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

(57) Aspects and embodiments provide a reconfigurable resonator assembly comprising: a resonator enclosure which defines a resonator cavity, a signal feed and a resonant structure. The resonant structure is located within the resonator cavity and arranged to receive a signal from the signal feed. The resonant structure comprises: a tuning member and first and second elongate elements having an overlap region along their length. The first and second elongate elements are arranged to define a volume in said overlap region between an inner surface of one of the elongate elements and an outer surface of the other of the elongate elements. The first and second concentric elements are reconfigurable within the cavity between: a first position in which a first volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a first frequency; and a second position in which a second volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a second frequency. Aspects and embodiments may also provide a filter including one or more reconfigurable resonator assemblies. Aspects and embodiments may support provision of a miniaturised coaxial resonator which is configured to simultaneously achieve frequency tenability whilst retaining a high quality factor and high power handling ability.

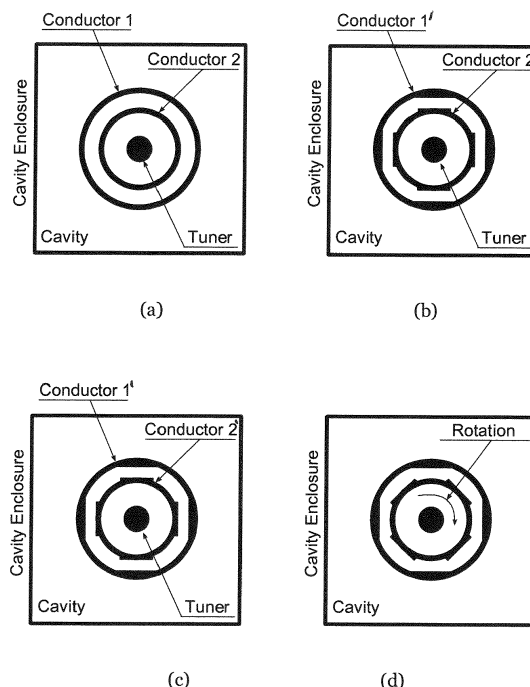


Figure 3

DescriptionFIELD OF THE INVENTION

5 **[0001]** The present invention relates to a reconfigurable resonator assembly and filters formed from such resonator assemblies.

BACKGROUND

10 **[0002]** Filters formed from coaxial resonators are widely used in data transmission systems and, in particular, telecommunications systems. In particular, filters formed from such resonators are often used in base stations, radar systems, amplifier linearization systems, point-to-point radio and radio frequency (RF) signal cancellation systems. For high to medium power base station filter applications, with an emphasis on the lower-end of the frequency spectrum (for example, 15 700 MHz) the physical volume and weight of RF hardware equipment poses significant challenges in relation, for example, to cost and deployment to network equipment manufacturers and network providers. Such challenges arise as a consequence of the fact that RF system electrical requirements may impose stringent specification requirements on a filter electrical performance, for example, isolation requirements in duplexers or out of band performance). Meeting such challenges typically results in increased physical size and insertion loss, but may also increase cost in relation to manufacture, assembly, tuning and similar activities.

20 **[0003]** Although filters tend to be chosen or designed depending on a particular application, there are often certain desirable characteristics common to all filter realisations. For example, the amount of insertion loss in the pass band of a filter ought to be as low as possible, whilst the attenuation in the stop band should be as high as possible. Furthermore, in some applications the frequency separation between the pass band and stop band (guard band) may need to be very small, which can require filters of high order to be deployed in order to achieve such a specific requirement. Even though 25 increasing the order of the filter increases the attenuation in the stop-band, it inevitably increases the losses in the pass-band, for example. Thus requirements for high order filters are typically followed by an increase in cost due to a greater number of components and an increase in the need for space which is often at a premium in telecommunications implementations such as those listed above.

30 **[0004]** In addition to requirement relating to low insertion loss, factors such as power handling capability, miniaturisation and tunability of a resonator and filters built of resonators are also of great importance. Power handling capability of a resonator or filter depends upon energy density of electromagnetic (EM) fields inside a cavity of a filter. In general, the greater the energy density of the EM fields, the lower the power handling capability. Since miniaturisation of a filter cavity inherently increases the energy density of EM fields, in general, miniaturisation results in reduced power handling capability.

35 **[0005]** Furthermore, it is often desirable that filters exhibit a degree of tenability; that is to say, that a filter has an ability to vary its frequency of operation and percentage bandwidth. Tunability may be highly desired in a resonator or filter arrangement, especially if variations in the operating frequency and bandwidth of the filter do not significantly deteriorate other important filter parameters such as pass-band loss and rejection.

40 **[0006]** It is desired to provide a cavity assembly which can be used in a filter to address some of the issues currently being faced in filter design.

SUMMARY

45 **[0007]** A first aspect provides a reconfigurable resonator assembly comprising: a resonator enclosure which defines a resonator cavity, a signal feed and a resonant structure, the resonant structure being located within the resonator cavity and arranged to receive a signal from the signal feed; the resonant structure comprising: a tuning member and first and second elongate elements, said first and second elongate elements having an overlap region along their length and arranged to define a volume in the overlap region between an inner surface of one of the elongate elements and an outer surface of the other of the elongate elements; the first and second elements being reconfigurable within the 50 cavity between: a first position in which a first volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a first frequency; and a second position in which a second volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a second frequency.

55 **[0008]** The first aspect recognises that design and assembly level re-configurability may be of particular use to operators within the radio frequency hardware sector. In particular, there is often a need to adjust radio frequency (RF) hardware according to particular product specifications. Particularly in relation to RF hardware used in the telecommunication industry, there may be a need to adjust hardware to be suited to different clients in different countries. Such adjustments may typically involve only a small difference in the frequency of operation of RF hardware, but typically require a complete re-design and re-manufacture. Such re-designing and re-manufacturing costs time and money. The first aspect recog-

nises that a product could be produced which has fewer frequency constraints. In particular, the first aspect recognises that it may be possible to provide a "universal" RF hardware component which may be adjusted using only minor physical changes to provide a product according to a different product specification. That different product specification may be achieved, according to the first aspect, relatively quickly and with limited extra cost.

[0009] The first aspect recognises that a resonator which is configured and operable at assembly level to provide a wide tuning range, with the possibility of covering two particular frequency bands (for example, 650 to 750 MHz and 850 to 950 MHz), is highly desirable.

[0010] Figure 1 illustrates schematically in plan and side view a conventional combline resonator. The combline resonator shown in Figure 1 includes a post fabrication tuning element in the form of a screw. Such conventional coaxial resonators are capable of providing a wide tuning range when compared to other filter technologies, but cannot achieve adequate wide tuning performance. The first aspect may provide a coaxial cavity resonator which is flexible and versatile, thereby allowing such resonators to be used in filters having different frequency specifications.

[0011] The first aspect also recognises that post fabrication reconfigurability may be of particular use within the RF hardware community. It is often the case that RF filters and/or duplexer hardware are produced in large quantities to allow for stockpiling and subsequent use in a variety of RF applications. It is also likely, however, that such stockpiling can lead to an excess of inappropriate RF filters and duplexers. Aspects and embodiments may provide a resonant cavity which supports a post fabrication process that can be used to reconfigure the RF resonant cavity and thereby allow for re-use of RF filter and/or duplexer components to comply with a new product specification where appropriate. In the telecommunications sector, many filter specifications are similar in terms of filter bandwidth and return losses. Aspects and embodiments may be operable to support such post-component-fabrication reconfiguration and may therefore allow for the provision of reconfigurable filters.

[0012] Aspects and embodiments described in detail herein may provide a resonant assembly and filter formed from such resonant assemblies in which significant consideration has been given to miniaturisation and power handling, so that assembly level reconfigurability and post fabrication reconfigurability do not impose additional problems with regard to the electrical performance of the resonant assembly or filters formed from such resonant assemblies. In particular, for example, consideration has been given to passive intermodulation (PIM) and other similar phenomena.

[0013] The reconfigurable resonator assembly may comprise a resonator enclosure which defines a resonator cavity. The resonator enclosure may be formed from a solid conductive material, for example, a metallic material, or may comprise a metallic coating on a non-conductive material.

[0014] The reconfigurable resonator assembly may comprise: a signal feed and a resonant structure. The resonant structure may be provided within the resonator cavity to support resonance at a particular resonant frequency. The resonant structure is located within the resonator cavity and arranged to receive a signal from the signal feed. The resonant structure may be formed from one or more appropriately formed conductive elements. The resonant structure may be reconfigurable within the resonator enclosure.

[0015] The resonant structure may comprise: first and second elongate elements having an overlap region along their length and arranged to define a volume in the overlap region between an inner surface of one of the elongate elements and an outer surface of the other of the elongate elements. The nature of the volume or set of volumes "enclosed" between the inner surface of one elongate element and the outer surface of the other elongate element determines the coupling between the first and second elongate elements and, in turn, determines the resonant frequency supported by the resonant structure within the cavity of the resonant assembly. The resonator assembly further comprises: a tuning member. Accordingly, fine tuning of a resonator assembly, after assembly of components may be achieved.

[0016] The first and second elements may be reconfigurable within the cavity between: a first position in which a first volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a first frequency; and a second position in which a second volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a second frequency. The first and second concentric elements may be reconfigured at the point of construction of the resonant assembly or filter formed from such resonant assemblies, or maybe reconfigured in-situ when forming part of, for example, a filter. Reconfiguration may occur as a result of rearranging the same components. The first frequency and the second frequency may be different frequencies. The first frequency and the second frequency may be different frequency bands.

[0017] The first and second elongate elements may be concentric. The first and second elongate elements maybe substantially cylindrical.

[0018] In one embodiment, the first and second elements are rotatable with respect to each other, and reconfiguring between the first and second positions comprises: rotation of one of the first and second elongate elements with respect to the other. Accordingly, reconfiguration of the resonant assembly may be simple to achieve, whilst not changing the overall volume of the resulting resonant assembly.

[0019] In one embodiment, reconfiguring between the first and second positions comprises: changing a length of the overlap region. Accordingly, the volume "trapped" between the elongate resonant elements may be altered and the resonant frequency changed.

[0020] In one embodiment, reconfiguring between first and second positions comprises: changing a distance between the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements in the overlap region. Accordingly, the volume "trapped" between the elongate resonant elements may be altered and the resonant frequency changed.

[0021] In one embodiment, at least one of the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements has a non-uniform radius in said overlap region. Accordingly, rotation of one elongate element with respect to the other, particularly if the rotation does not occur around a common axis, or if the other element has a feature, for example, a polygon as a cross section, or includes an opening, the volume "trapped" between the elongate resonant elements may be altered and the resonant frequency of the resonant assembly changed.

[0022] In one embodiment, a portion of both the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements has a non-uniform radius in the overlap region. In one embodiment, at least one of the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements is substantially elliptical in cross section in the overlap region. In one embodiment, a portion of both the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements is substantially elliptical in cross section in the overlap region.

[0023] In one embodiment, at least one of the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements is a polygon in cross section in the overlap region. In one embodiment, a portion of both the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements is a polygon in cross section in the overlap region. Accordingly, by rotating one polygon with respect to another, the enclosed volume and therefore coupling between resonant elements may be altered, causing a change in resonant frequency of the resonant assembly.

[0024] In one embodiment, at least one of the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements includes at least one opening in the overlap region. The opening may comprise a hole, or series of holes. The opening may comprise crenellation of an open ends of one or both of the elongate elements.

In one embodiment, a portion of both the inner surface of one of the elongate elements and the outer surface of the other of the elongate elements includes at least one opening in the overlap region. Accordingly, by moving, or rotating one opening with respect to another opening the volume properly enclosed between the surfaces of the respective elongate members may be altered, thus changing the coupling between elongate elements.

[0025] In one embodiment, at least one of the first and second concentric elongate elements comprises a hollow portion into which a portion of the other of the first and second concentric elongate elements extends. Accordingly, the elongate elements may comprise substantially nested substantially cylindrical members in the region of overlap. The elongate elements maybe identical in shape in cross section, but different in radius. One or both of the first and second concentric elongate elements may comprise a hollow portion. In some arrangements, at least one of the first and second elongate elements, which may be substantially cylindrical, may further comprise an end wall provided for ease of mounting the element to an enclosure surface.

[0026] In some arrangements, the first and second concentric elements extend into the cavity from opposite surfaces of the resonator enclosure. Accordingly, such an arrangement may provide a mechanism for providing a resonator assembly which occupies a smaller overall volume than a coaxial resonator assembly comprising a single resonating element within a cavity, for a given frequency of operation.

[0027] 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.

[0028] A third aspect provides a method of providing a reconfigurable resonator assembly, the resonator assembly comprising: a resonator enclosure which defines a resonator cavity, a signal feed and a resonant structure, the method comprising: locating the resonant structure within the resonator cavity and arranging the resonant structure to receive a signal from the signal feed; the resonant structure comprising: a tuning member and first and second concentric elongate elements having an overlap region along their length and arranged to define a volume in the overlap region between an inner surface of one of the elongate elements and an outer surface of the other of the elongate elements; the first and second concentric elements being reconfigurable within the cavity between: a first position in which a first volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a first frequency; and a second position in which a second volume is defined in the overlap region and the resonant structure is configured to resonate within the cavity at a second frequency.

[0029] 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.

[0030] 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

[0031] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 illustrates in plan and in cross-section a conventional combline resonator including a post fabrication tuning element in the form of a screw;

Figures 2a and 2b illustrate schematically in plan and side view one embodiment of a miniaturised coaxial resonator. A resonant assembly such as that shown in Figures 2a and 2b may allow for increased flexibility to introduce assembly-level reconfigurable electrical performance;

Figures 3a to 3d illustrate schematically a comparison between a non-reconfigurable coaxial resonator and one possible arrangement for a miniaturised coaxial resonator having an extended tuning range. Figure 3a illustrates schematically in plan view the components of a non-reconfigurable miniaturised resonator; Figure 3b illustrates schematically in plan the main components of one arrangement of a reconfigurable resonator; the proposed resonator comprises a cavity enclosure, a cavity and three main elements: conductor 1', conductor 2' and a tuner. Conductor 1' protrudes into the cavity from one surface and conductor 2' protrudes into the cavity from an opposite surface of the cavity. The tuner may protrude into the cavity from either the same side as conductor 1' or the same side as conductor 2'. The two structural configurations shown schematically in Figures 3c and 3d allow for the resonator assembly to provide an extended tuning range at assembly level;

Figures 4a to 4d illustrate schematically in plan view an arrangement of a miniaturised coaxial resonator having an extended tuning range compared to a less reconfigurable miniaturised coaxial resonator. Figure 4a illustrates schematically in plan view a miniaturised resonator which is not reconfigurable to allow for an extended tuning range; Figure 4b illustrates schematically in plan view a proposed resonator in which conductors 1" and 2" have a substantially octagonal cross-section. It will be appreciated that such an octagonal cross-section need not be implemented on both sides of conductor 1" and conductor 2", it is only required that the inner side of the outer conductor and the outer surface of the inner conductor has such an octagonal cross-section, and the outer surface of the outer conductor and the inner surface of the inner conductor may be substantially circular or square in cross-section, or alike or any other similar cross-section; Figures 4c and 4d show schematically in plan view such a resonator arrangement in two distinct structural configurations which allow for an extended tuning range at assembly level;

Figures 5a to 5d illustrate schematically in side cross-section components of a miniaturised coaxial resonator which is configurable to provide an extended tuning range. Figure 5a illustrates schematically in side view a crenelated form of outer conductor; Figure 5b illustrates schematically in side view a second conductor having a crenelated portion; Figure 5c illustrates schematically a configuration of conductor 1'", conductor 2'" and a tuner within a cavity, according to a non-reconfigurable miniaturised coaxial resonator; and Figure 5d illustrates schematically in side view a cavity assembly in which crenelated conductors 1'" and 2'" are provided together with the tuner, and relative rotation of conductor 1'" and conductor 2'" may provide for two or more distinct structural configurations which allow for an extended tuning range to be provided by the resonant assembly at assembly level; and

Figure 6 illustrates schematically a process at assembly level according to which utilisation of an extended tuning range may be implemented; in particular, an arrangement of components of a resonant assembly at initial assembly is shown.

DESCRIPTION OF THE EMBODIMENTS

[0032] Before discussing the embodiments in any more detail, first an overview will be provided.

[0033] Resonant assemblies which address frequency tenability and/ or re-configurability are known. However, such arrangements typically do not balance various requirements desirable within a resonant assembly. For example, high quality factor and high power handling ability may be obtained at the expense of miniaturisation, or tunability may be obtained at the expense of high quality factor and power handling. In particular, for printed circuit board (PCB) filtering applications, typically, electronic tenability may be achieved using a varactor diode suitably connected to an open-ended part of a resonator. However, such an arrangement to provide electronic tunability comes at a heavy cost: power handling of such a resonator or filter formed from such resonant assemblies may be reduced due to poor intermodulation performance of the varactor diode. Furthermore, the insertion losses associated with such a resonator or filter are significantly increased (a low quality factor is provided) due to parasitic resistance of the varactor diode.

[0034] In relation to cavity filter technologies, there are no widely accepted means by which frequency tenability may be attained. Typical approaches incorporate an electronically controllable device within the cavity of a typical coaxial filter. The electronically controllable devices may typically be in the form of varactor diodes, in which case the cavity filter tends to exhibit the same problems as those described above in relation to a printed circuit board counterpart, or may take the form of microelectromechanical systems (MEMS). The problems associated with MEMS-based cavity filters are substantially similar to those described in relation to varactor diodes, with the exception that the power handling of a MEMS-based cavity filter is, to an extent, increased, while the tunable range is decreased, due to the existence of stray capacity between metallic contacts of a MEMS switch.

[0035] In relation to purely passive tuning arrangements, frequency tenability of a coaxial resonator at assembly level is substantially non-existent and the problem of reaching ability is normally addressed by redesigning a filter or duplexer from scratch.

[0036] In relation to post fabrication reconfigurability of coaxial cavity filter solutions, such reconfigurability is typically limited to the deployment of tuning screws. However, it will be appreciated that the provision of a tuning screw may not offer full reconfigurability such as that addressed by aspects and embodiments described in detail herein, since the frequency tuning capability of a tuning screw is limited. The capability of a tuning screw to re-tune a resonant assembly occurs since allowable tuning screw intrusion into a cavity is limited and, in practical terms, frequency tunability using tuning screws alone can potentially come at the expense of higher levels of passive intermodulation (PIM). Such phenomenon occurs as a consequence of the re-use of screws for fine-tuning of a filter.

[0037] It will be appreciated that post-fabrication reconfigurability, in accordance with aspects and embodiments described herein, maybe of significant importance in relation to filters and duplexers which can be reused at a different frequency operation. Provision of a completely different frequency of operation may occur when a filter or duplexer which was provided initially for one frequency of operation may then be used to operate in a different region or different country and therefore needs to be tuned for another frequency of operation. Provision of a simple tuning screw cannot provide such reconfigurability.

[0038] The basic concept behind aspects and embodiments described herein maybe explained in relation to Figure 2. Figure 2 illustrates schematically one possible miniaturised coaxial resonator arrangement. Figure 2a shows such a resonator arrangement in plan and Figure 2b shows such an arrangement from one side. The resonant assembly shown in Figures 2a and 2b comprises: a cavity enclosure which defines a cavity; a first conductor, a second conductor and a tuner.

[0039] The assembly shown schematically in Figures 2a and 2b may be considered to be a "miniaturized coaxial resonator". As shown in Figures 2a and 2b, a first conductor is configured to protrude into the cavity from one side or inner surface of the cavity enclosure. A second conductor is configured to protrude into the cavity from an opposite side or inner surface of the cavity enclosure. The tuner may be configured to protrude into the cavity either from the same side of the cavity enclosure as the first conductor or the opposite side, ie the same side as the second conductor. In the example shown in Figures 2a and 2b, three resonator elements: conductor 1, conductor 2 and the tuner, each having a different radius, extend into the cavity concentrically from mutually opposite sides of the resonant cavity enclosure and are configured so that at least a portion of the first and second conductors are brought to a close proximity of each other.

[0040] In the arrangement shown, the two resonators (conductor 1 and conductor 2) take the form of hollow resonant posts of different radii, which are arranged such that at least the tip of one hollow cylinder protrudes into the volume defined by the other hollow cylinder. The amount of the intrusion or overlap between the first and second resonating members, determines the amount of mutual electromagnetic coupling. That is to say, if the volume between the outer surface of one resonator and the inner surface of the other resonator, in the overlap region, changes, then the mutual electromagnetic coupling between the two resonators changes. It will be understood from the schematic representations of Figures 2a and 2b, that the frequency of operation of the resonator assembly is strongly dependent on the amount of overlap between the two conductors, conductor 1 and conductor 2, differences in their radii and difference in length of protrusion/ overlap between the two conductors.

[0041] The third resonator, the tuner, is provided to allow for additional coupling with, in the example shown, the second resonator element (conductor 2) and allows for fine adjustment of the resonant frequency. The third resonator, the tuner, may typically be in the form of a tuning screw which has a variable intrusion into the resonant cavity, and thus the three-resonator structure shown has a tunable frequency of operation. Aspects and embodiments recognise that it is possible to construct a resonant assembly which allows for reconfiguration of the first and second conductors with respect to one another, such that the mutual electromagnetic coupling between the first and second conductors is altered in a predictable manner. Some arrangements recognise that the reconfiguration of first and second conductors may be achieved by making use of rotation of one conductor in relation to the other. Rotation of one the conductors, may result in the amount of coupling between conductors 1 and 2 being adjusted, which in turn can result in a change of frequency of operation of the resonator assembly. Given that the two conductors (conductor 1 and 2 shown in Figures 2a and 2b) are typically assembled together to form the resonator assembly, it will be appreciated that it is possible to rotate one of the conductors with respect to the other in order to allow for assembly level re-configurability. Post-assembly tuning is still possible using

standard means such as a tuning screw (tuner, as shown in Figure 2a and 2b).

[0042] It will be understood that since both conductors shown in Figures 2a and 2b are axis-symmetric, the rotation of such an arrangement (without a length overlap change, for example) would not itself introduce a change in effective coupling between the first and second conductors and thus, according to some embodiments, the first and second conductors are shaped such that by introducing perturbations with respect to the angle of rotation of one conductor with respect to the other, adjustable coupling between the conductors is achieved.

[0043] Arrangements recognise that by adjusting, at assembly level, the configuration of a set of resonator assembly parts, it is possible to construct a resonator from identical parts which can operate at a different frequency according to a chosen assembly configuration.

[0044] It will be appreciated that various methods to change assembly configuration of components forming a resonator, and thus effective coupling between a first and second conductor, may be appropriate. For example, if using relative rotation of conductors as a means to change assembly configuration, one way to change effective electromagnetic coupling between conductors might be, for example, to use different centre axes in relation to each of the two conductors, and to change the cross-section of one of the two conductors to make it non-uniform, for example, ellipsoid. However, such a "different axes" approach may pose manufacturing issues, and alternative methods of changing assembly configuration may be more suited to efficient manufacturing methods, for example, modification of the two conductors along their length.

[0045] A general overview of possible assembly reconfiguration approaches is described with reference to Figure 3. Some alternative arrangements are described in relation to the remaining Figures.

[0046] Figure 3 illustrates schematically one possible miniaturized reconfigurable coaxial resonator which is configured to provide an extended tuning range. Figure 3a illustrates schematically a top view of conventional (non-reconfigurable) miniaturized resonator; Figure 3b illustrates schematically a top view of one possible reconfigurable resonator arrangement. The resonator of Figure 3b comprises: a cavity enclosure which defines a cavity, and three further main components: conductor 1', conductor 2', and a tuner. As shown in Figure 3b, conductor 1' is configured to protrude into the cavity from one side of the cavity enclosure and conductor 2' is configured to protrude into the cavity from an opposite side of the cavity enclosure. The tuner may protrude into the cavity either from the same side of the cavity enclosure as conductor 1 or from the opposite side.

[0047] Figures 3c and 3d demonstrate a first and second structural configuration of the components of the reconfigurable resonator of Figure 3b. Figures 3c and 3d illustrate schematically, in plan view, two distinct assembly level configurations that can allow a resulting resonator to provide an extended tuning range. That is to say, the resonator assembly may support a first resonant frequency in a first configuration and a second resonant frequency in a second configuration. The first and second resonant frequencies may be different.

[0048] As shown in Figure 3a, a conventional resonator is such that conductors 1 and 2 are of uniform circular cross-section, whereas the configuration shown schematically in Figure 3b is one in which the two conductors include targeted variations in their cross section so that it is no longer uniform. In Figure 3c and Figure 3d, it can be seen that the non-uniform nature of the cross section of the conductors means that rotation of conductor 2' around a common axis with respect to conductor 2' offers two assembly configurations of the components of the resonator assembly, each of which allows for a different distinct frequency band of operation of the resonator. The tuner shown can be used at a later stage (post-assembly) to provide fine-tuning of the resonator frequency. Figure 4a to 4d and 5a to 5d illustrate schematically alternative reconfigurable resonator arrangements according to which assembly level reconfiguration can allow for the components to be rearranged to support different resonant frequencies. Each arrangement is such that reconfiguration of components adjusts the overlap volume between conductors 1 and thus the effective electromagnetic coupling is changed.

[0049] In the arrangement shown schematically in Figure 4, the conductors 1" and 2" each have a cross section which allows for adjustment of overlap volume when one conductor is rotated with respect to the other. For example, in the arrangement shown in Figure 4, conductor 1" has an octagonal inner surface cross-section and the outer side of conductor 2" has an octagonal cross-section. Rotation of the conductors with respect to one another changes the overlap volume.

[0050] In Figure 4, it will be appreciated that the octagonal cross section of Figure 4b need not be implemented both the inner and outer surfaces of each of the conductors; it is only required as the inner side of the outer conductor and the outer surface of the inner conductor in the overlap region, and the remaining surfaces may, for example, have a circular or square cross section or similar.

[0051] It will be appreciated that in an arrangement such as that shown in Figure 4, sharp edges of the octagonal cross section regions of the conductors are designed to be mechanically smooth so as not to pose extra challenges with regards to power handling.

[0052] In the arrangement shown schematically in Figure 5, the overlap volume (and therefore frequency) adjustment is achieved by changing the length of the conductors 1'" and 2'" at different angular positions.

[0053] Table 1 illustrates simulated performance of the example resonator arrangements shown in Figures 3 and 5 when in each of their two distinct structural configurations. The results in Table 1 demonstrate the variation of resonant

frequency as a function of the rotation in the structural configuration, namely configurations 1 and 2 as shown in Figures 3c and 3d and 5c and 5d respectively.

Table 1: Simulated performance of resonators

The simulation structures do not include the tuner element.			
(Based on HFSS Eigenmode solver, (Au/Au) 5.4x10 ⁰⁷ S/m)).			
Resonator	Figure	Resonant frequency/Q-Factor configuration 1	Resonant frequency Q-Factor configuration 2
Example 1	Figure 3	863.0 MHz/3060	900.1 MHz/3157
Example 2	Figure 5	915.7 MHz/3040	1069.7 MHz/3390

[0054] In relation to the reconfigurable nature of the resonant assembly, at assembly level of a set of provided components, it will be appreciated that some arrangements maybe such that the angle of rotation between conductors may be fixed at two distinct points, for example, the volume max and min extreme points. Those extreme point positions may be highlighted on the hardware for the purposes of convenience and/or reduced assembly complexity. Alternatively, the relative rotation between conductor 1' and conductor 2' can be implemented in a smooth manner, allowing a particular implementation to use a required frequency supported by a volume somewhere between the two extremes.

[0055] It will be appreciated that a tuner is provided to support the performance of post-fabrication, post-assembly, fine tuning. Provision of a tuner allows a resonant assembly to support two extreme frequencies provided by the two configurations at assembly level (obtained by the rotation of conductors relative to each other) and fine tuning by use of the tuner can be supported at post fabrication stage. Typically the tuner will allow fine tuning in the vicinity of the extreme frequencies obtained at assembly level. For example, in one configuration of components at assembly level the resonator may be arranged to operate at the frequency of 650 MHz. When one conductor is rotated with respect to the other conductor, the resonator assembly may be arranged to operate at a frequency of 750 MHz. In each instance, the tuner will allow fine tuning in the range of +/- 5% of the nominal frequency of operation.

[0056] The power handling capability of a resonator such as those shown in Figures 3 to 5 is dependent strongly on the overlap length and gap distance between the two main conductors. Those dimensions not only determine the power handling capacity of the resonator but also the factor of miniaturization compared to "conventional" resonator technology. Thus, there is a degree of trade-off to consider when designing such assemblies. The more the resonator is miniaturized, the less the resonator power handling capacity is likely to be. Therefore, depending on intended application and power handling requirements, it is possible to use aspects and embodiments to miniaturize, for example, combine filter units. Furthermore, by changing a mechanical envelope, i.e. the overlap gap distance and length, it may be possible to produce similar electrical performance, i.e. resonant frequency and Q-factor.

[0057] Figure 6 illustrates schematically a process, at assembly level, that supports provision of a resonator assembly having an extended tuning range by means of allowing two configurations of resonator components. The process shown involves arranging assembly of a cavity housing, a cavity lid, two conductors and a tuner. The process illustrated allows for switching, at assembly level, between two structural configurations. For convenience the resonator assembly can be designed accordingly and the assembly of components may be fixed to allow for two distinct angular rotations, for example, 0 deg and 45 deg, of the conductors with respect to each other. Those distinct angular rotations may represent the greatest frequency tenability, or the min and max volume positions. Alternatively, the rotation of the two conductors may be substantially analogue and can be made in a non-fixed manner.

[0058] Atypical envisioned application scenario includes a mobile cellular operator, who has a definite plan to transition his services to a different frequency band sometime in the future, procuring cavity filters for his base stations. If the operator purchases conventional filters, the operator will have to purchase a second set of filters when he decides to transition to the new frequency band. In contrast, aspects and embodiments may eliminate a need to purchase a second set of filters, by providing a mechanism to support simple retuning of filters. In another possible application scenario, OEM's of mobile cellular base stations tend to stockpile cavity filters, rather than procure them in a built-to-order fashion. Retunability of stockpiled filters, albeit factory retunability (as opposed to field retunability, the technology for which is yet to be invented), without the need to open the filter up is greatly valued.

[0059] Aspects and embodiments may support provision of a miniaturised coaxial resonator which is configured to simultaneously achieve frequency tunability, and retention of a high quality factor and high power handling.

[0060] 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 maybe, 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.

[0061] 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.

[0062] 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.

[0063] 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 reconfigurable resonator assembly comprising: a resonator enclosure which defines a resonator cavity, a signal feed and a resonant structure,
said resonant structure being located within the resonator cavity and arranged to receive a signal from said signal feed; said resonant structure comprising: a tuning member and first and second elongate elements, said first and second elongate elements having an overlap region along their length and arranged to define a volume in said overlap region between an inner surface of one of said elongate elements and an outer surface of the other of said elongate elements;
said first and second elements being reconfigurable within said cavity between:
 - a first position in which a first volume is defined in said overlap region and said resonant structure is configured to resonate within said cavity at a first frequency; and
 - a second position in which a second volume is defined in said overlap region and said resonant structure is configured to resonate within said cavity at a second frequency.
2. A reconfigurable resonator assembly according to claim 1, wherein said first and second elements are rotatable with respect to each other, and reconfiguring between said first and second positions comprises: rotation of said one of said first and second element with respect to the other.
3. A reconfigurable resonator assembly according to claim 1 or claim 2, wherein reconfiguring between said first and second positions comprises: changing a length of said overlap region.
4. A reconfigurable resonator assembly according to any preceding claim, wherein reconfiguring between first and second positions comprises: changing a distance between said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements in said overlap region.
5. A reconfigurable resonator assembly according to any preceding claim, wherein at least one of said inner surface

of one of said elongate elements and said outer surface of the other of said elongate elements has a non-uniform radius in said overlap region.

6. A reconfigurable resonator assembly according to any preceding claim, wherein a portion of both said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements has a non-uniform radius in said overlap region.

7. A reconfigurable resonator assembly according to any preceding claim, wherein at least one of said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements is substantially elliptical in cross section in said overlap region.

8. A reconfigurable resonator assembly according to any preceding claim, wherein a portion of both said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements is substantially elliptical in cross section in said overlap region.

9. A reconfigurable resonator assembly according to any preceding claim, wherein at least one of said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements is a polygon in cross section in said overlap region.

10. A reconfigurable resonator assembly according to any preceding claim, wherein a portion of both said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements is a polygon in cross section in said overlap region.

11. A reconfigurable resonator assembly according to any preceding claim, wherein at least one of said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements includes at least one opening in said overlap region.

12. A reconfigurable resonator assembly according to any preceding claim, wherein a portion of both said inner surface of one of said elongate elements and said outer surface of the other of said elongate elements includes at least one opening in said overlap region.

13. A reconfigurable resonator assembly according to any preceding claim, wherein at least one of said first and second elongate elements comprises a hollow portion into which a portion of the other of said first and second elongate elements extends.

14. A reconfigurable resonator assembly according to any preceding claim, wherein said first and second elements extend into said cavity from opposite surfaces of said resonator enclosure.

15. 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;
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.

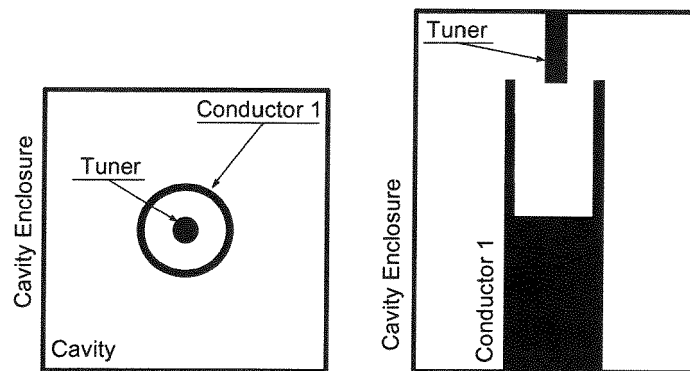


Figure 1

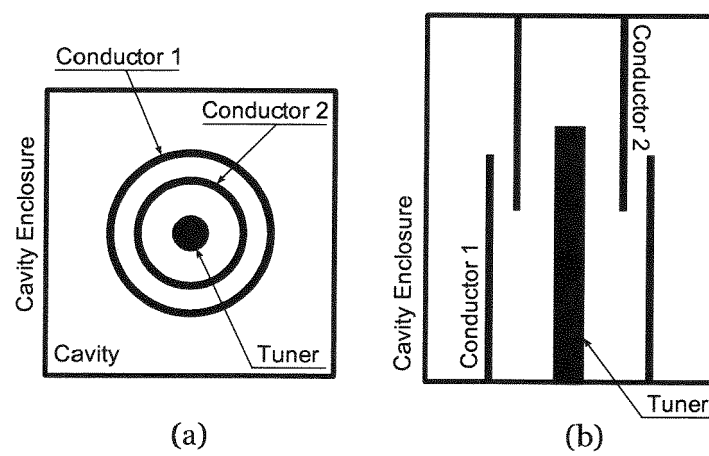


Figure 2

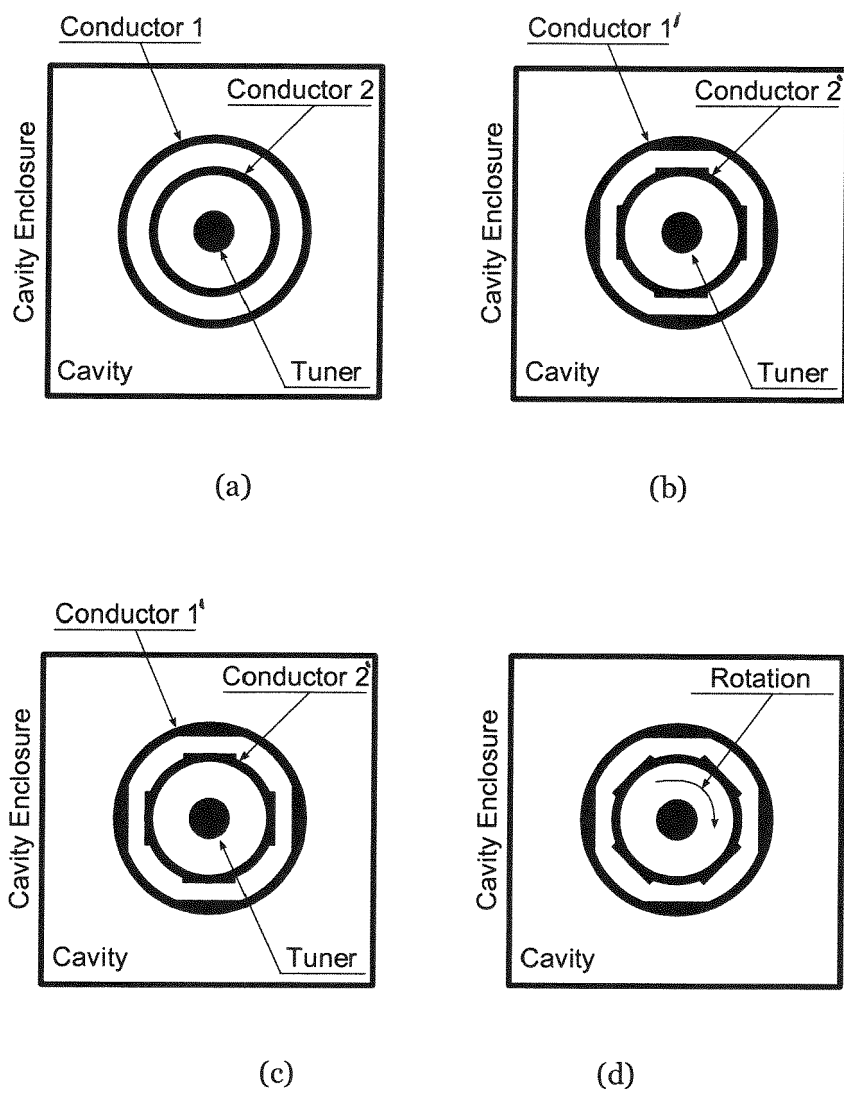


Figure 3

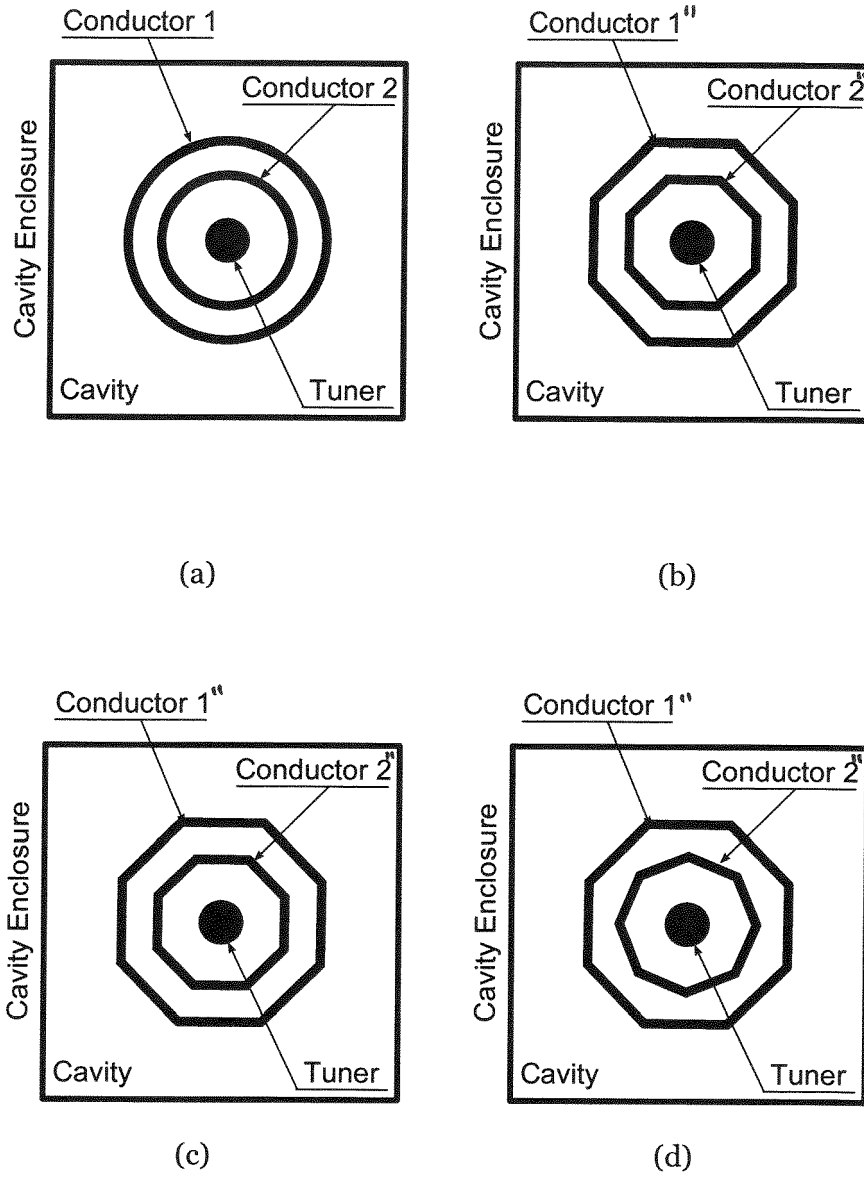


Figure 4

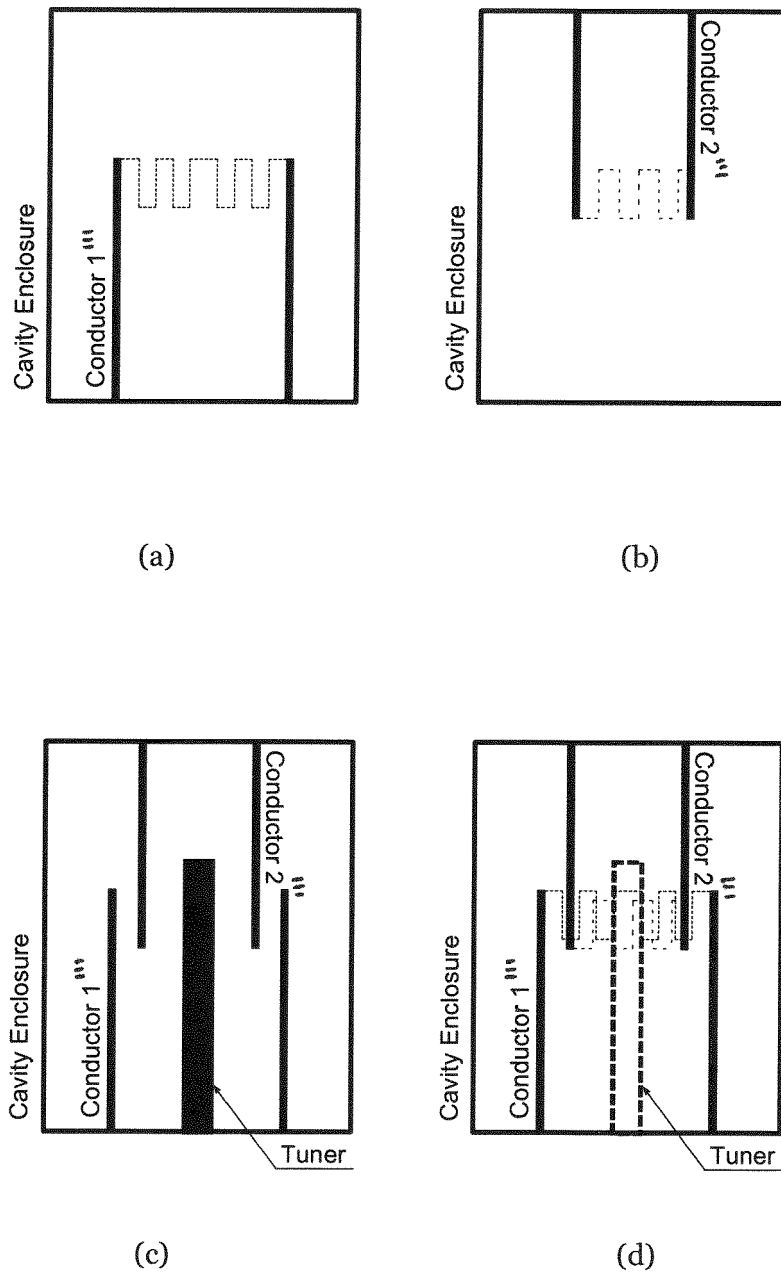


Figure 5

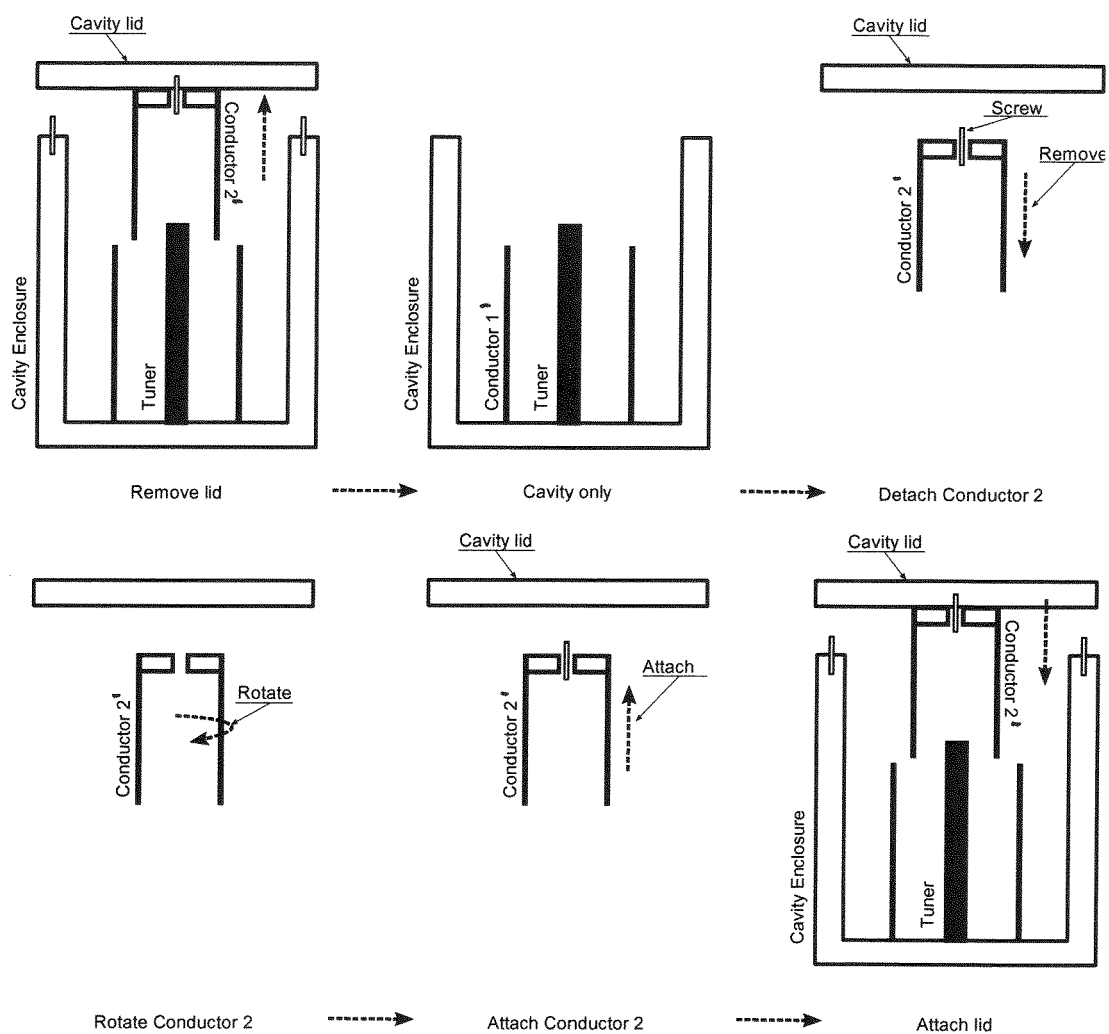


Figure 6



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X	EP 2 533 356 A1 (POWERWAVE FINLAND OY [FI]) 12 December 2012 (2012-12-12)	1-3, 13-15	INV. H01P7/04
Y	* paragraph [0023] - paragraph [0026]; figures 6,7 *	11,12	
Y	* paragraph [0034] - paragraph [0035]; figure 10 *		
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Place of search		Date of completion of the search	Examiner
The Hague		1 November 2016	Pastor Jiménez, J
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			

**ANNEX TO THE EUROPEAN SEARCH REPORT
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