



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.10.2016 Bulletin 2016/41

(51) Int Cl.:
H01P 1/205^(2006.01) H01P 7/04^(2006.01)

(21) Application number: **15305524.9**

(22) Date of filing: **09.04.2015**

(84) Designated Contracting States:
AL 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 RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

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(54) **A RESONATOR ASSEMBLY AND FILTER**

(57) Aspects and embodiments relate to cavity resonator assemblies and filters formed from those cavity resonator assemblies. A first aspect provides a resonator assembly comprising: a conductive resonator cavity, a primary resonant member, an auxiliary resonant member and a signal feed. The primary resonant member is located within the conductive resonator cavity and arranged to receive a signal from the signal feed and configured to resonate within the cavity at a primary funda-

mental frequency. The auxiliary resonant member is located within the conductive resonator cavity, arranged to receive a signal from the signal feed and configured to resonate within the cavity at an auxiliary fundamental frequency and configured to impede coupling of a signal from the signal feed to the primary resonant member at the auxiliary fundamental frequency. Arrangements described may allow for independent control of spurious frequencies in resonator or filter output.

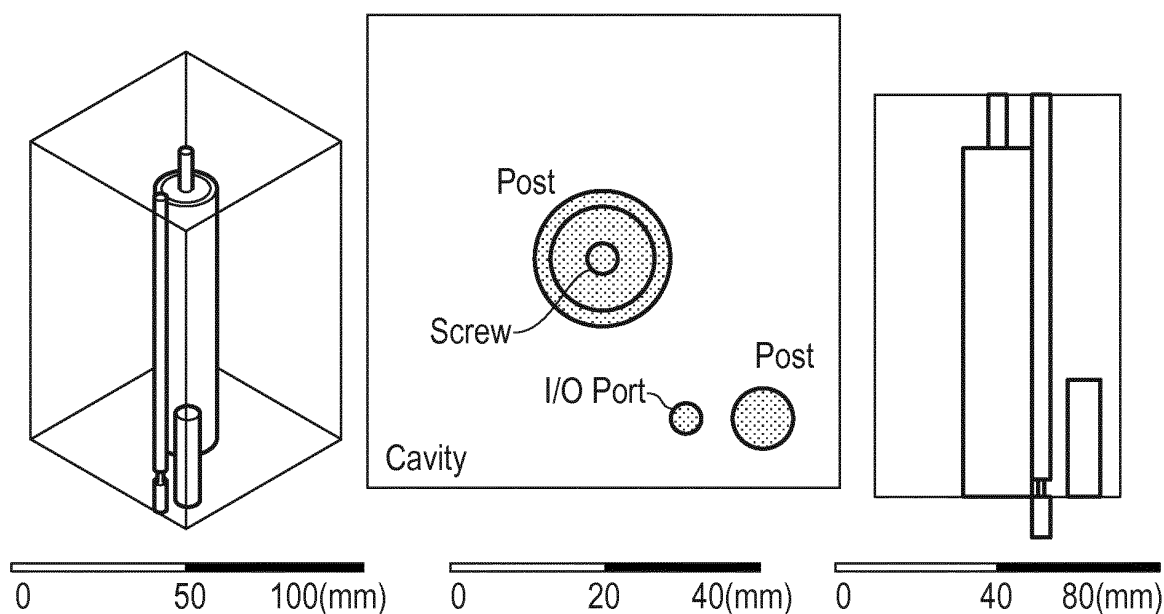


FIG. 4

Description

FIELD OF THE INVENTION

[0001] The present invention relates to cavity resonator assemblies and filters formed from those cavity resonator assemblies.

BACKGROUND

[0002] Filters formed from resonators are widely used in a data transmission context and, in particular, telecommunications. In a telecommunication context, filters may be used, for example, in base stations, radar systems, amplifier linearization systems, point-to-point radio and radio frequency (RF) signal cancellation systems. A specific filter is often chosen or designed dependent upon a given application. There are, however, some characteristics which may be applicable to various filter realisations.

[0003] For example, insertion losses in the pass band of a filter may desirably be as low as possible; attenuation in the stop band should be as high as possible. Furthermore, in some applications, frequency separation between a pass band and stop band (guard band) may be required to be very small which can require filters of high order to be deployed. Typically, the requirement for a high order filter may be followed by an increase in filter cost, due to a greater number of components or complexity associated with such a filter and an increased need for physical space.

[0004] It is recognised that, in the telecommunication context at least, in the arrival of small cell base stations, in which the footprint of such a base station may advantageously be low, the desire to reduce the size and effectiveness of cavity filters is increasing. Furthermore, in relation to macro cell base stations there is an increasing need to provide multi band solutions within a similar footprint to that associated with single band solutions without sacrificing overall system performance. It is desirable to reduce the size of a filter or resonator whilst maintaining performance properties.

SUMMARY

[0005] Accordingly, a first aspect provides a resonator assembly comprising: a conductive resonator cavity, a primary resonant member, an auxiliary resonant member and a signal feed; the primary resonant member being located within the conductive resonator cavity, arranged to receive a signal from the signal feed and configured to resonate within the cavity at a primary fundamental frequency; the auxiliary resonant member being located within the conductive resonator cavity, arranged to receive a signal from the signal feed and configured to resonate within the cavity at an auxiliary fundamental frequency and configured to impede or prevent coupling of a signal to the primary resonant member at the auxiliary

fundamental frequency.

[0006] The first aspect recognises that the building block of microwave filters and duplexers in coaxial cavity technology is a coaxial resonator. A coaxial resonator is a distributed transmission line with an associated physical length that provides a required electrical length to support a standing wave at a given frequency. That frequency is known as the frequency of operation for the resonator and any resulting filter. A conventional TEM combine coaxial resonator typically comprises a metallic cavity enclosure and an associated resonating element. The metallic cavity enclosure often has a circular or rectangular cross-sectional shape. The associated resonating element may take a range of physical forms, but may typically comprise: a substantially cylindrical metallic post located in the centre of the circle or rectangle. That post is often grounded at one side and open-ended at the opposing side.

[0007] Figure 1 illustrates schematically a single coaxial cavity resonator, that resonator having been designed to operate with a resonating post having a physical and effective electrical length of approximately a quarter wavelength of a selected frequency. The coaxial cavity resonator example shown in Figure 1 may operate as a so-called "distributed resonator". The distributed nature of the resonator means that multiple modes can be supported across a large frequency spectrum. That is to say, the physical length of the resonating element corresponds to an electrical length which supports mode configurations at higher frequencies. Such modes are higher order modes and the term "harmonics" is typically employed to describe them. If a filter is formed from a plurality of such distributed resonators, the harmonics may propagate through the filter just as the fundamental frequency of operation propagates through the filter and harmonic outputs are produced at the output port of such filters.

[0008] Furthermore, the first aspect recognises that a broadband signal may be fed into a cavity assembly and, despite careful construction of that resonant assembly, an unwanted frequency may be able to propagate within the cavity and couple to the resonator output. The first aspect recognises that it may be possible, technically and practically, to suppress a predictable, or repeatable, unwanted frequency signal forming part of an output signal from a cavity assembly. In some embodiments, the first aspect recognises it may be possible to suppress harmonic outputs within a signal from a cavity resonator or from a coaxial cavity filter. In particular, some arrangements may allow for first harmonic and/or higher harmonic frequencies to be suppressed. Suppression of harmonic frequencies may allow for an easing in specification requirements in relation to low pass filters at the output of such coaxially cavity filters provided at, for example, base stations. Such an ease in specification requirements can allow for a consequent saving in physical volume by reducing the size of the necessary low pass filters, and may reduce insertion loss associated with the low pass filters which can result in an overall reduction

in insertion losses associated with the filtering units.

[0009] One way of addressing spurious pass bands (harmonic outputs) in relation to a conventional coaxial filter with uniform rods is to make use of coaxial filters which utilise coaxial resonators or posts which are capacitively loaded. In general, a conventional coaxial filter with uniform rods has a first harmonic which occurs at approximately three times the fundamental frequency, f_0 . If a coaxial filter is formed using a capacitively loaded post, as may typically be done in order to reduce the physical size of the coaxial resonators forming the filter, a consequence of that capacitive loading is that harmonic outputs are driven to higher frequencies, usually more than three times that of the fundamental frequency. A similar shifting of harmonic outputs may be achieved by using stepped rod resonators. Although use of stepped rod resonators and capacitively loaded resonators can push harmonic output frequencies higher in frequency, they do not act to suppress them. Alternative approaches may use a mixture of stepped impedance and conventional uniform cavity resonators to suppress harmonics at filter outputs. Such an arrangement achieves that suppression by reducing coupling through the filter. The harmonic resonance of the conventional uniform rod and the stepped rod resonators are dissimilar and, thus, coupling between resonators is reduced. Such an approach involves design and fabrication of two different types of resonant elements and has associated time and cost efficiency implications.

[0010] The first aspect provides an alternative mechanism for controlling harmonic output from a resonator or coaxial filter. In particular, the first aspect provides an additional or auxiliary resonant member within a cavity. That additional resonating member is configured within the cavity, in terms of physical dimension and effective electrical length dimension, to resonate at a frequency which it is desired to suppress in the resonator output. Specific provision of an additional resonator at the frequency which it is wished to suppress, and configuring that additional resonator to couple to the input signal feed, but not then couple to the primary resonator, or any other resonating member, nor the resonator assembly output, allows the energy at the auxiliary fundamental frequency to be "trapped" within the resonator assembly. In fact, once the additional resonating member is operational within the cavity, energy from the signal feed at the auxiliary fundamental frequency is rejected, thus acting to suppress the spurious frequency at a resonator assembly output.

[0011] The first aspect may provide a resonator assembly. The resonator assembly may comprise: a conductive resonator cavity. The conductive resonator cavity may be substantially cylindrical. The cylinder may have a substantially rectangular or circular cross section. The resonator assembly may comprise: a primary resonant member. The primary resonant member may be located substantially centrally within said resonator cavity. The resonator assembly may comprise: an auxiliary resonant

member. The auxiliary resonant member may be located in the region of the periphery of the resonant cavity. The auxiliary resonant member may have significantly smaller physical dimensions than those of the primary resonant member. The resonator assembly may comprise: a signal feed. The primary resonant member may be located within the conductive resonator cavity. The primary resonant member may be arranged to receive a signal from the signal feed. That is to say, the primary resonant member may couple to the signal from the feed. The primary resonant member may be configured to resonate within the cavity at a primary fundamental frequency. The auxiliary resonant member may be located within the conductive resonator cavity. The auxiliary resonant member may be arranged to receive a signal from the signal feed. That is to say, the auxiliary resonant member may couple to the feed from the signal feed. The auxiliary resonant member may be configured to resonate within the cavity at an auxiliary fundamental frequency. The auxiliary resonant member may be configured to prevent coupling of the auxiliary fundamental frequency to the primary resonant member. That is to say, the auxiliary resonant member may be located so that the auxiliary fundamental frequency may not couple between the auxiliary resonant member and the primary resonant member. The auxiliary fundamental frequency may be higher than the primary fundamental frequency. The resonant assembly may comprise an output signal coupling.

[0012] In one embodiment, the auxiliary fundamental frequency is selected to be a harmonic of the primary fundamental frequency. In one embodiment, the auxiliary fundamental frequency is selected to be the first harmonic of the primary fundamental frequency. Accordingly, further frequencies which may be supported within the resonator assembly by the primary resonating member may be suppressed.

[0013] In one embodiment, the resonator assembly comprises: a further auxiliary resonant member located within the conductive resonator cavity configured to resonate within the cavity at the auxiliary fundamental frequency and configured to prevent coupling of the auxiliary fundamental frequency to the primary resonant member. Provision of more than one auxiliary resonating member configured to resonate at the auxiliary fundamental frequency may allow the resonator assembly to more effectively control the suppressed (auxiliary fundamental) frequency.

[0014] In one embodiment, the further auxiliary resonant member is member located within the conductive resonator cavity and is configured to receive a signal directly from the signal feed. Accordingly, such an arrangement may allow for more effective suppression at said auxiliary fundamental frequency.

[0015] In one embodiment, the further auxiliary resonant member is member located within the conductive resonator cavity to receive a signal coupled to the further auxiliary resonant member from the auxiliary resonant member. Accordingly, such an arrangement may allow

for more effective bandwidth suppression around said auxiliary fundamental frequency.

[0016] In one embodiment, a secondary auxiliary resonant member may be located within the conductive resonator cavity, arranged to receive a signal from the signal feed and configured to resonate within the cavity at a secondary auxiliary fundamental frequency and configured to prevent coupling of the secondary auxiliary fundamental frequency to the primary resonant member. Accordingly, more than one frequency may be suppressed within the resonator assembly signal output. Principles of operation of the secondary auxiliary resonant member are the same as those described in relation to the auxiliary resonant member.

[0017] In one embodiment, configuring the auxiliary resonant member to resonate within the cavity at the auxiliary fundamental frequency comprises: selecting at least one physical dimension of the resonant member. That physical dimension may comprise length, and/or width of the resonant member and may comprise effective electrical length of the resonant member. Configuring the auxiliary resonant member may also comprise locating the resonant member appropriately within the resonant cavity.

[0018] In one embodiment, at least one of the primary and auxiliary resonating members comprises a resonating post. In one embodiment, the auxiliary resonating member is formed from a tunable screw insert extending into the cavity. That tunable screw insert may be distinct from the tuning screw of the primary resonant member.

[0019] In one embodiment, the signal feed comprises a feed post extending across the cavity.

[0020] In one embodiment, the primary and auxiliary resonating members project into the cavity from an inner surface of the cavity. In one embodiment, the primary and auxiliary resonating members extend from the same inner surface of the cavity. In one embodiment, at least one of the primary and auxiliary resonating members comprises a substantially mushroom-shaped member.

[0021] A second aspect provides a filter comprising: a plurality of resonator assemblies, at least one of the resonator assemblies comprising a resonator assembly according to any preceding claim, the filter comprising an input resonator assembly and an output resonator assembly arranged such that a signal received at the input resonator assembly passes through the plurality of resonator assemblies and is output at the output resonator assembly; an input feed line configured to transmit a signal to an input resonator member of the input resonator assembly such that the signal excites the input resonator member, the plurality of resonator assemblies being arranged such that the signal is transferred between the corresponding plurality of resonator members to an output resonator member of the output resonator assembly; an output feed line for receiving the signal from the output resonator member and outputting the signal.

[0022] Accordingly, providing at least one resonator assembly having an auxiliary resonating member config-

ured as described in relation to the first aspect within a filter may provide a means to suppress a selected undesired output frequency, that undesired output frequency being at said auxiliary fundamental frequency.

[0023] In one embodiment, the input resonator assembly comprises a resonator assembly according to the first aspect.

[0024] In one embodiment, the output resonator assembly comprises a resonator assembly according to the first aspect.

[0025] In one embodiment, the filter comprises a duplexer.

[0026] In one embodiment, the filter is at least one of: a radio frequency filter or a combline filter.

[0027] Further particular and preferred aspects 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.

[0028] Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 illustrates schematically one possible configuration of a quarter wavelength single coaxial cavity resonator;

Figures 2a to 2c illustrate schematically feed systems of a typical single coaxial cavity resonator having (a) an inductive pin, (b) a capacitive disc and (c) a post provided for input/output excitation;

Figures 3a and 3b illustrate schematically a layout configuration (in plan view) of a single coaxial cavity resonator with input/output excitation port. Figure 3b illustrates schematically an arrangement which includes provision of an additional or "auxiliary" resonating post. In this arrangement, the additional post is situated at the corner of a cavity enclosure. The physical dimensions of the additional post are such that it may resonate within the metallic enclosure at approximately a harmonic frequency of the main resonating post provided within the cavity;

Figure 4 illustrates schematically one possible layout of a single coaxial cavity resonator having an input/output excitation port and in which an additional (auxiliary) post is included. In the arrangement shown, the additional post is situated at one side of a cavity and has physical dimensions such that it can resonate within the metallic enclosure at a harmonic frequency of the main post provided within the cavity.

The illustrated arrangement demonstrates schematically the physical size ratios of the two posts: the "fundamental" or main post and the additional "harmonic" post;

Figure 5 illustrates schematically an arrangement of a typical two pole coaxial cavity filter. The layout shown includes the cavity enclosure for a 2-pole filter having a thin iris wall which extends from a top surface of the cavity towards the bottom surface of the cavity (which is also a ground plane for the main resonating post);

Figure 6 illustrates schematically an arrangement of a two pole coaxial cavity filter according to one arrangement. The layout illustrated shows a cavity enclosure of a possible 2-pole filter including additional resonating posts within each effective cavity and in which a thin iris wall which extends from a top surface of the cavity towards the bottom (ground) surface is provided;

Figure 7a illustrates graphically simulated in-band response of a two pole coaxial cavity filter -conventional vs proposed. The solid black line represents the conventional a two pole coaxial cavity filter and the dashed grey line represents a two pole coaxial cavity filter including at least one additional resonating member;

Figure 7b illustrates graphically simulated out-of-band response of a two pole coaxial cavity filter -conventional vs proposed. The solid black line represents the conventional two pole coaxial cavity filter and the dashed grey line represents a two pole coaxial cavity filter including at least one additional resonating member;

Figure 8 illustrates an alternative typical layout configuration of a two pole coaxial cavity filter. The layout illustrated comprises a cavity enclosure for a 2-pole filter and a thin iris wall that extends from the two side surfaces of the cavity;

Figure 9 illustrates schematically a layout configuration of a two pole coaxial cavity filter according to an arrangement in which additional resonating posts are provided.

The layout includes a cavity enclosure for a 2-pole filter and a thin iris wall which extends from two side surfaces of the cavity;

Figure 10a illustrates graphically simulated in-band response of a two pole coaxial cavity filter -conventional vs proposed;

Figure 10b illustrates graphically simulated out-of-band response of a two pole coaxial cavity filter -conventional vs proposed. The dashed grey line illustrates the conventional construction response and the solid black line illustrates the proposed construction response;

Figure 11a illustrates schematically a typical layout configuration in plan of a single coaxial cavity resonator with an input/output excitation port;

Figure 11b illustrates schematically a layout config-

uration in plan of a single coaxial cavity resonator with input/output excitation port including inclusion of an additional auxiliary resonating post;

Figure 11c illustrates schematically in plan a layout configuration of a single coaxial cavity resonator with an input/output excitation port showing inclusion of two additional auxiliary posts, in the arrangement shown, a second additional post is situated in proximity to the first additional post;

Figure 11d illustrates schematically in plan a layout configuration of a single coaxial cavity resonator with input/output excitation port including two additional auxiliary posts, the second post being situated in proximity to the excitation port;

Figure 12 illustrates schematically a layout configuration of a two pole coaxial cavity filter in which a cavity enclosure of a 2-pole filter is provided with a thin iris wall which extends from two side surfaces of the cavity enclosure, a floating additional resonating post is provided;

Figure 13a illustrates schematically a layout configuration of a coaxial cavity duplexer (partial); at an antenna port of a telecommunications application; and

Figure 13b illustrates schematically a layout configuration of a coaxial cavity duplexer (partial) at an antenna port of a telecommunications application.

DESCRIPTION OF THE EMBODIMENTS

[0030] Before describing any arrangements in detail, an overview of possible structures of coaxial cavity resonators and excitation techniques is provided. Figures 2a to 2c illustrate schematically one typical coaxial cavity resonator implementation and three possible excitation or feed techniques. The coaxial cavity resonator shown in Figures 2a to Figure 2c comprises a metal cavity in which a resonator element (in this case, a post grounded at one side of the cavity and open at the other side of the cavity) extends. There is also provided a tuning screw which extends from the top of the cavity towards the resonant post. Figure 2a shows an arrangement in which an inductive pin is provided to feed or excite the coaxial cavity. The inductive pin extends from a coaxial connector to the main body of the resonant element; in this case, a post. The inductive pin is typically connected at a low level of the post and is configured to match electrically the typical 50 Ohm impedance of the coaxial transmission line to the strong resonant element.

[0031] Figure 2b illustrates an excitation technique according to which, where the coaxial connector enters the coaxial cavity resonator, the inductive pin extends into the resonant cavity and is provided, at its end, with a capacitive disc.

[0032] Figure 2c illustrates an excitation method according to which a metallic post is provided within the coaxial cavity. That metallic feed post extends from the bottom part of the metallic enclosure to the top part of

the metallic enclosure. The feed post is mechanically and electrically connected at the top and bottom of the metallic enclosure and is configured to excite the strong resonant element.

[0033] Figure 3a illustrates schematically a typical coaxial cavity resonator and Figure 3b illustrates schematically a coaxial cavity resonator according to one possible arrangement. The principles of operation of various arrangements are described in general in relation to Figure 3b.

[0034] Figure 3a shows schematically a plan view of one possible layout configuration of a typical single coaxial cavity resonator. That resonator has an input/output excitation port comprising a metallic post which extends from the bottom part of a metallic enclosure to the top part of that metallic enclosure and is mechanically and electrically connected to the metallic enclosure at both top and bottom. Within the metallic cavity enclosure a resonating post is provided. That resonating post is situated substantially centrally within the cavity to form a resonator. A tuner or tuning screw is provided in order to tune the resonant frequency of the coaxial cavity resonator.

[0035] In operation, the resonator can be excited by the input/output excitation post. Such a configuration can support a resonant mode, $m\ 1f$, at a fundamental frequency f_0 .

[0036] It is a feature of coaxial cavities such as the one shown in Figure 3a that the resonating element may also support a number of additional harmonic modes. That is to say, the structural configuration shown in Figure 3a may support more than one resonant mode as the feed frequency spectrum is augmented. The first spurious or harmonic mode, $m\ 1h$, resonates at a frequency f_{1h} .

[0037] According to one arrangement shown in Figure 3b, an additional post, or auxiliary post, can be provided and may be configured to be situated within the cavity enclosure as shown in Figure 3b. According to such a structural configuration, the auxiliary post can be chosen such that its fundamental resonant mode $m2f$ occurs at a frequency f_{2f} . The auxiliary post can be positioned so that it can couple directly to the excitation port post provided within the cavity. Accordingly, the structure shown in Figure 3b can allow for two fundamental modes to be directly excited by the excitation port; namely modes $m\ 1f$ and $m2f$. By appropriate configuration or adjustment of the physical dimensions of the auxiliary post, it is possible to ensure that the first harmonic mode $m\ 1h$ and the fundamental resonant frequency of the auxiliary post $m2f$ approximately coincide in frequency. That is to say, the harmonic mode $m\ 1h$ occurs at a frequency $f_{2f} \approx f_{1h}$.

[0038] The position of the additional auxiliary post can be selected such that adjustment of coupling from the input port to the auxiliary resonant post can be controlled. According to one embodiment, the auxiliary post may be assumed to be resonant when it has dimensions of approximately a quarter wavelength, assuming that the auxiliary post is grounded at one end and open-ended at the

other. It will be appreciated that the auxiliary post included in the arrangement shown in Figure 3b is likely to have significantly smaller physical dimensions compared to the centrally located main resonator post which is configured to support a resonance at the significantly lower frequency, f_0 .

[0039] It will be appreciated that the physical dimensions of the auxiliary post may be chosen such that it resonates within the cavity enclosure at a harmonic frequency of the fundamental resonator provided within the same cavity enclosure. Such a structural configuration allows control of the input impedance of a filter ($m1f$ modes and at frequency f_0) at its harmonic mode frequencies ($m1h$) f_{1h} , whilst leaving the input impedance almost unaffected at the fundamental mode $m\ 1f$ and at frequency f_0 .

[0040] Figure 4 illustrates schematically in isometric, plan and side views, a single coaxial cavity resonator having an input/output excitation port which includes a primary resonator member and an additional auxiliary resonator post. The auxiliary post is situated, in the embodiment shown in Figure 4, at one side of the cavity enclosure. In this embodiment the physical dimensions of the auxiliary resonator member are such that it resonates within the metallic enclosure at a harmonic frequency of the primary resonator. In this instance, the figure illustrates schematically a likely physical size ratio between the primary and auxiliary resonator members; in this case, both posts. It can be seen clearly in Figure 4 that the fundamental post is significantly larger, both in length and width, than the auxiliary or harmonic post.

[0041] It will be appreciated that arrangements may be envisaged in which the primary and auxiliary resonator members do not comprise posts. In particular, in some arrangements, the auxiliary post may be replaced with an appropriate tuner or screw to allow for a more flexible design and to assist in post-fabrication tuning of filters formed from such resonator assemblies.

[0042] Figure 5 illustrates schematically, in side view and in plan view, a conventional two pole coaxial cavity filter. The layout shown comprises a cavity enclosure for the two pole filter, that cavity enclosure including a thin iris wall which extends downwardly from the top surface of the cavity towards the bottom of the cavity (the ground plane). Figure 5 shows the structural configuration of a conventional two pole filter. This structural configuration can be compared with that of the structural configuration of a two pole filter according to a new arrangement.

[0043] Figure 6 illustrates schematically, in side view and plan view, a layout of one possible arrangement of a two pole coaxial cavity filter in accordance with some arrangements. The layout includes the cavity enclosures of the two pole filter, that cavity enclosure including a thin iris wall which extends from the top surface of the cavity enclosure towards the ground plane.

[0044] Figure 7a is a graph showing the simulated in-band response of a two pole coaxial cavity filter. The conventional filter shown in Figure 5 is compared with

the arrangement of Figure 6.

[0045] Figure 7b is a plot of the simulated out-of-band response of a two pole coaxial cavity filter. The plot compares the conventional two pole coaxial cavity filter of Figure 5 with the arrangement shown in Figure 6.

[0046] As can be seen from Figures 7a and 7b, the in-band response plot demonstrates that the impact of the auxiliary additional posts coupled to the input and output excitation ports has a minimally detrimental effect on the response of the filter at the fundamental frequency. The simulated performance plots shown in Figures 7a and 7b clearly demonstrate improved out-of-band response and minimal impact in-band.

[0047] Figures 8, 9 and 10a and 10b illustrate schematically an alternative two pole coaxial cavity filter arrangement. The arrangements shown in Figures 8, 9 and 10 differ from that shown in Figures 5 to 7a and 7b, only in relation to the iris provided between primary resonator elements within the cavity enclosure. Figures 8, 9 and 10 demonstrate that different iris implementations may make only a minimal difference to the performance of the two pole filter. It will be understood that the independence of the results compared to a particular iris is as a result of the approach described herein being largely independent of the form of the iris, the phenomenon occurring at the level of the input/output excitation ports.

[0048] Provision of an auxiliary resonating member does not have a significant detrimental impact in relation to Ohmic loss within the resonator assembly or filter devices built from such resonant assemblies. In particular, since the auxiliary resonating member is typically physically significantly smaller than the resonating member employed within a cavity to perform the primary or basic filtering function at a fundamental mode $m1f$ at frequency f_0 , they tend to impose only minimised degradation to the Ohmic loss of devices formed from such resonator assemblies.

[0049] It is possible that provision of auxiliary resonating members within cavity enclosures, as described in relation to various arrangements herein, may be used for high power applications. Such auxiliary resonating members are physically positioned in low field areas within the cavity; that is to say, a low field region for the fundamental mode $m1f$ at frequency f_0 supported by the primary resonating member. As a result, provision of one or more auxiliary resonating members is unlikely to significantly impact upon the performance of the fundamental frequency elements.

[0050] It has been demonstrated (see, for example, Figures 5 to 10) that the coupling walls and irises used to couple a signal through a filter formed from resonant assemblies are such that the electrical performance characteristics associated with provision of additional resonating members is improved, or at least not detrimentally impacted, compared to a typical arrangement.

[0051] The examples illustrated in Figures 5 through to 10 demonstrate that provision of auxiliary posts to suppress harmonics is useful across different structural con-

figurations of irises employed in real life coaxial cavity filters. The results shown in Figures 5 through to 10 demonstrate that the impact of provision of auxiliary resonating members is minimal in relation to the fundamental mode at frequency f_0 . Inclusion of auxiliary resonating members within a filter may therefore result in minimal effort being required to retune that filter. Furthermore, provision of auxiliary resonating members may be included at the design stage with minimal additional effort. It will be appreciated that if the auxiliary resonating members are provided in the form of tuning screws, the tuning of the suppression of a particular frequency can be relatively simply implemented.

[0052] Provision of one or more auxiliary resonating members has been shown to suppress the transmission magnitude at the output of the two pole filter examples at the frequency where the auxiliary elements were made resonant at mode $m2f$. This can be the case when $m2f = m1h$ (that is to say, harmonic suppression) or may be implemented in relation to another suppressed frequency. That is to say, the approach described herein can be used to suppress the filter output outside the stopband, which may be preferable at the high end of the frequency spectrum. Such functionality may be of use in multi band, multi standard telecommunication radio frequency equipment. It will be appreciated that techniques described herein are particularly suitable in relation to narrow bandwidth coaxial cavity filters, but may also be implemented to cover the vast majority of bandwidth specifications used in mobile communication applications.

[0053] Figure 11a illustrates schematically, in plan view, a possible layout of a single coaxial cavity resonator with an input/output excitation port.

[0054] Figure 11b illustrates schematically, in plan view, a possible layout configuration of a single coaxial cavity resonator having an input/output excitation port which includes an auxiliary resonating member.

[0055] Figure 11c illustrates schematically, in plan view, one possible layout configuration of a single coaxial cavity resonator having an input/output excitation port in which two auxiliary resonating members are included. In the example shown in Figure 11c, the second auxiliary resonating member is configured to be situated in proximity to the first auxiliary resonating member. In particular, the two auxiliary posts are located such that the second can couple at the fundamental frequency of the auxiliary post to the first auxiliary post.

[0056] Figure 11d illustrates schematically, in plan view, a layout configuration of a single coaxial cavity resonator having an input/output excitation port in which two auxiliary resonating members are included. In this instance, the second auxiliary resonating member is located within the cavity such that it can couple to the excitation port and to the first auxiliary resonating member at the fundamental frequency of that auxiliary resonating member.

[0057] The arrangements and configurations shown in Figure 11 illustrate various arrangements in which more

than one auxiliary resonating member can be placed within a resonant cavity. The arrangement shown in Figure 11c is one in which more than one auxiliary post is provided and those two auxiliary resonating members are located within the cavity such that they can couple to each other at the auxiliary fundamental frequency. Locating the auxiliary resonating members in such a manner may allow the bandwidth of the coupled resonance (instead of a single resonance) to extend the bandwidth of the frequency being suppressed by provision of the auxiliary resonating members.

[0058] The arrangement shown in Figure 11d comprises an arrangement in which more than one auxiliary resonating member is coupled to the excitation port. By locating the auxiliary resonating members within the resonant cavity in such a way, it may be possible to augment the intensity of the suppression when the two auxiliary posts resonate at the same frequency. It will, of course, be appreciated that the arrangement shown in Figure 11d may operate to enhance the bandwidth of suppression and the depth of the effectiveness of the suppression provided by the auxiliary resonant members at the auxiliary resonant frequency and at the auxiliary fundamental frequency.

[0059] Figure 12 illustrates schematically a side view and plan view of one possible arrangement of a two pole coaxial cavity filter including an auxiliary resonating member in each cavity. The layout shown comprises a cavity which encloses the two pole filters, or primary resonating elements, and a thin iris wall which extends from the two side surfaces of that cavity to effectively create two resonating cavities, one around each of the primary resonating members. In this particular example, an auxiliary resonating member is not located on the ground plate with the primary resonating member, but can be provided such that it is effectively suspended within the cavity. It is located within the cavity such that it can couple to the feed but is not able to couple its energy to the primary resonating member. In the arrangement shown in Figure 12 the half wave auxiliary resonant member which would be provided on the ground plane has been replaced by a half wave resonant post suspended within the cavity. It will be appreciated that features of the arrangements shown in Figures 11 and 12 may be combined to achieve required suppression. In particular, it will be appreciated that the grounded post shown in embodiments of Figures 4 through to 11 may be replaced with a floating member or any appropriate torus or part of a torus or other shaped resonating auxiliary member appropriately configured.

[0060] Figure 13 illustrates schematically, in plan view, two possible arrangements of a layout for a coaxial cavity duplexer at the antenna port. In Figure 13a, a single auxiliary resonating member is provided, labelled m2f. In the arrangement shown in Figure 13b, two auxiliary resonating members are provided, m2f and m3f. The number of auxiliary elements provided may be increased as appropriate. As described in relation to previous arrangements,

the purpose of the auxiliary elements is to couple to a signal provided at the input or output port and suppress or address more frequencies which are not the primary frequency being supported by mf1 or mf2; that is to say, the primary resonating members within the Enclosure. It will be appreciated that auxiliary resonating elements need not be the same size and that if different sized resonating elements are provided it may be true to say that those different sized elements resonate at different frequencies. Furthermore, as described in relation to Figures 11c and 11d, it may be possible to increase the number of auxiliary elements of a particular size, addressing in particular auxiliary frequency in order to increase intensity of suppression at that auxiliary fundamental frequency and where all elements are sized and configured to produce a substantially identical response.

[0061] It will be appreciated that arrangements may allow for spurious frequency outputs of, for example, coaxial cavity filters when appropriately constructed, to be suppressed at the input or output ports. In particular, arrangements allow for independent control of input port impedance by creating an auxiliary fundamental resonating element which can couple to the input port. The benefits of such an arrangement include that it may be possible to relax electrical and mechanical specification requirements of low pass filters, thereby saving cost, physical volume and time. Arrangements such as those described herein can provide viable solutions for state-of-the-art and multi-standard, multi-frequency systems where a clean spectrum at, for example, the output of any filter may be of particular importance.

[0062] Features of arrangements in accordance with those described herein include the provision of resonant elements at frequencies which are not desired in an output. In some arrangements that may comprise provision of resonant elements at harmonic frequencies to a primary frequency to be handled by a filter. In either case, provision of additional resonant elements may allow control and suppression at the output of coaxial cavity filters. Arrangements may provide a technique for spurious frequency and harmonic frequency suppression at input/output port level, whilst being relatively easy to fabricate. In some arrangements posts may be provided as auxiliary resonating members. In other arrangements the auxiliary resonating member may comprise a tuning screw. Arrangements may provide for independent control of input impedance of the filter at the two distinct frequencies, f_0 and f_{lh} .

[0063] The benefits of arrangements such as those described herein may include that specification requirements for output low pass filters employed for harmonic suppression may be relaxed. Filters in accordance with arrangements described may display improved performance characteristics. Simulated results indicate that there may be, in some implementations, a rejection improvement of spurious frequencies of the order of approximately 25 dB. Such an improvement refers to the worst case scenario where there is only stage of inter-

resonator coupling which can be suppressed and irises utilised represent the least advantageous irises in terms of coupling performance at the frequency to be suppressed.

[0064] Arrangements may allow for cost reduction in fabrication techniques. Arrangements described may easily be fabricated and physical implementations are not overly complex. This may directly impact upon resulting cost which can be of utmost importance within the filter technology sector. It will be appreciated that simplification of resonator construction results in consequent simplification of filter construction, since filters are typically built from a number of resonator components. Arrangements such as those described herein also do not typically impact upon the design of the fundamental mode circuitry, thereby allowing for relatively time efficient design processes. The relative simplicity of arrangements described herein can also lead to a reduction in complexity in relation to fabrication compared to other approaches for spurious frequency suppression. Furthermore, arrangements described may allow for independent control of spurious frequencies in filter output. Implementations of arrangements described may make it possible to substantially independently control input impedance of a filtering function at a fundamental mode of operation, as well as independent control of the auxiliary resonating member.

[0065] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

[0066] The functions of the various elements shown in the Figures, including any functional blocks labelled as "processors" or "logic", may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" or "logic" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random

access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the Figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0067] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0068] 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 resonator assembly comprising: a conductive resonator cavity, a primary resonant member, an auxiliary resonant member and a signal feed; said primary resonant member being located within said conductive resonator cavity, arranged to receive a signal from said signal feed and configured to resonate within said cavity at a primary fundamental frequency; said auxiliary resonant member being located within said conductive resonator cavity, arranged to receive a signal from said signal feed and configured to resonate within said cavity at an auxiliary fundamental frequency and configured to impede coupling of a signal from said signal feed to said primary resonant member at said auxiliary fundamental frequency.
2. A resonator assembly according to claim 1, wherein said auxiliary fundamental frequency is selected to

- be a harmonic of said primary fundamental frequency.
3. A resonator assembly according to claim 1 or claim 2, wherein said auxiliary fundamental frequency is selected to be the first harmonic of said primary fundamental frequency. 5
 4. A resonator assembly according to any preceding claim, comprising a further auxiliary resonant member located within said conductive resonator cavity configured to resonate within said cavity at said auxiliary fundamental frequency and configured to prevent coupling of said auxiliary fundamental frequency to said primary resonant member. 10
 5. A resonator assembly according to claim 4, wherein said further auxiliary resonant member is member located within said conductive resonator cavity and is configured to receive a signal directly from said signal feed. 20
 6. A resonator assembly according to claim 4 or claim 5, wherein said further auxiliary resonant member is member located within said conductive resonator cavity to receive a signal coupled to said further auxiliary resonant member from said auxiliary resonant member. 25
 7. A resonator assembly according to any preceding claim, wherein configuring said auxiliary resonant member to resonate within said cavity at said auxiliary fundamental frequency comprises: selecting at least one physical dimension of said resonant member. 30
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 8. A resonator assembly according to any preceding claim, wherein at least one of said primary and said auxiliary resonating member comprises a resonating post. 40
 9. A resonator assembly according to any preceding claim, wherein said auxiliary resonating member is formed from a tunable screw insert extending into said cavity. 45
 10. A resonator assembly according to any preceding claim, wherein said signal feed comprises a feed post extending across said cavity. 50
 11. A filter comprising: a plurality of resonator assemblies, at least one of said resonator assemblies comprising a resonator assembly according to any preceding claim, said filter comprising an input resonator assembly and an output resonator assembly arranged such that a signal received at said input resonator assembly passes through said plurality of resonator assemblies and is output at said output resonator assembly; 55
an input feed line configured to transmit a signal to an input resonator member of said input resonator assembly such that said signal excites said input resonator member, said plurality of resonator assemblies being arranged such that said signal is transferred between said corresponding plurality of resonator members to an output resonator member of said output resonator assembly;
an output feed line for receiving said signal from said output resonator member and outputting said signal.
 12. A filter according to claim 11, wherein said input resonator assembly comprises a resonator assembly according to any one of claims 1 to 10.
 13. A filter according to claim 11 or claim 12, wherein said output resonator assembly comprises a resonator assembly according to any one of claims 1 to 10.
 14. A filter according to any one of claims 11 to 13, configured to form a filter of a duplexer.
 15. A filter according to claim 11, said filter being at least one of: a radio frequency filter or a combline filter.

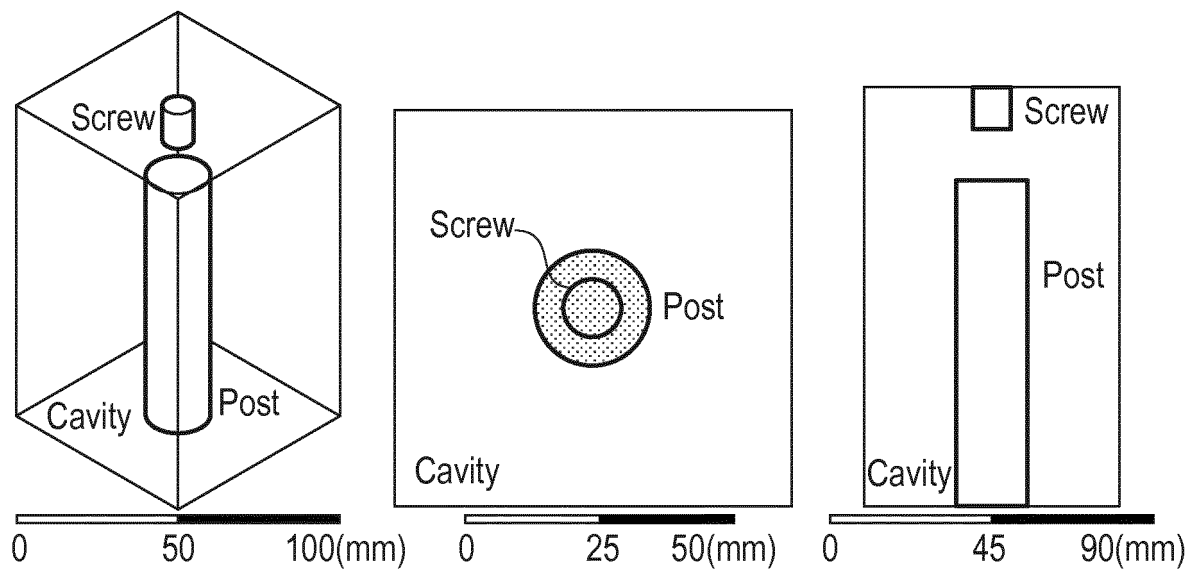


FIG. 1

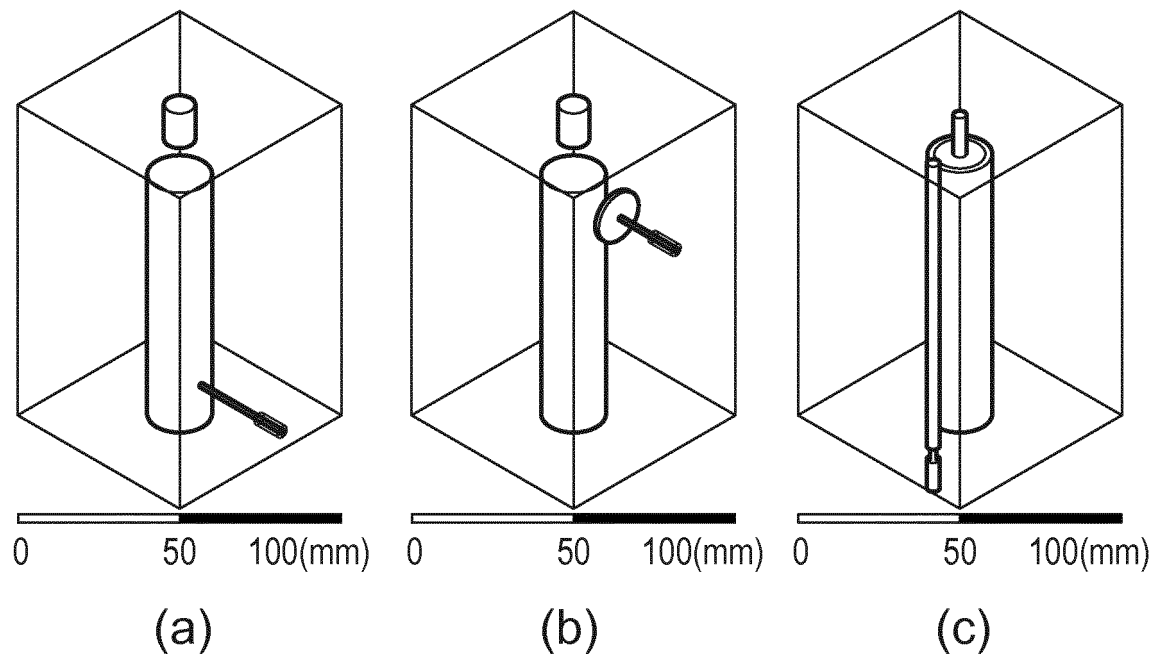
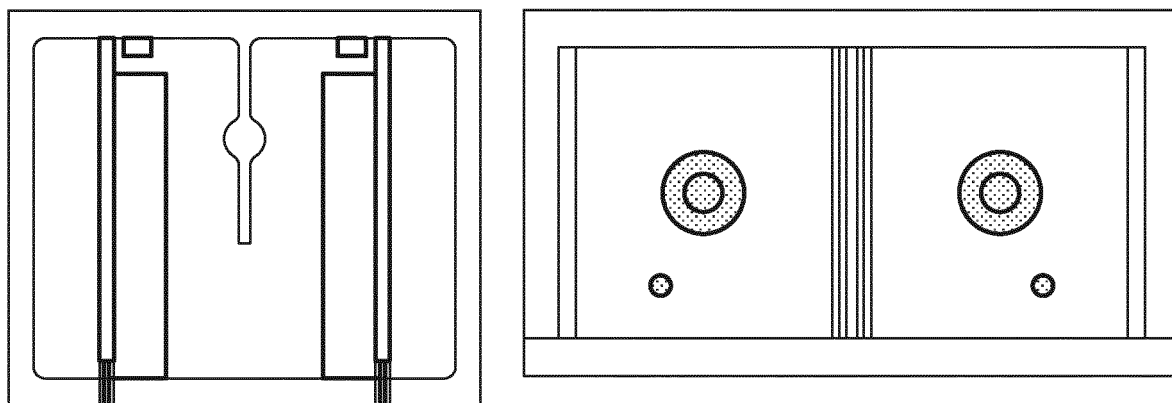
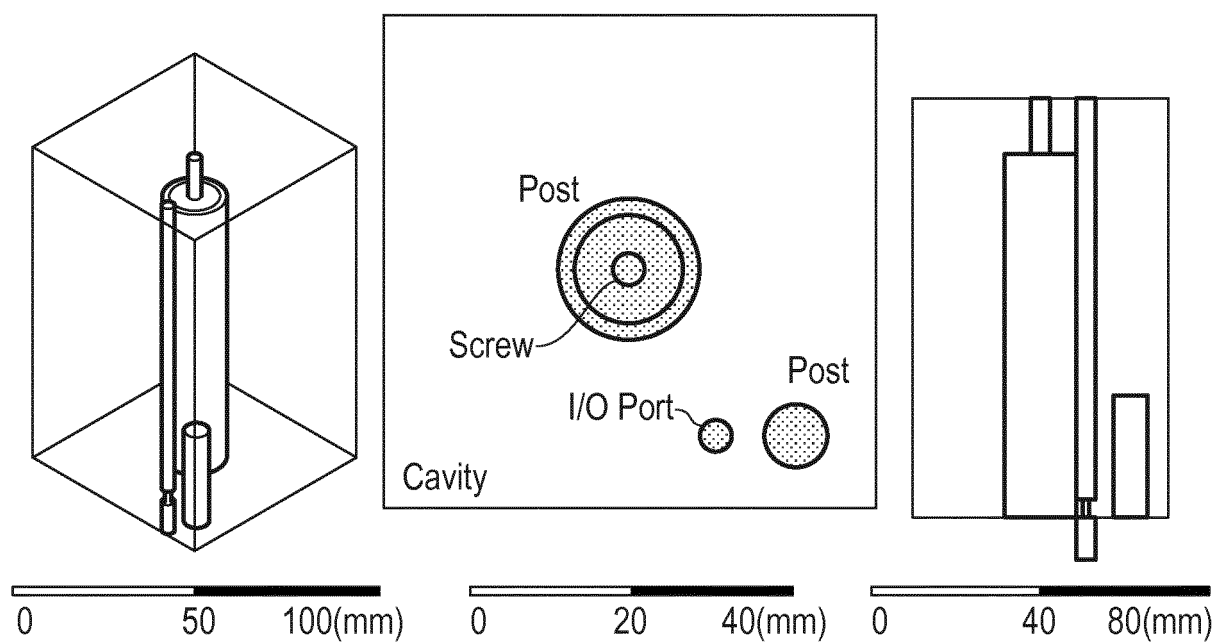
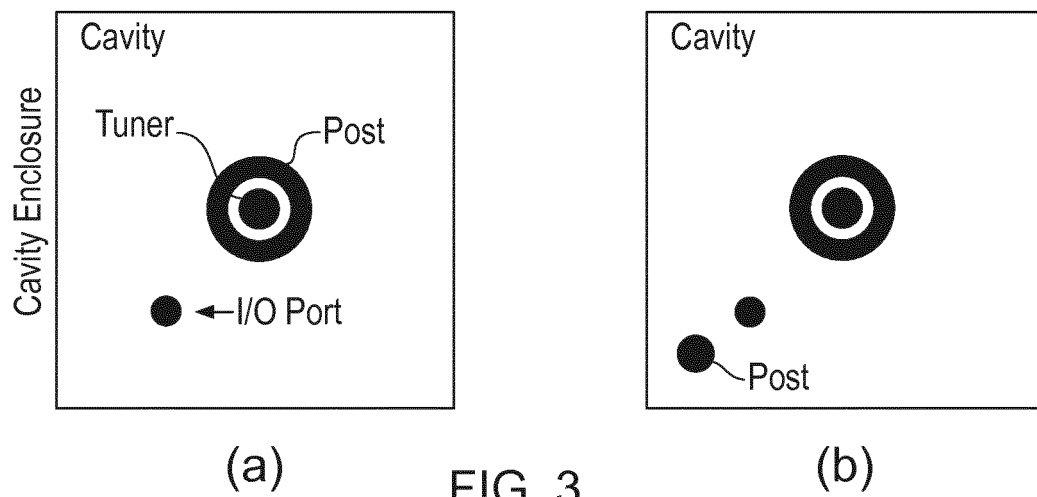


FIG. 2



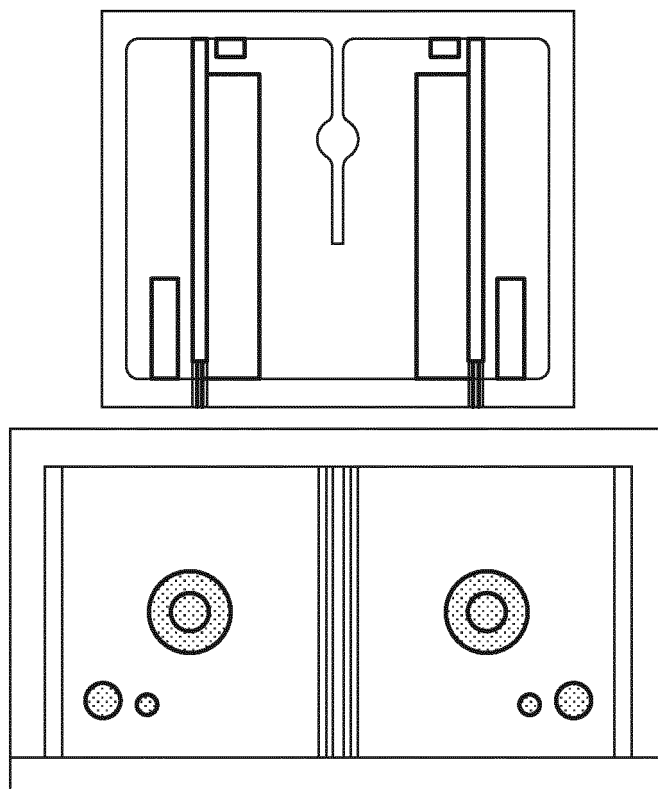


FIG. 6

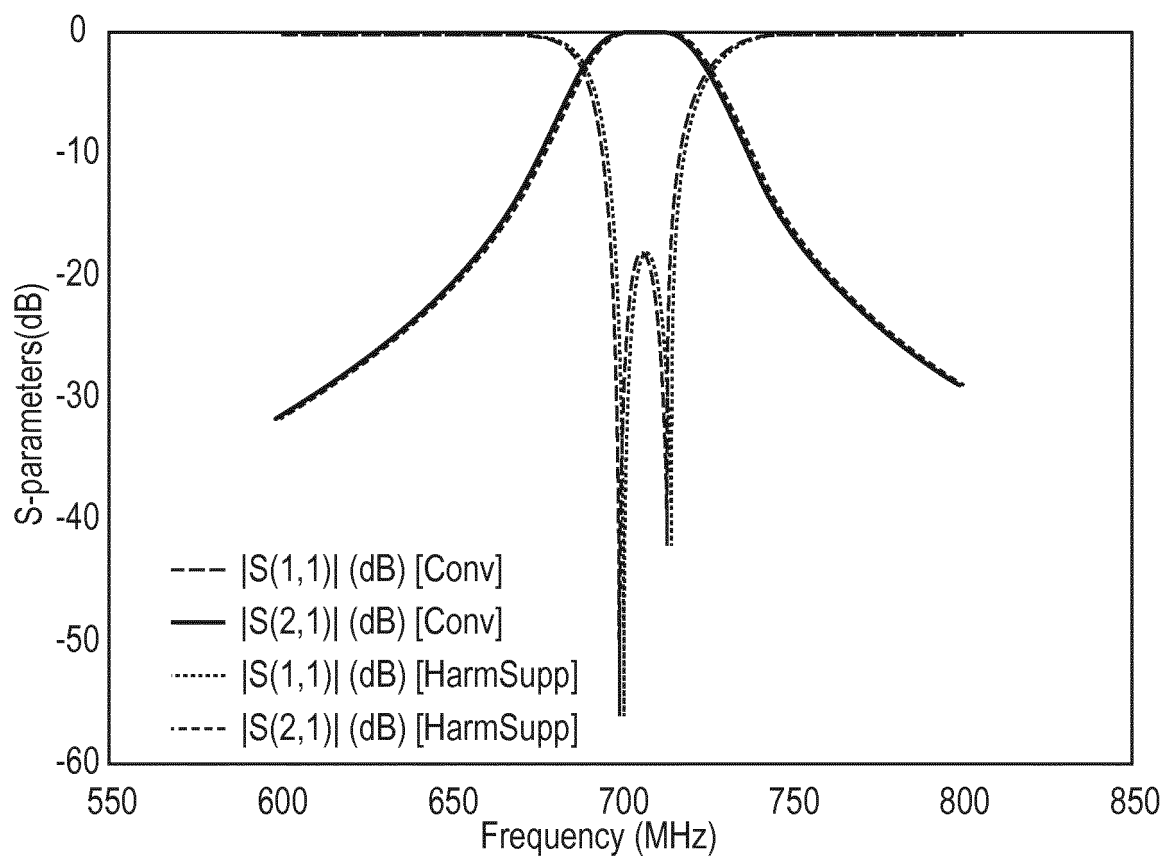


FIG. 7a

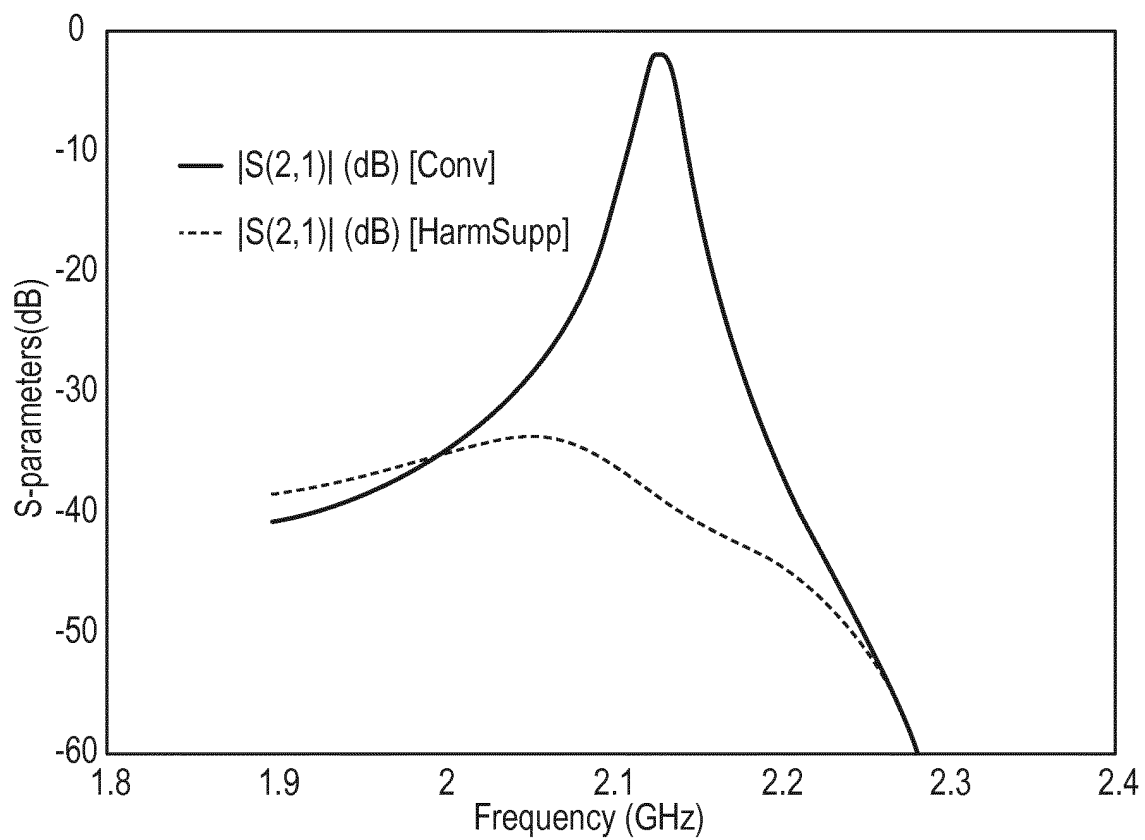


FIG. 7b

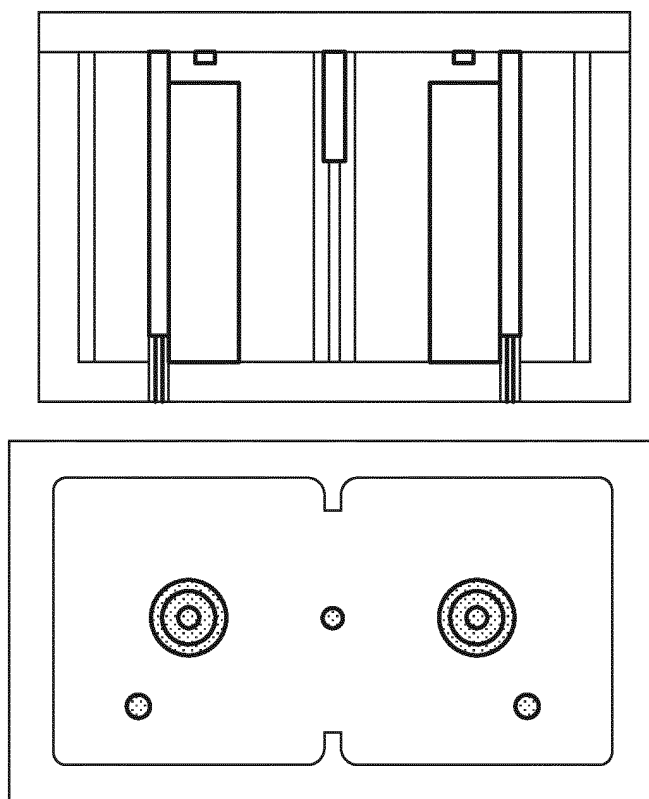


FIG. 8

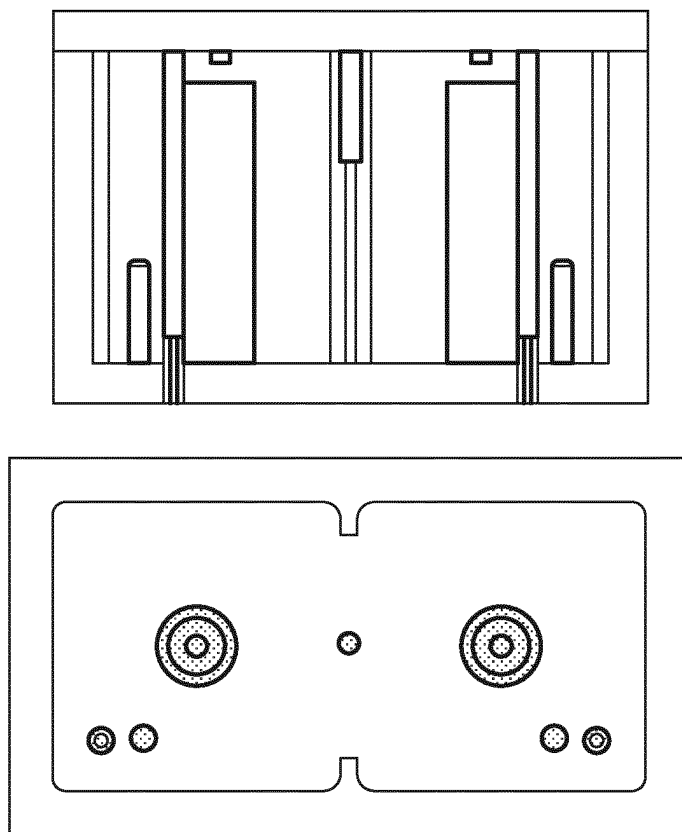


FIG. 9

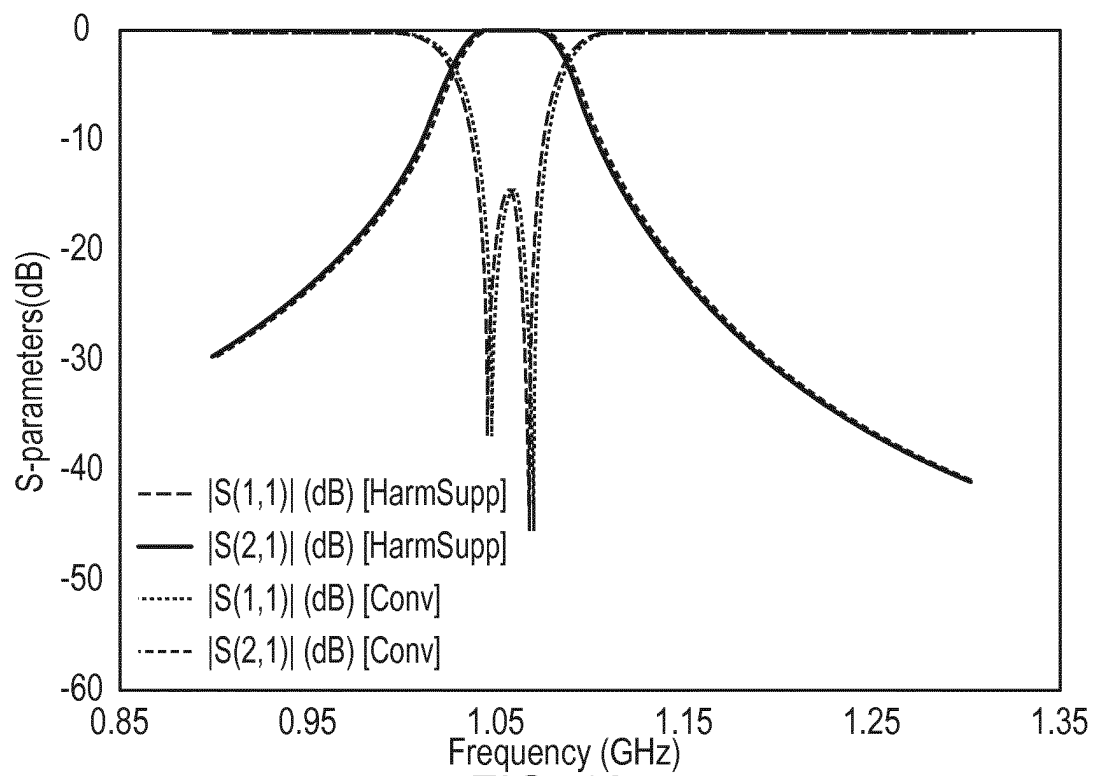
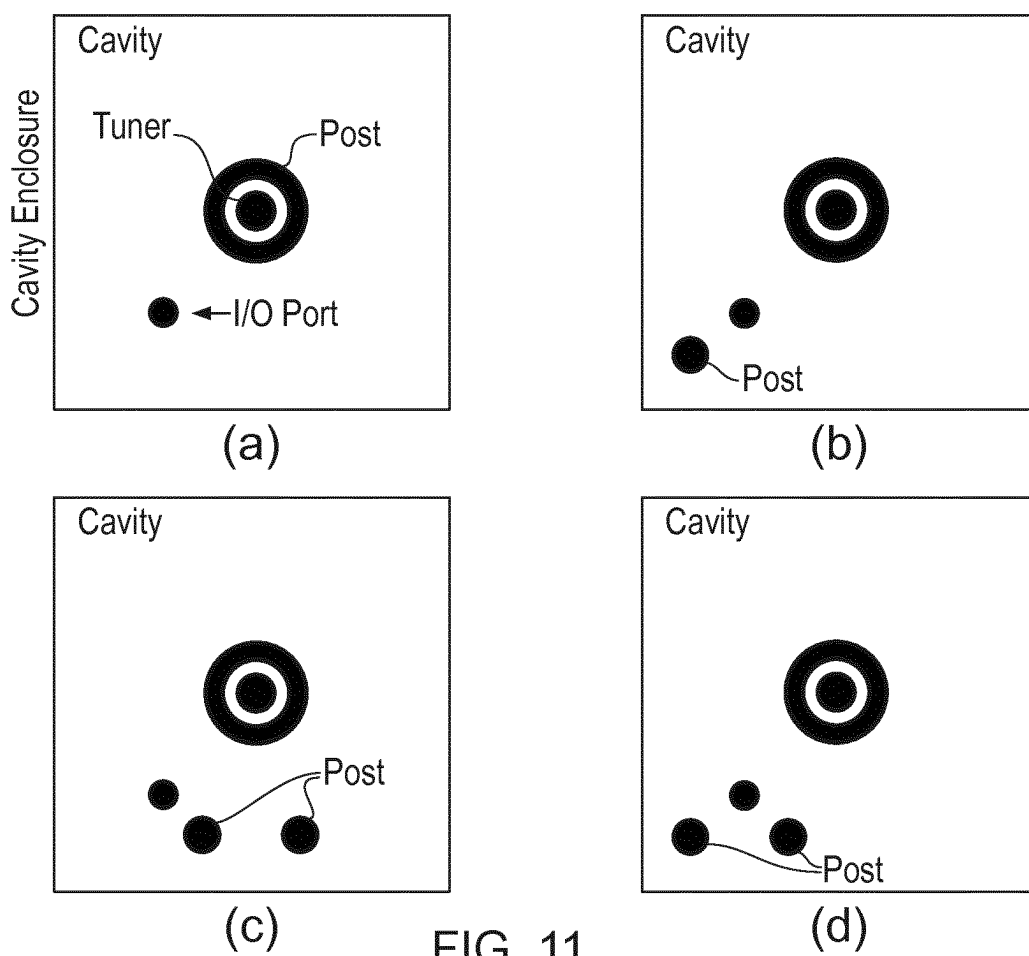
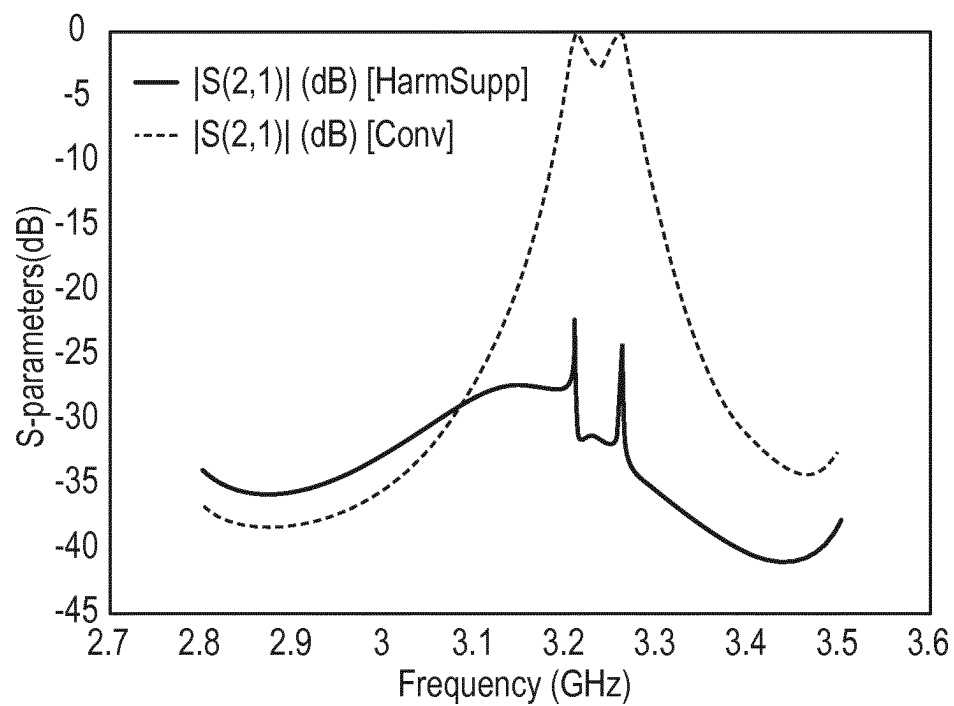


FIG. 10a



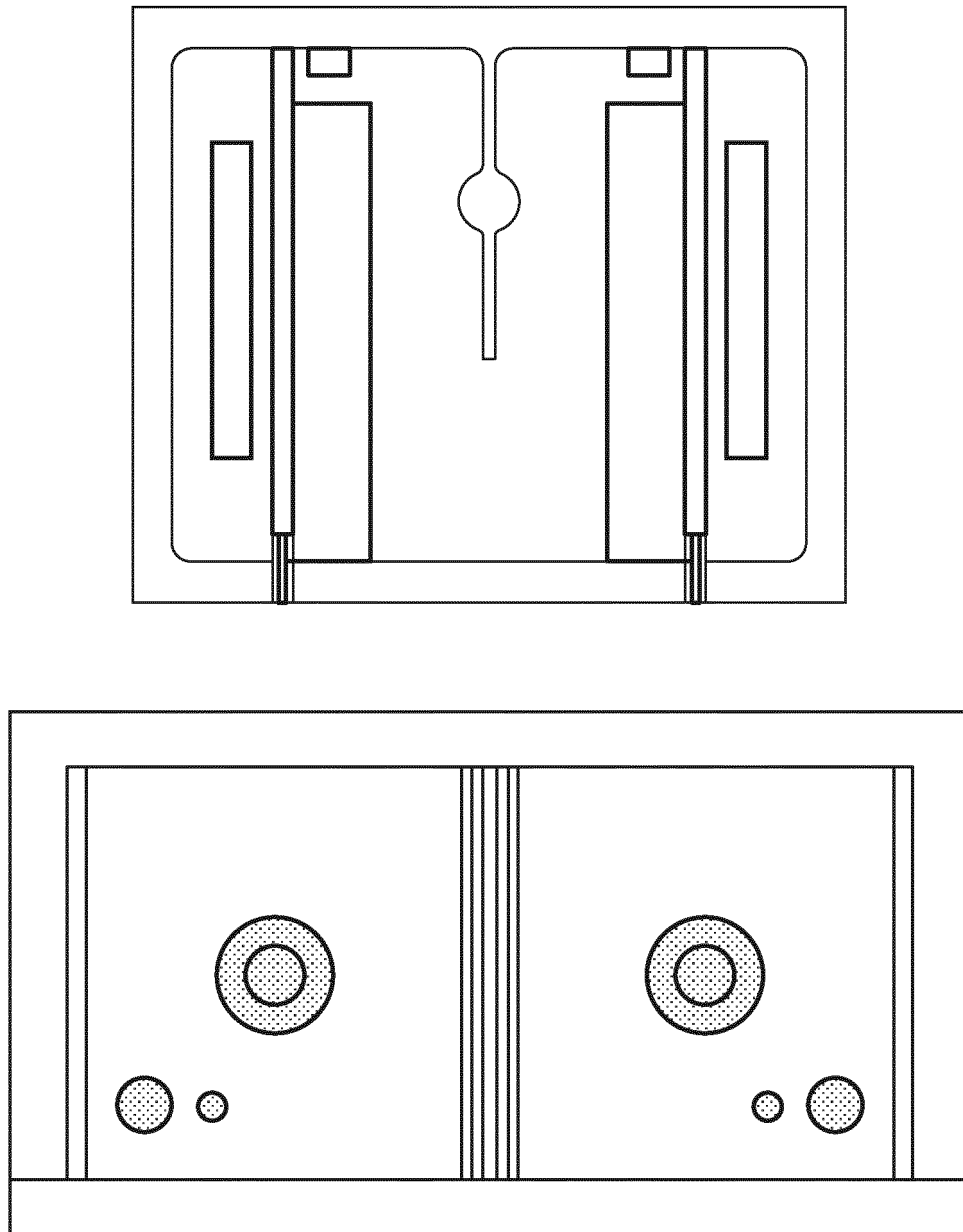


FIG. 12

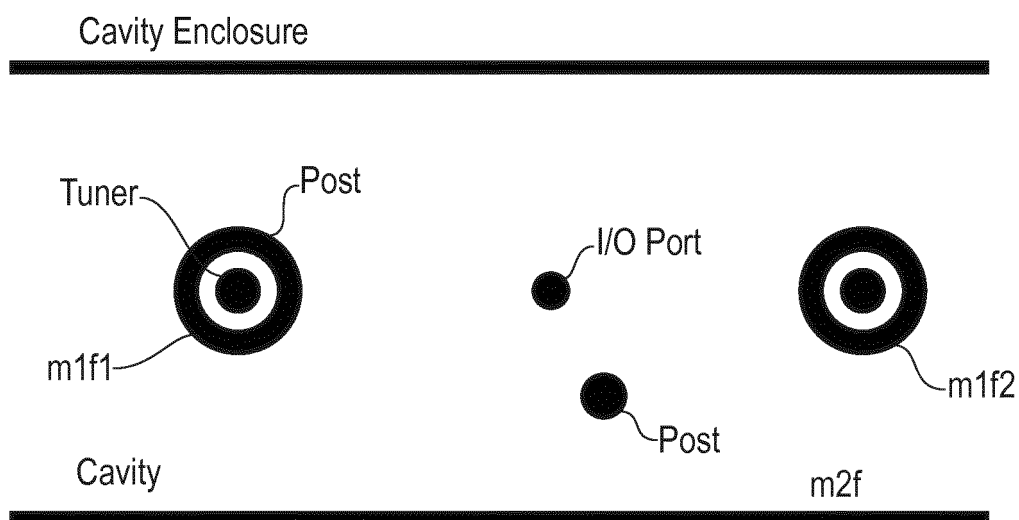


FIG. 13a

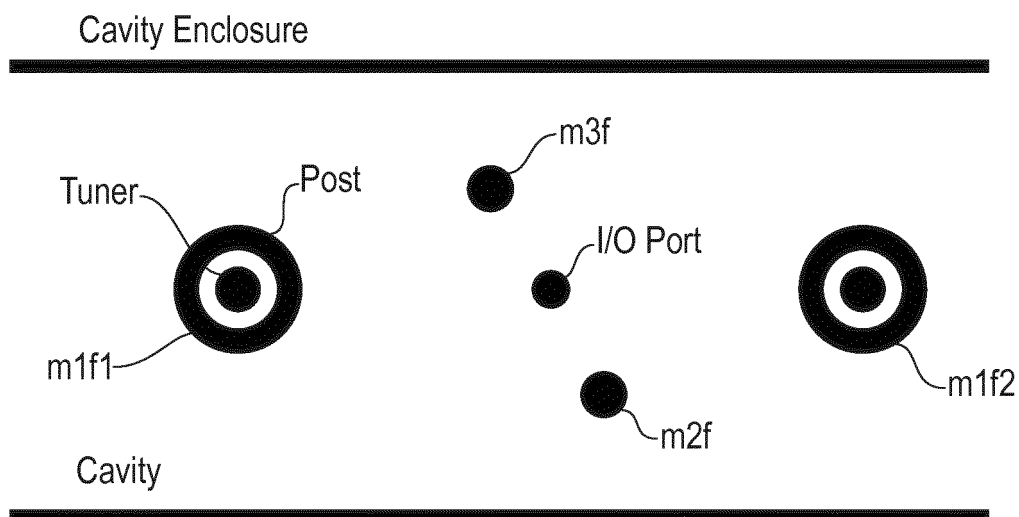


FIG. 13b



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Application Number
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			H01P
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 September 2015	Examiner Kaleve, Abraham
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