



(11) **EP 2 256 855 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.12.2010 Bulletin 2010/48

(51) Int Cl.:
H01P 7/06 (2006.01) H01P 7/10 (2006.01)

(21) Application number: **09360025.2**

(22) Date of filing: **11.05.2009**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL
PT RO SE SI SK TR**
Designated Extension States:
AL BA RS

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(54) **Resonant device**

(57) A resonant device and method are disclosed. The method comprises the steps of: providing a dielectric substrate having a first permittivity; applying a permittivity compensation material selected to have a second permittivity which is lower than the first permittivity to the dielectric substrate to compensate for a difference between the first permittivity and the predetermined permittivity; and forming a metal surface layer on the permittivity compensation material to space the dielectric substrate from the metal surface layer to provide the resonant device having the predetermined permittivity. The lower permittivity material is applied in order to control and compensate for variations in the higher permittivity dielectric material. Because the compensation material has a lower permittivity, its susceptibility to variation is reduced. Likewise, the degree of mechanical tolerance which needs to be exhibited on this layer is reduced. Hence, the inclusion of the permittivity compensation material enables the effective permittivity of the device to be adapted more easily to compensate for variations in the high permittivity dielectric substrate.

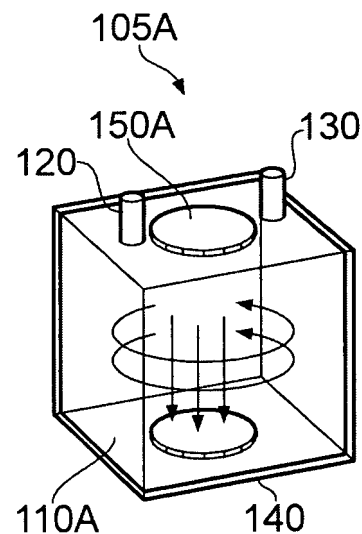


FIG. 3A

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a resonant device and method.

BACKGROUND

[0002] Resonator devices are known. In low-frequency electronics, a resonant circuit contains a capacitor and a coil. The capacitor is used to store electrical energy and the coil stores magnetic energy. At resonance, energy stored in the resonant circuit is continuously converted between two states, swapping between capacitor and coil over time. At higher frequencies, transmission lines can resonate. A half-wavelength transmission line with both ends open can be seen as a combination of a capacitor and coil, or as a travelling wave on the line, the wave being reflected at the ends of the line and bouncing back and forth to give a standing wave. Increasing the permittivity of the transmission line by using, for example, ceramic materials reduces the size of the resonator device. Ceramic resonator devices are often used in radio-frequency (RF) front ends. Such high-permittivity, low-dissipation ceramics are typically complex mixtures of various materials. Each resonator device has its own characteristics, including its own resonance frequency. The resonance frequency is dependent on the characteristics of the device and, in particular, on the characteristics of the mixtures of various materials making up the device.

[0003] It is desired to provide an improved resonant device.

SUMMARY

[0004] According to a first aspect, there is provided a method of constructing a resonant device having a predetermined permittivity, the method comprising the steps of: providing a dielectric substrate having a first permittivity; applying a permittivity compensation material selected to have a second permittivity which is lower than the first permittivity to the dielectric substrate to compensate for a difference between the first permittivity and the predetermined permittivity; and forming a metal surface layer on the permittivity compensation material to space the dielectric substrate from the metal surface layer to provide the resonant device having the predetermined permittivity.

[0005] The first aspect recognises that a problem with resonant devices is accurately controlling the resonant frequency. In a resonator, the resonance frequency varies with varying permittivity. The resonant device is typically a complex mixture of materials processed in complicated ways, under complicated conditions. As a result, there is often significant lot-to-lot variation in the properties of the resonant device, particularly in the permittivity

or dielectric constant of the device.

[0006] To compensate for the variation of permittivity, the physical size of the resonator device is often adapted to in order to tune the device to a particular resonant frequency. This is expensive, time-consuming and difficult to control because the dielectric is often difficult to machine accurately enough to control the permittivity to the required tolerance. Likewise, resonant devices may be sorted into increasingly narrowly tolerated ranges; however, this can lead to very low yields.

[0007] Accordingly, a method of constructing a resonant device is provided in which a dielectric substrate is determined to have a first permittivity. A lower permittivity material is applied which compensates for the variation or deviation of the higher permittivity dielectric substrate from an intended value or range. A metal surface layer is then applied to provide a resonant device having the desired permittivity.

[0008] Applying a lower permittivity material to the dielectric substrate, particularly at volume regions of high electric field strength, has a strong influence on resonant frequency. Therefore, rather than trying to adjust the resonance frequency of the device by attempting to more strictly control the reproducibility of the permittivity of the dielectric material or by trying to directly machine the dielectric material itself, a lower permittivity material can be applied in order to control and compensate for variations in the higher permittivity dielectric material. Because the compensation material has a lower permittivity, its susceptibility to variation is reduced. Likewise, the degree of mechanical tolerance which needs to be exhibited on this layer is reduced. Hence, the inclusion of the permittivity compensation material enables the effective permittivity of the device to be adapted more easily to compensate for variations in the high permittivity dielectric substrate and provides a device having a desired resonance frequency using a specific, averaged permittivity. Furthermore, forming a metal surface on the compensation material rather than on the dielectric substrate itself increases the metal conductivity.

[0009] In one embodiment, the step of applying comprises: applying the permittivity compensation material selected to have the second permittivity based on the difference between the first permittivity and the predetermined permittivity. Accordingly, the particular permittivity of the compensation material may be selected based on the measured permittivity of the dielectric substrate. This provides a compensation material having a permittivity which is based on the measured deviation of the desired permittivity in order to provide the required correction.

[0010] In one embodiment, the step of applying comprises: applying the permittivity compensation material selected to have a geometry based on the difference between the first permittivity and the predetermined permittivity. Accordingly, the particular geometry of the compensation material may also be selected to take account of the deviation from the desired permittivity. This provides a compensation material, having a particular ge-

ometry which is based on the measured deviation of the desired permittivity in order provide the required correction.

[0011] In one embodiment, the step of applying comprises: applying the permittivity compensation material selected to have the geometry based on an electrical field strength to be experienced by the resonant device. Accordingly, the geometry of the material may be varied to suit the size and distribution of the electrical field to be experienced by the resonator. Generally, the compensation material will be placed in areas where the electrical field is likely to be concentrated.

[0012] In one embodiment, the step of applying comprises: applying the permittivity compensation material selected to have the geometry obtained by removing portions of the permittivity compensation material. Hence, the permittivity compensation material may be applied to the surface of the dielectric substrate and portions of the compensation material removed to achieve the desired permittivity. For example, holes of suitable size and/or shape may be cut to vary the permittivity. This process of removal may be continuous (e.g. by laser cutting or sawing) or discrete (e.g. by removing several pre-formed sections of the material piece by piece).

[0013] In one embodiment, the step of applying comprises: applying the permittivity compensation material selected to have the geometry obtained by removing portions of the permittivity compensation material to vary a ratio of surface of the permittivity compensation material and surface of dielectric substrate exposed to the electrical field strength. By varying the ratio of surface of compensation material to surface of exposed dielectric substrate, the effective permittivity of the resonator may altered.

[0014] In one embodiment, the step of applying comprises: applying the permittivity compensation material provided as a planar net by folding the planar net to conform with an external shape of the dielectric substrate. Accordingly, the compensation material may be pre-formed as a blank or net which is foldable or shapable to cover the external surface of the dielectric substrate. In this way, the compensation material may readily be applied to the dielectric substrate.

[0015] In one embodiment, the dielectric substrate comprises a parallelepiped and the step of applying comprises: applying the permittivity compensation material provided as a six-faced planar net by folding the planar net to conform with the parallelepiped. Hence, the planar net or blank can be folded to conform with the outer surface of the cuboid dielectric substrate. It will be appreciated that such an arrangement will typically provide a triple mode cavity resonator.

[0016] In one embodiment, the step of forming the metal surface layer comprises: enclosing the permittivity compensation material within a metal housing having faces dimensioned to be substantially parallel to faces of the dielectric substrate. Accordingly, the composite structure of the dielectric substrate and the permittivity

compensation material may be further enclosed within a metal housing. By spacing the metal housing away from the dielectric substrate using the compensation material, the metal housing does not touch the dielectric substrate but rather is kept a predetermined distance away. Such an arrangement is advantageous because a significant part of dissipative losses occurring at resonance are conductive losses arising from currents flowing at the surface of the metal housing. When metalising the surface of the dielectric substrate directly, it is difficult and expensive to avoid losses due to surface roughness, lossy surface layers between the dielectric substrate and the overlying metal and due to non-perfect metal conductivity. Often, a glass-metal mixture is post fired on the as fired (i.e. rough) dielectric substrate, thereby at least doubling the conductive losses compared to a pure, smooth silver layer. Providing the compensation material ensures a gap exists and enables the use of a smooth silver conductor on the inside of the metal housing and any roughness of the underlying dielectric substrate is largely irrelevant because of the dielectric only contacts air and the compensation material. This leads to a reduction of conductive losses whilst avoiding expensive polishing and plating processes.

[0017] In one embodiment, the permittivity compensation material is compressible to accommodate variations in relative dimensions of the metal housing and dielectric substrate. By using a compressible (such as foamed, non-sintered, woven, or structured) material, any slight variations in the shape of the housing or dielectric substrate may be accommodated through the compression of the compensation material. Also, as the temperature of the device changes, the ceramic and metal housing with expand at different rates. Providing the compressible plastic spacer layer will accommodate for that expansion mismatch. Furthermore, as the gap between the metal housing and dielectric substrate varies with temperature (thereby varying the thickness of the compressible spacer layer), the resonant frequency of the device will change. Additionally, the permittivity of the dielectric substrate will change over temperature, leading to a resonant frequency change. The permittivity of the plastic spacer lay will change over temperature too, also leading to resonant frequency change. All three effects can be arranged to cancel each other (thereby keeping the resonant frequency essentially constant over temperature) if the temperature coefficient of permittivity of the high-permittivity material is chosen appropriately (for many microwave high-permittivity ceramics, it can be chosen in a certain range; also expansion of the metal housing can be chosen in a range (typically by keeping a thin silver plating at the surface)). Hence, by using a compressible compensation material, mechanical and electrical variations due to temperature effects on the device can be accommodated.

[0018] In one embodiment, the step of applying comprises: applying one of a plurality of predetermined different configuration structures as the permittivity com-

compensation material. Accordingly, a number of different preconfigured structures may be provided, the most suitable of which may then be applied to the dielectric substrate to achieve the desired permittivity. For example, a range of different geometries and a range of different materials may be provided which can then be selected to suit the particular resonator. In a typical arrangement, a number of different pre-manufactured nets may be provided to compensate for low, intermediate and high variations from the desired permittivity.

[0019] In one embodiment, the dielectric substrate comprises at least one chamfered region along an edge, the method comprising the step of: forming a coupling strip along the at least one edge to couple resonant modes. Accordingly, mode coupling between the modes of the resonator may readily be achieved. The coupling strip may be provided in proximity to the chamfered region. The coupling strip may be provided either with the compensation material or within the metal housing. Typically, the coupling strip will have a square cross section, but may be rounded.

[0020] In one embodiment, the coupling strip comprises an adjustment screw extendible towards the dielectric substrate, the method comprising the step of: adjusting the adjustment screw to vary a coupling coefficient between the resonant modes. By providing a screw located between the ends of the coupling strip, the coupling coefficient between modes may be varied as a function of screw depth. In embodiments, more than one coupling strip may be provided to increase the coupling coefficient. Typically, for a cuboid arrangement, the coupling strip will be provided on diametrically opposing edges in order to couple the same resonant modes.

[0021] In one embodiment, the method comprises the step of: forming an elongate slot in the metal housing and fixing a transmission line across the slot to provide a coupling. Hence, a transmission line (e.g. a micro strip, strip line, or co-axial cable) crosses a slot in the ground plane of the metal housing and is shorted afterwards. Large displacement currents are generated across the slot, realising the coupling to wall currents of the resonator modes. Given the symmetries of the structure, a centred narrow slot will couple to only one of the three resonating modes of the cavity. A wide and/or large slot eventually needed for stronger coupling, will also couple somewhat to the other modes. Coupling to a neighbouring cavity can also be realised by slot-type openings in the wall. External coupling to more than one mode can be advantageous and attenuation poles can be realised.

[0022] According to a second aspect, there is provided a resonant device having a predetermined permittivity, comprising: a dielectric substrate having a first permittivity; a permittivity compensation material having a second permittivity which is lower than the first permittivity to the dielectric substrate to compensate for a difference between the first permittivity and the predetermined permittivity; and a metal surface layer on the permittivity compensation material to space the dielectric substrate from

the metal surface layer to provide the resonant device having the predetermined permittivity.

[0023] In one embodiment, the permittivity compensation material has the second permittivity based on the difference between the first permittivity and the predetermined permittivity.

[0024] In one embodiment, the permittivity compensation material has a geometry based on the difference between the first permittivity and the predetermined permittivity.

[0025] In one embodiment, the permittivity compensation material has the geometry based on an electrical field strength to be experienced by the resonant device.

[0026] In one embodiment, the permittivity compensation material has removable portions to obtain the geometry.

[0027] In one embodiment, the permittivity compensation material has a ratio of surface of the permittivity compensation material and surface of dielectric substrate exposed to the electrical field strength.

[0028] In one embodiment, the permittivity compensation material comprises a planar net foldable to conform with an external shape of the dielectric substrate.

[0029] In one embodiment, the dielectric substrate comprises a parallelepiped and the permittivity compensation material comprises a six-faced planar net foldable to conform with the parallelepiped.

[0030] In one embodiment, the metal surface layer comprises a metal housing enclosing the permittivity compensation material and having faces dimensioned to be substantially parallel to faces of the dielectric substrate.

[0031] In one embodiment, the permittivity compensation material is compressible to accommodate variations in relative dimensions of the metal housing and dielectric substrate.

[0032] In one embodiment, the dielectric substrate comprises at least one chamfered region along an edge, the device comprising a coupling strip formed along the at least one edge to couple resonant modes.

[0033] In one embodiment, the coupling strip comprises an adjustment screw extendible towards the dielectric substrate to vary a coupling coefficient between the resonant modes.

[0034] In one embodiment, the dielectric substrate comprises an elongate slot in the metal housing and a transmission line fixed across the slot to provide a coupling.

[0035] Further particular and preferred aspects of the present invention are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] Embodiments of the present invention will now

be described further, with reference to the accompanying drawings, in which:

Figures 1A to 1C illustrate components of a resonant device according to embodiments;
 Figure 2 is a flow chart illustrating a method according to one embodiment;
 Figures 3A to 3C show three resonators according to embodiments;
 Figure 4 illustrates an example resonator device;
 Figures 5A and 5B show a net or blank applied to a dielectric substrate by wrapping according to one embodiment;
 Figures 6A to 6C show different predetermined nets of compensation material according to embodiments;
 Figures 7A to 7C show three resonators according to embodiments;
 Figures 8A to 8C illustrate arrangements of resonant mode coupling strips according to embodiments;
 Figures 9A to 9E illustrate arrangements of resonant mode coupling strips having tuning screws according to embodiments;
 Figure 10 illustrates an arrangement for providing a coupling to the resonator device according to one embodiment; and
 Figure 11 illustrates a triple-mode resonator according to one embodiment.

DESCRIPTION OF THE EMBODIMENTS

[0037] Figures 1A to 1C illustrate components of a resonant device according to embodiments. As shown in Figure 1A, a resonant device 5A is provided having a generally cylindrical shape. A dielectric material 10A is provided around which a metallic structure 20A is formed. An electromagnetic field (with the electric field vectors primarily pointing in the direction indicated by the arrows, and the electric field strength indicated by the density of the arrows) in the metallic structure 20A and the dielectric material 10A (such as air, a vacuum or other material) resonates at specific frequencies. Such resonance is known as a mode. Such a resonant device 5A may often be used in a radio frequency (RF) filter. As can be seen, the electric field indicated by arrows is arranged to be concentrated generally towards the central region of the resonant device 5A and reaches with equal strength to the upper and lower walls of the metallic structure 20. The physical size of the resonant device 5A can be reduced (for a given resonance frequency) by increasing the permittivity of the dielectric material 10 filling the resonator. This filling can be done completely or partially. For a homogeneously filled resonant device, the resonance frequency decreases as a square root of the relative permittivity of the device.

[0038] Figure 1B illustrates a different shaped, generally parallelepiped or cuboid, resonant device 5B also having a dielectric material 10B around which a metallic

structure 20B is formed.

[0039] Figure 1C illustrates a resonant device 5C inhomogeneously filled with high permittivity dielectric 15C. The effect of the reduction of the resonant frequency is strongest when the high permittivity dielectric 15C is placed in a region of high electric field strength. These and other dielectric substrate structures may be provided, as will be described in more detail below.

[0040] Figure 2 is a flow chart illustrating a method of constructing a resonant device having a predetermined permittivity according to one embodiment. At step S10, the dielectric material, such as that illustrated in Figures 1A to 1C is characterised. Such characterisation may occur through measurement of each dielectric substrate, through permittivity information provided with each dielectric substrate or based on dielectric range information provided for batches of dielectric substrates.

[0041] At step S20, an appropriate type and configuration of compensation material is selected and applied to the dielectric substrate; more detail on the type and configuration of the compensation material can be found below with reference to Figures 3 and 5 below. The application of such a compensation material enables the effective permittivity of the resultant resonant device to be adapted to compensate for variations in the higher permittivity dielectric substrate.

[0042] Once the compensation material has been applied then, at step S30, the structure is enclosed in a housing.

[0043] In this way, it can be seen that variations in the high dielectric material can readily be compensated for by applying a lower permittivity material. The electrical and mechanical temperature characteristics of the compensation material are selected to compensate for variations in the resonant frequency of the device caused by changes in the electrical and mechanical temperature characteristics of the dielectric material and a housing. As will be clear from the following description, it will be appreciated that such an approach provides a convenient and comparatively low-tolerance technique for correcting the permittivity and tuning the resonant frequency or frequencies of the resonant device.

[0044] Figures 3A to 3C show three resonators 105A to 105C formed of dielectric materials experiencing an example batch variation. Each of the resonators 105A to 105C are cavity resonators with a varying high permittivity dielectric material. In this example, the relative permittivity of the dielectric material 110A is 38, the relative permittivity of the dielectric 110B is 40 and the relative permittivity of the dielectric 110C is 42. In each, coaxial connectors 120, 130 are provided for coupling to external circuitry and an outer metal box 140 is provided.

[0045] Assuming a constant size of the metal box 140, a gap between the metal box 140 and the ceramic cube dielectric 110A to 110C of 0.5 mm and a ceramic cube dielectric 110A to 110C size of 20 x 20 x 20 mm, a variation of permittivity of between 38 and 42 would result in a variation of resonance frequency of approximately plus

or minus 2.5 % ($\pm(\sqrt{(42/40)-1})\times 100\%$). Accordingly, by selecting a polytetrafluoroethylene (PTFE) pad of compensation material 150A to 150C having a permittivity of 2.05, a relevant part of the air gap may be filled with a pad of suitable size and configuration to keep the overall resonance frequency constant.

[0046] In this case, applying, a pair of PTFE pads of diameter 9.8 mm to the resonator of Figure 3A achieves a resonance frequency of 2128MHz. Likewise, applying a pair of PTFE pads of diameter 6.6 mm to the resonator of figure 3B, also achieves a resonance frequency of 2128MHz. Likewise, applying a pair of PTFE pads of diameter 2.0 mm to the resonant device of Figure 3C, achieves a resonant frequency of 2128 MHz.

[0047] The adaptation of the compensation material can be achieved by mechanical structuring of the compensation material. In the arrangements shown in Figures 3A to 3C, pads or discs of varying diameter are provided. These discs may be preformed which differing diameters, may be applied as a single sheet to the surface of the dielectric substrate and the excess material not required removed by laser cutting or sawing, or predefined sections of the compensation material may be removed to achieve the desired surface area. In this way, the resonant frequency can be varied by varying the ratio of the compensation material 150A to 150C bridging the gap between the dielectric 110A to 110C and the metal wall of the housing 140, to the area where no compensation material bridges the gap between the dielectric 110A to 110C and the metal wall, weighted by the relative strength of the electric field in those regions. The compensation material 150A to 150C may be adhesively attached onto the dielectric substrate 110A to 110C, to the metal housing 140 or to both. Alternatively, as will now be described in more detail below, the compensation material may be wrapped around the dielectric substrate.

[0048] Figure 4 illustrates a resonator device 205 which exhibits several resonance modes with similar or closely nearby resonant frequencies. Such a device is useful because multi-resonator structures such as filters can use the same physical resonator device more than once, thereby providing a volume saving solution. In the example show in Figure 4, a perfect cube exhibits 3 orthogonal (in other words independent) resonant modes at the same frequency. By slightly deviating from the cubic shape, resonant modes at different frequencies can be achieved. As will be explained in more detail with reference to Figures 8 and 9 below, if coupling discontinuities are added to couple between the three modes, a triple resonance filter with the form factor of a single resonant device is provided. A compensation material can be wrapped around the cube structure (or indeed any structure) to provide for permittivity compensation to such devices as will now be discussed.

[0049] As shown in Figures 5A and 5B, a six faced net or blank 250A is applied to the dielectric substrate 210 by wrapping. The metal housing 240 is then received over the compensation material 250A which helps to

keep the metal housing or enclosure 240 a predetermined constant distance from the dielectric substrate 210.

[0050] Such an approach helps to avoid dissipative losses occurring at resonance from currents flowing at the surface of the surrounding metal housing or box 240. Such losses are a problem for existing structures in which the surface of the dielectric material is metalised directly. This is due to surface roughness, glassy surface layers between the dielectric and metal and non-perfect metal conductivity. Often, a glass-metal mixture will be post fired on the as fired dielectric surface, thereby at least doubling the conductor losses compared to assuming pure, smooth silver conductivity. However, the use of the compensation material 250A provides a gap which enables the use of a smooth silver conductor on the inside of the metal housing or box 240. The surface roughness of the dielectric substrate 210 then becomes largely irrelevant because the dielectric only contacts air and the compensation material 250A. This leads to a reduction in conductor losses to a minimum without requiring the use of expensive and time-consuming polishing and plating processes. To accommodate slight imperfections in the dielectric substrate and/or the metal housing 240, the compensation material 250A will typically be a compressible foam.

[0051] As shown in Figures 6A to 6C, different predetermined blank nets of compensation material 250A to 250C are provided, which may be used to compensate for different ranges of relative permittivity exhibited by different dielectric substrates 210. For example, the compensation material shown in Figure 6A is useful to provide a correction for a low permittivity dielectric substrate, the compensation material of Figure 6B for an intermediate permittivity dielectric substrate, and Figure 6C as a correction for a high permittivity dielectric substrate.

[0052] As shown in more detail in 7A to 7C, a constant size outer metal box 340 is provided, the gap between the metal box 340 and a ceramic cube dielectric 310A to 310C is 0.8 mm, the ceramic cube dielectric 310A to 310C has a size of 21 x 21 x 21 mm and a variation of permittivity of between 33 and 35 occurs in the dielectric 310A to 310C.

[0053] By selecting a net formed of High Density Polyethylene (HDPE) compensation material 350A to 350C, a relevant part of the air gap may be filled with a structure of suitable size and configuration to keep the overall resonance frequency constant.

[0054] In this case, for the dielectric 310A having a relative permittivity of 33, applying net covering 41 % of the surface area of the dielectric 310A provides a resonance frequency of 2165MHz and a Q-factor of 6240. Likewise, for the dielectric 310B having a relative permittivity of 34, applying net covering 36% of the surface area of the dielectric 310B provides a resonance frequency of 2165MHz and a Q-factor of 6530. Likewise, for the dielectric 310C having a relative permittivity of 35, applying net covering 32% of the surface area of the dielectric

310C provides a resonance frequency of 2165MHz and a Q-factor of 6870. It will be appreciated that the Q-factor, which is dimensionless parameter that compares the time constant for decay of an oscillating amplitude to its oscillation period for the device, will depend on losses within the structure and are dependent on, for example, conductivity of the metal box 340 and loss tangents of the ceramic cube dielectric and the compensation material. As can be seen, the Q factor increases only slightly as the coverage of the surface area of the dielectric by the compensation material increases.

[0055] Of course, although the arrangements illustrated above are preformed, a similar result may be achieved by applying a compensation material across the whole of the surface of the resonator device and then removing portions either by cutting or by removing preformed pieces of the compensation material to achieve the required permittivity and resonant frequency. Also, although the arrangements shown in Figures 5 to 7 illustrate an identical configuration compensation material applied to every face, it will be appreciated that differing configuration compensation materials may be applied to different faces in order to account for variations in the resonant frequency of the different modes caused by a different permittivity experienced in the directions indicated by the arrows of Figure 4.

[0056] Figures 8A to 8D illustrate arrangements of resonant mode coupling strips according to embodiments. As seen in Figures 8A to 8D, edges 460 of the dielectric substrate 410 have been chamfered. A metallic coupling strip 470 is attached to the compensation material 450 in the vicinity of one of the chamfered edges 460. The presence of the coupling strip 470 provides coupling between two resonant modes of the resonant device. The two respective couplings to the third resonant mode of the device are not affected by the coupling strip 470 because of the symmetry of the structure. Locating coupling strips similar to the coupling strip 470 at other edges of the resonator will realise couplings between other pairs of resonant modes.

[0057] As shown in Figure 8C, further coupling strips 470 may be placed at a diametrically opposing position in order to provide for increased coupling between the two modes.

[0058] Figure 8D provides an enlarged view of the location of the coupling strip 470. It will be appreciated that the coupling strip 470 may be affixed to either the compensation material 450, the metal housing 440, or both.

[0059] Figures 9A to 9E show a mechanism for varying the coupling ratio between the two modes. A metallic screw device 550 is provided between the ends of the coupling strip 540. As is clearest from Figures 9C and 9E, twisting the screw 550 varies its depth and changes the amount of gap between the screw 550 and the dielectric substrate 510. Decreasing the amount of gap between the screw 550 and the dielectric substrate 510 increases the degree of coupling between the two modes. In this way, it can be seen that the amount of

coupling between the modes can be readily varied.

[0060] Figure 10 illustrates an arrangement for providing a coupling between an external device (which can be a transmission line) and the resonator device 605. A transmission line 690 (such as a micro strip, strip line or coax cable) is provided to cross transversely a slot 680 provided in the metal housing 640 and is shorted afterwards. Large displacement currents are generated across the slot 680, realising the coupling to wall currents of the resonator modes. Due to the symmetry of the structure, a centred, narrow slot will principally couple one of the resonating modes. A wide and/or larger slot (which may be needed for stronger coupling) will also couple increasingly to the other modes. It will be appreciated that external coupling to more than one mode may be advantageous as attenuation poles can be realised. Furthermore, it is possible to couple to a neighbouring cavity by utilising such slot type openings.

[0061] In the arrangement shown in Figure 10, the shorted transmission line couples through a slot to the depicted mode in the direction of the field indicated by the arrow.

[0062] As shown in Figure 11, an arrangement is provided where an input signal is provided through a coupling slot 780A. The input signal is coupled to a first resonant mode, the first resonant mode couples to a second resonant mode, the second resonant mode couples to a third resonant mode which finally couples via a coupling slot 780B to an output transmission line (not shown).

[0063] Hence, it can be seen that applying a lower permittivity material layer to the dielectric substrate has a strong influence on resonant frequency. By applying a lower permittivity material layer, variations in the higher permittivity dielectric material can be controlled and compensated for. Because the compensation material layer has a lower permittivity, its susceptibility to variation is reduced and the degree of mechanical tolerance which needs to be exhibited on this layer is reduced. Hence, the inclusion of the permittivity compensation material enables the effective permittivity of the device to be adapted more easily to compensate for variations in the high permittivity dielectric substrate.

[0064] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. A method of constructing a resonant device having a predetermined permittivity, said method comprising the steps of:

providing a dielectric substrate having a first permittivity;
 applying a permittivity compensation material selected to have a second permittivity which is lower than said first permittivity to said dielectric substrate to compensate for a difference between said first permittivity and said predetermined permittivity; and
 forming a metal surface layer on said permittivity compensation material to space said dielectric substrate from said metal surface layer to provide said resonant device having said predetermined permittivity.

2. The method of claim 1, wherein said step of applying comprises:

applying said permittivity compensation material selected to have said second permittivity based on said difference between said first permittivity and said predetermined permittivity.

3. The method of claim 1 or 2, wherein said step of applying comprises:

applying said permittivity compensation material selected to have a geometry based on said difference between said first permittivity and said predetermined permittivity.

4. The method of any preceding claim, wherein said step of applying comprises:

applying said permittivity compensation material selected to have said geometry based on an electrical field strength to be experienced by said resonant device.

5. The method of any preceding claim, wherein said step of applying comprises:

applying said permittivity compensation material selected to have said geometry obtained by removing portions of said permittivity compensation material.

6. The method of any preceding claim, wherein said step of applying comprises:

applying said permittivity compensation material selected to have said geometry obtained by removing portions of said permittivity compen-

sation material to vary a ratio of surface of said permittivity compensation material and surface of dielectric substrate exposed to said electrical field strength.

7. The method of any preceding claim, wherein said step of applying comprises:

applying said permittivity compensation material provided as a planar net by folding said planar net to conform with an external shape of said dielectric substrate.

8. The method of any preceding claim, wherein said dielectric substrate comprises a parallelepiped and said step of applying comprises:

applying said permittivity compensation material provided as a six-faced planar net by folding said planar net to conform with said parallelepiped.

9. The method of any preceding claim, wherein said step of forming said metal surface layer comprises:

enclosing said permittivity compensation material within a metal housing having faces dimensioned to be substantially parallel to faces of said dielectric substrate.

10. The method of claim 9, wherein said permittivity compensation material is compressible to accommodate variations in relative dimensions of said metal housing and dielectric substrate.

11. The method of any preceding claim, wherein said step of applying comprises:

applying one of a plurality of predetermined different configuration structures as said permittivity compensation material.

12. The method of any preceding claim, wherein said dielectric substrate comprises at least one chamfered region along an edge, said method comprising the step of:

forming a coupling strip along said at least one edge to couple resonant modes.

13. The method of claim 12, wherein said coupling strip comprises an adjustment screw extendible towards said dielectric substrate, said method comprising the step of:

adjusting said adjustment screw to vary a coupling coefficient between said resonant modes.

14. The method of any preceding claim, comprising the step of:

forming an elongate slot in said metal housing
and fixing a transmission line across said slot to
provide a coupling. 5

15. A resonant device having a predetermined permittivity, comprising:

a dielectric substrate having a first permittivity;
a permittivity compensation material having a
second permittivity which is lower than said first
permittivity to said dielectric substrate to com-
pensate for a difference between said first per-
mittivity and said predetermined permittivity; 10
and
a metal surface layer on said permittivity com-
pensation material to space said dielectric sub-
strate from said metal surface layer to provide 15
said resonant device having said predetermined
permittivity. 20

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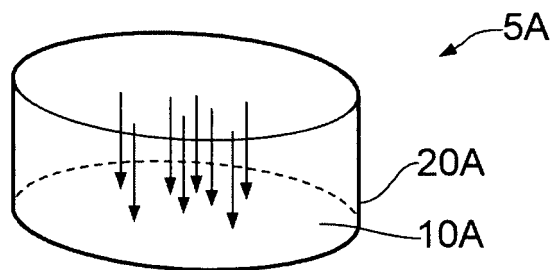


FIG. 1A

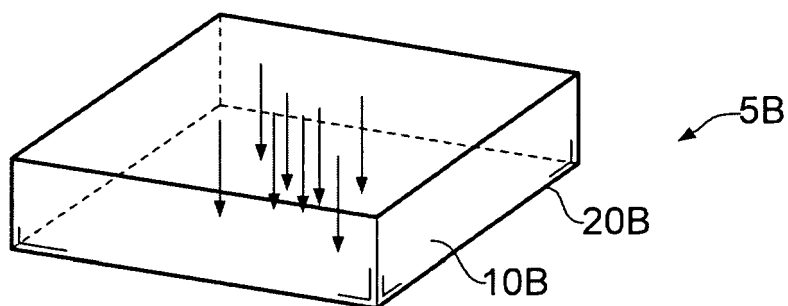


FIG. 1B

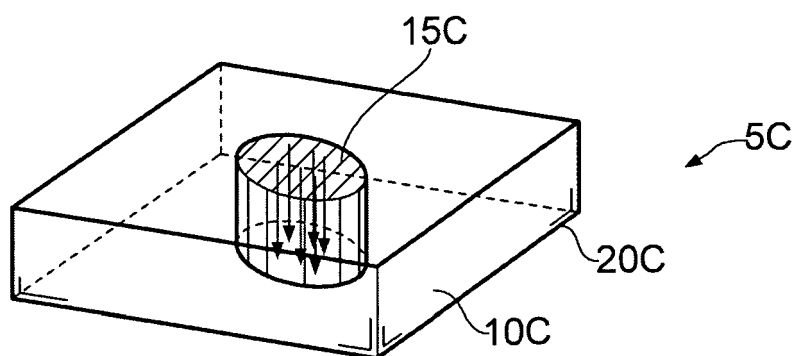


FIG. 1C

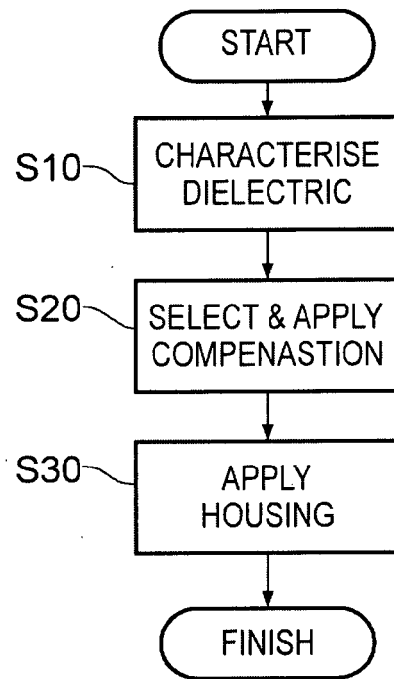


FIG. 2

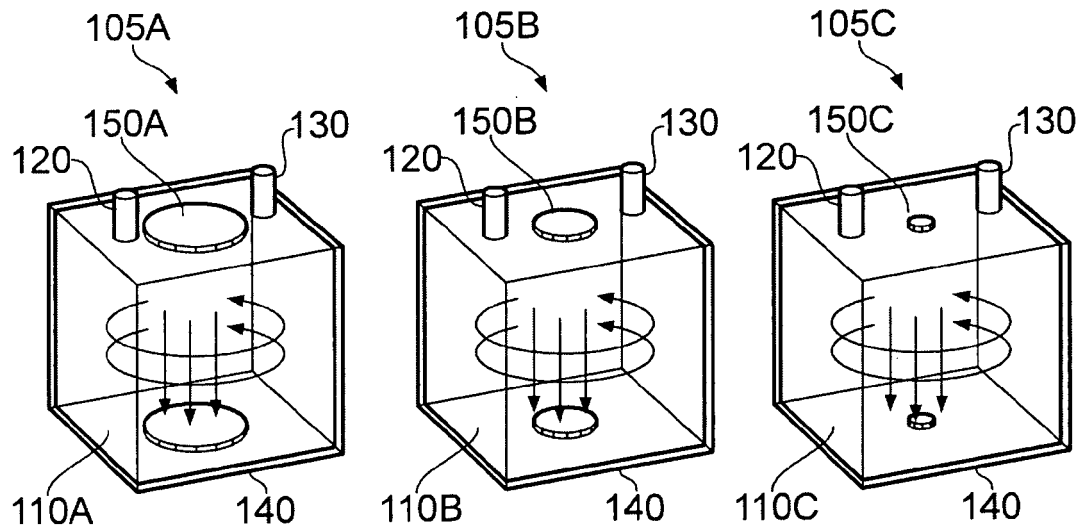
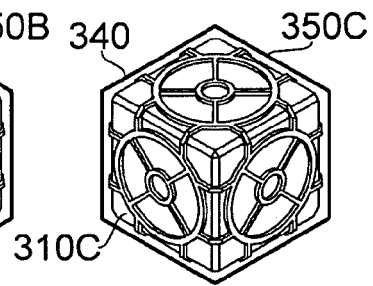
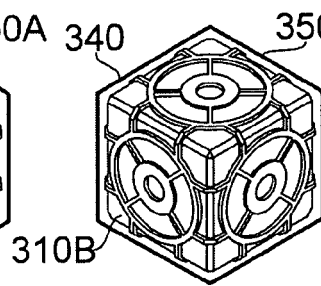
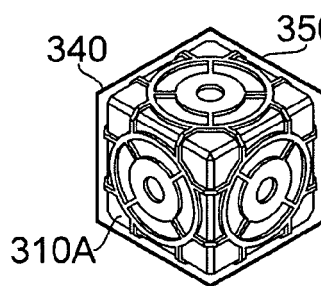
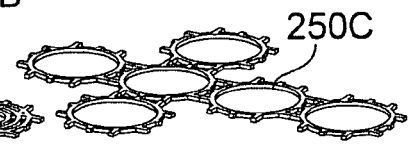
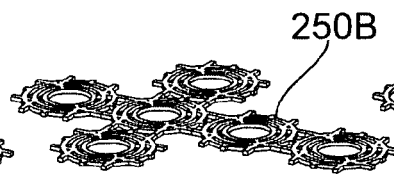
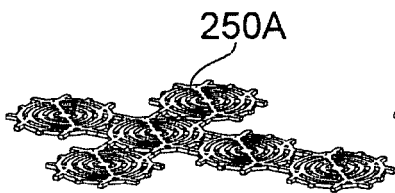
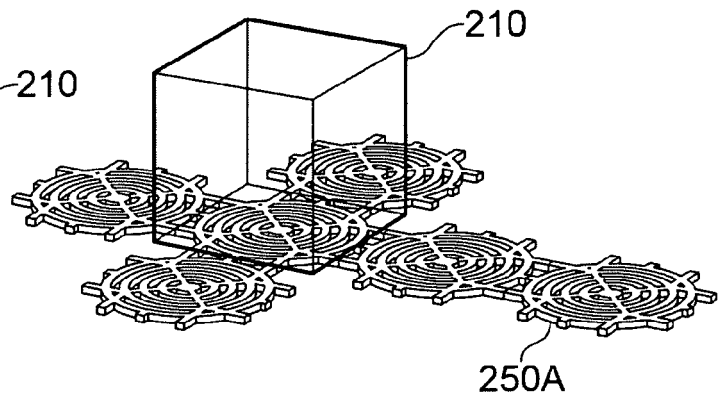
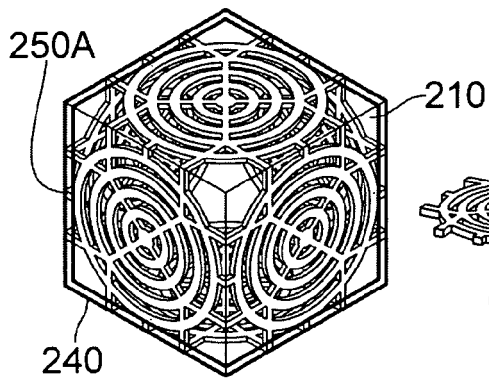
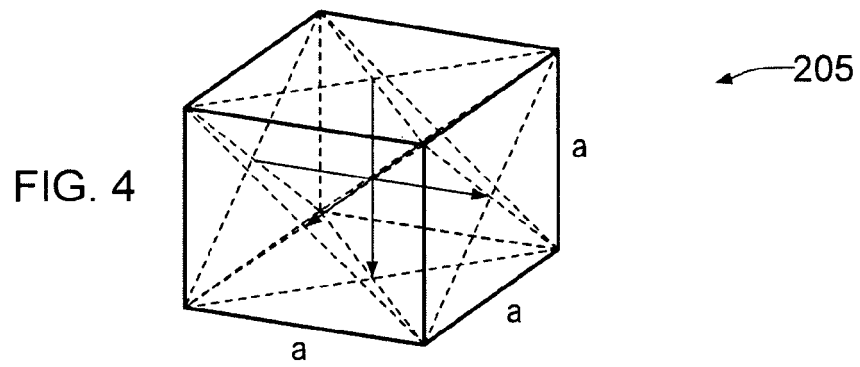


FIG. 3A

FIG. 3B

FIG. 3C



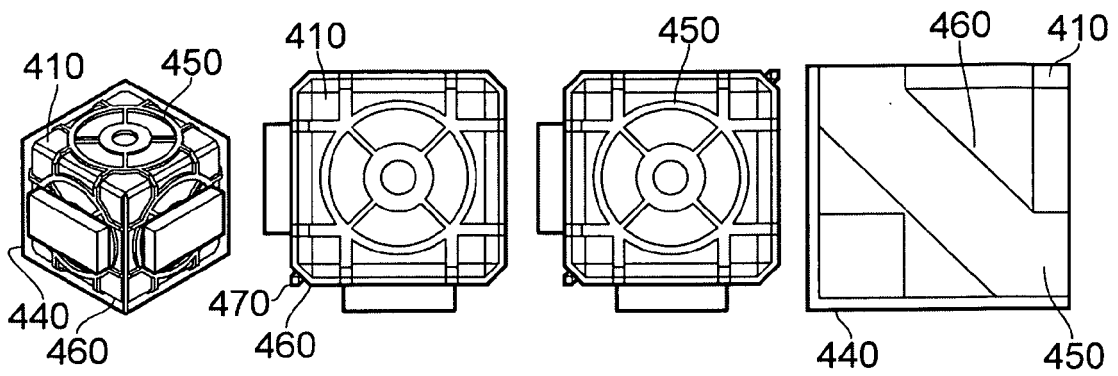


FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

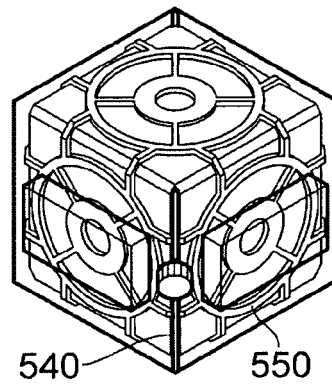


FIG. 9A

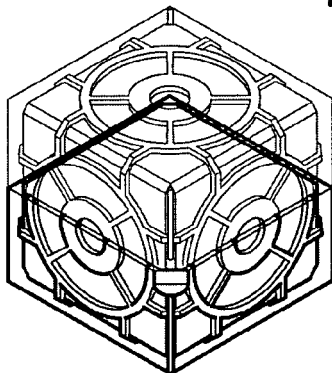


FIG. 9B

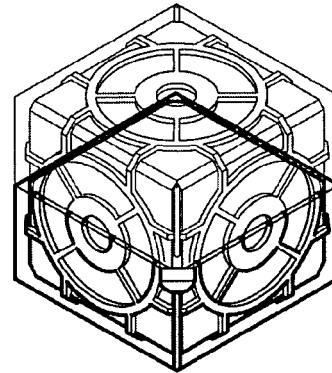


FIG. 9D

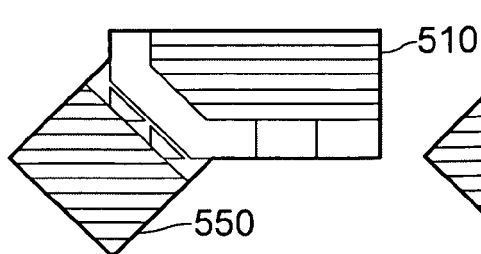


FIG. 9C

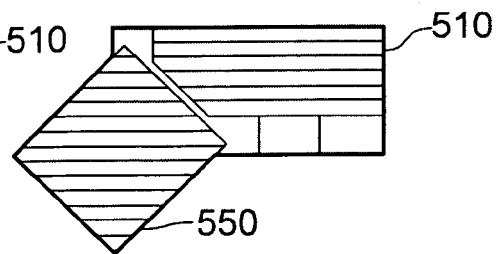


FIG. 9E

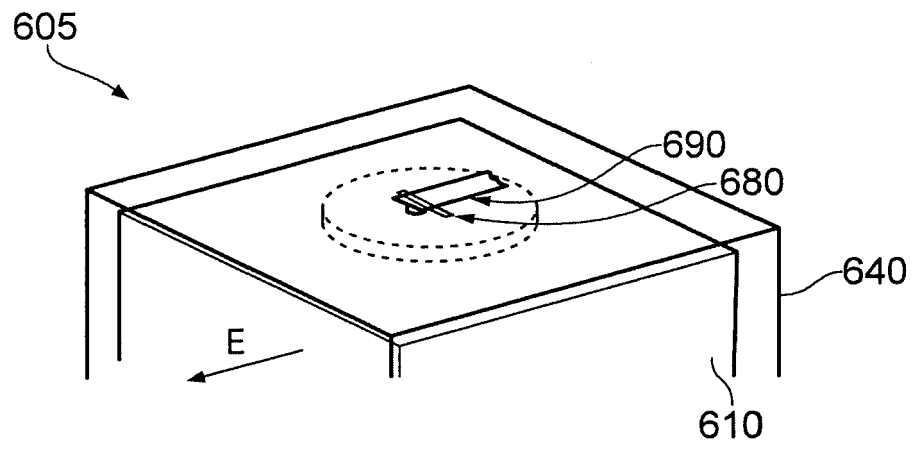


FIG. 10

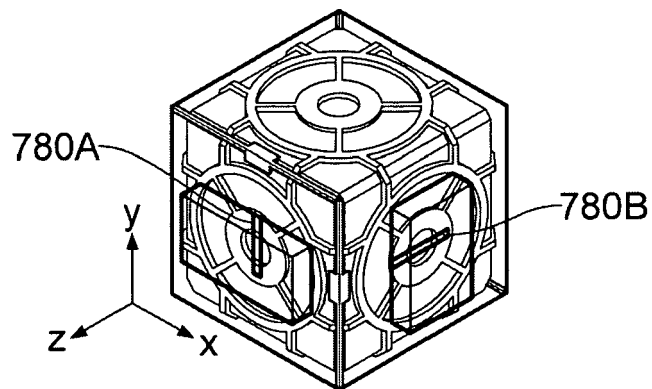


FIG. 11



EUROPEAN SEARCH REPORT

Application Number
EP 09 36 0025

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 01/48856 A1 (POSEIDON SCIENT INSTR PTY LTD [AU]; UNIV WESTERN AUSTRALIA [AU]; TOBAR) 5 July 2001 (2001-07-05) * page 8, line 9 - page 13, line 9 * * figures 1a,1b,2a,2b,2c,3a,3b,4a,4b,5a,5b *	1-3,9, 11,15	INV. H01P7/06 H01P7/10
X	JP 54 063653 A (SUMITOMO ELECTRIC INDUSTRIES) 22 May 1979 (1979-05-22) * abstract; figure 6 * -----	1-3,9, 11,15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01P
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 6 April 2010	Examiner Kruck, Peter
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 09 36 0025

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-04-2010

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 0148856	A1	05-07-2001	US 6882252 B1	19-04-2005
JP 54063653	A	22-05-1979	NONE	