Another possibility is to feed the resonator plane 2 by electromagnetic coupling from a feeding line, whereby the impedance level of the antenna can be changed by changing the distance from the coupling feeding line to the resonator plane 2 and/or to the ground plane 3.

[0029] From the above observations, the physical dimensions of the patch antenna can be determined. The width of the resonator element 2 should be as large as possible and the distance a between the resonator plane 2 and the ground plane 3 should be as large as possible in order to gain as much frequency bandwidth and efficiency as possible. However, if the distance h becomes too large, surface waves will occur. The space available for the patch antenna according to the present invention in a mobile phone is usually very small, so that the distance h is already restricted in this respect and surface waves should not be an item. The length of the resonator plane corresponds to a quarter wavelength, so that the physical length of the resonator plane is approximately determined by the frequency and the dielectric material. The length of the resonator plane 2 can thereby be decreased by increasing the distance between the resonator plane 2 and the ground plane 3 in the region of the closed end compared to the open end of the antenna. This feature is realized in the patch antenna 7 shown in figure 2 and the patch antenna 16 shown in figure 3.

[0030] The tolerances of the physical dimensions of the patch antenna according to the present invention is a critical item mainly due to the low frequency bandwidth of the antenna. However, tolerances of the distance h between the resonator plane 2 and the ground plane 3 and of the width of the resonator plane 2 will not give any direct change in the resonance frequency of the patch antenna, but will change the impedance level of the antenna so that the matching network will be affected.

[0031] The solid dielectric material 4 provided between the resonator plane 2 and the ground plane 3 in the region of the open end of the antenna has mainly two functions, namely to reduce the size of the antenna due to the relative dielectric constant which is larger than 1 and to work as a spacer between the resonator plane 2 and the ground plane 3 to keep the tolerance of the distance h low. The relative dielectric constant of the solid dielectric material 4 should be in the range of 2 to 4. A too low constant makes the antenna too large and a too high constant makes the frequency bandwidth too narrow. Further, the dielectric constant should be very constant in view of temperature changes.

[0032] The position of the resonator plane 2 in relation to the ground plane 3 is another feature to be considered. As can be seen in figures 1, 2 and 3, the ground plane 3 or the ground element extends with a much longer distance from the closed end of the resonator plane 2 as from the open end. This is due to the fact that the Q-value depends strongly on the length of the ground plane 3 between the open end of the resonator plane 2 and the corresponding end of the ground plane 3. Further, the ground plane 3 has an optimum entire length with respect to the Q-value taking the dielectric material between the resonator plane 2 and the ground plane 3 into account, this optimum length is approximately one half wavelength.

[0033] All general statements above and below made in relation to the patch antenna 1 of figure 1 apply identically to the patch antennas 7 and 16 shown in figures 2 and 3, respectively, and vice versa.

[0034] Figure 2 shows a second embodiment of a patch antenna 7 according to the present invention, in which the distance between the resonator element and the ground plane 3 in the region of the closed end is larger than the distance between the resonator element and the ground plane 3 in the region of the open end of the antenna. A resonator element consists essentially of a first step section 8 in the region of the closed end and a second step section 9 in the region of the open end of the antenna. Both step sections 8 and 9 are essentially parallel to the ground plane 3, but the distance of the first step section 8 to the ground plane 3 is Larger than the distance of the second step section 9 to the ground plane 3. Between the second step section 9 and the ground plane 3, the solid dielectric material is provided, whereas no dielectric material is provided between the first step section 8 and the ground plane 3. The first step section 8 and the second step section 9 are connected by a connecting section 10 protecting upwardly from the end of the solid dielectric material 4. Due to the stepped design of the resonator element, the length of the resonator element can be made shorter compared to the resonator element formed as a resonator plane 2 of the embodiment shown in figure 1. The first step section 8 of the resonator element of the patch antenna 7 is connected to the ground plane by a connector 5 to form a closed end like in the first embodiment. The first step section 8, the second step section 9 and the connecting section 10 consist of electrically conductive material, e. g. metal.

[0035] Figure 3 shows a preferred embodiment of a patch antenna according to the present invention. The patch antenna 16 shown in figure 3 comprises a ground element consisting of a first step section 12 and a second step section 11. The resonator element consists of a first section 14 and a second section 13. The first section 14 is located over a part of the first step section 12 of the ground element and the second section 13 of the resonator element is located over and essentially parallel to a part of the second step section 11 of the ground element. Between the second section 13 of the resonator element and the corresponding part of the second step section 11 of the ground element, the solid dielectric material 4 is provided.

[0036] The end of the first section 14 of the resonator element on the opposite side of the second section 13 of the resonator element is electrically connected to the ground element by means of a connecting section 15 to form a closed end similar to the first two embodiments. The connecting section 15 extends upright from the first step section 12 of the ground element. The distance between the first section 14 of the resonator element and the first step section 12 of the ground element is larger than the distance between the second section 13 of the resonator element and the second step section 11 of the ground element. Thereby, the first section 14 of the resonator element is slant so that the distance between the first section 14 of the resonator element and the first step section 12 of the ground element increases towards the closed end. This proposed design allows to maximize the distance between the resonator element and the ground element and thereby to optimize the bandwidth of the patch antenna. The second step section 11 of the ground element can also serve as shield for circuitry located underneath. The first section 14 and the second section 13 of the resonator element as well as the connecting section 15 are electrically conductive and can e. g. be metal sheets. The solid dielectric material 4 is low cost, low loss material with a low relative dielectric constant, e. g. polystyrene or polyethylen.

[0037] The three embodiments of the patch antenna according to the present invention shown in figures 1, 2 and 3 provide a lightweight and low cost patch antenna particularly useful for applications as internal antenna in portable devices. The solid dielectric material 4 is only provided in the region of the open end of the resonator element, since this part is the main transmitting/receiving part of the antenna and therefore the tolerances in this part of the antenna are more critical than in the other parts. Further, by making the distance between the resonator element and the ground element in the region of the open part of the antenna considerably smaller than in the region of the closed end of the antenna, Less dielectric material is needed and the antenna becomes even cheaper to produce. The solid dielectric material 4 can in all three embodiments comprise printed metal layers on its first and second main surface. These metal layers are in contact with the corresponding parts of the resonator element and the ground element, so that the dimensional tolerances, namely the distance between the resonator element and the ground element in the region of the open part of the antenna can be accurately set. The patch antenna according to the present invention has a high efficiency and a very good radiation pattern and gain.

Claims

1. Patch antenna, comprising

   a ground element (3; 11, 12) being electrically conductive,
   a resonator element (2; 8, 9; 13, 14) being electrically conductive, and
   a solid dielectric element (4) located between said resonator element and said ground element, whereby said ground element (3; 11, 12) and said resonator element (2; 8,9; 13, 14) are electrically connected at a first end of the resonator element so that a closed end is formed and not electrically connected at a second end of said resonator element so that an open end is formed,
   characterized in,
   that said solid dielectric element (4) is only provided in the region of the open end and not in the region of the closed end of the antenna.

2. Patch antenna according to claim 1,
   characterized in,
   that the distance between said resonator element (2; 8, 9; 13, 14) and said ground element (3; 11, 12) in the region of said open end is smaller than in the region of said closed end.

3. Patch antenna according to claim 2,
   characterized in,
   that said ground element (3; 11, 12) has a stepped shape with a first and a second step section, whereby said second step section corresponds to

said region of the open end at which the solid dielectric material (4) is provided and said first step section corresponds to the region of the closed end and has a larger distance to the resonator element than said second step section.

4. Patch antenna according to claim 2 or 3, **characterized in,** that said resonator element (2; 8, 9; 13, 14) has essentially a stepped shape with a first and a second step section, whereby said second step section corresponds to said region of the open end at which the solid dielectric material (4) is provided and said first step section corresponds to the region of the closed end and has a larger distance to the ground element than said second step section.

5. Patch antenna according to one of the claims 1 to 4, **characterized in,** that said resonator element (2; 8, 9; 13, 14) and said ground element (3; 11, 12) are parallel in the region of the open end where the solid dielectric material (4) is provided.

6. Patch antenna according to one of the claims 1 to 5, **characterized in,** that said solid dielectric element (4) has a sheet-like shape with a first and a second main surface, which respectively comprise a printed metal layer, the metal layers contacting said resonator element (2; 8, 9; 13, 14) and said ground element (3; 11, 12), respectively.

7. Patch antenna according to one of the claims 1 to 6, **characterized in,** that the length of said resonator element (2; 8, 9; 13, 14) is generally half of the length of the ground element (3; 11, 12).

FIG 1

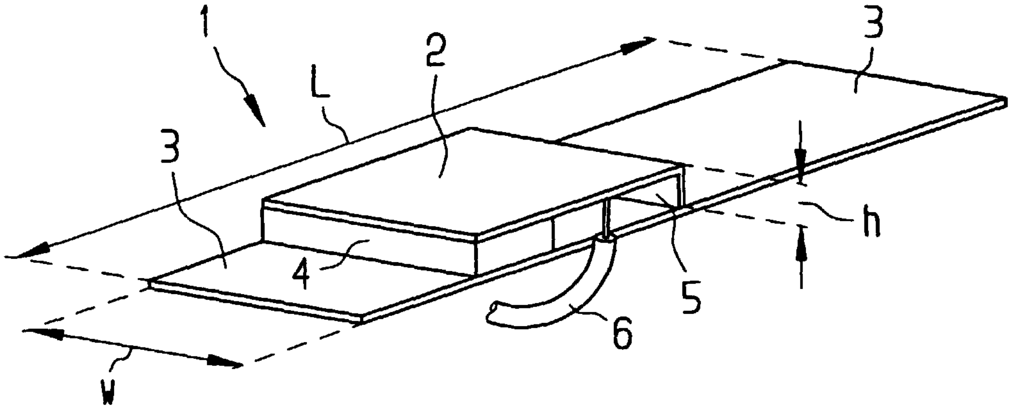


FIG 2

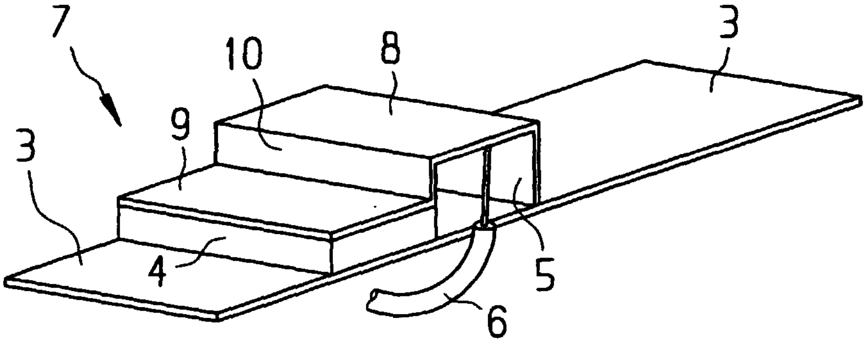
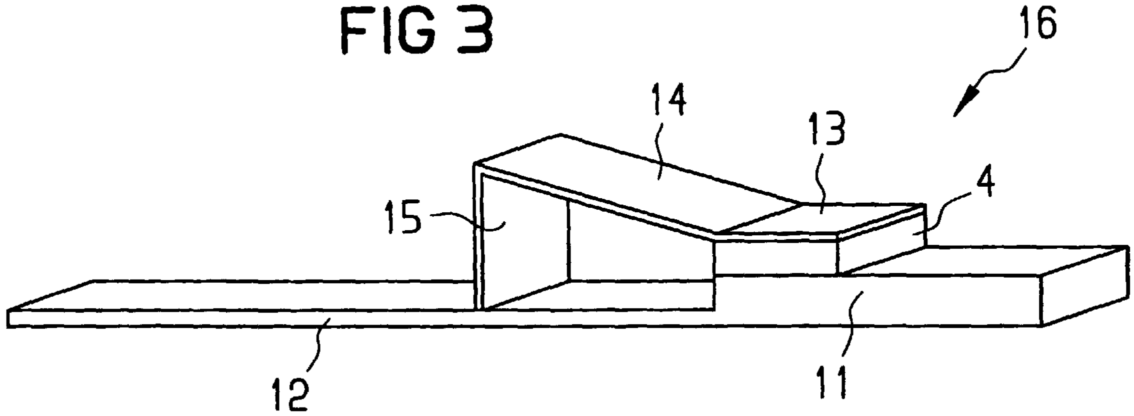


FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 98 12 4588

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 526 643 A (MITSUBISHI ELECTRIC CORP ;NIPPON TELEGRAPH & TELEPHONE (JP)) 10 February 1993 * column 5, line 20 - column 6, line 50 * ---	1,5	H01Q9/04 H01Q1/24
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	18 May 1999	Kahn, K-D

CATEGORY OF CITED DOCUMENTS

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