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(71) Applicant: **ALCATEL LUCENT**
92100 Boulogne-Billancourt (FR)

(72) Inventors:
• **Doumanis, Efstratios**
Dublin, 15 (IE)

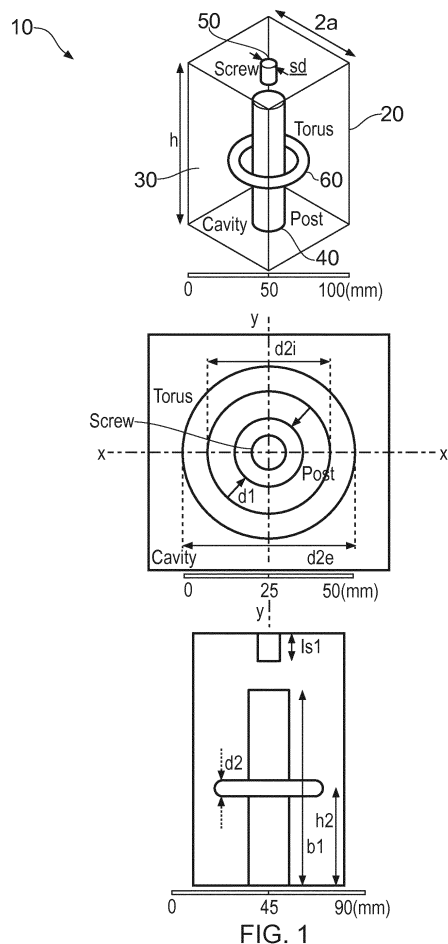
• **Pivit, Florian**
Dublin, 15 (IE)

(74) Representative: **Leppard, Andrew John et al**
Script IP Limited
Turnpike House
18 Bridge Street
Frome
Somerset BA11 1BB (GB)

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(54) **Coaxial resonator filter**

(57) A resonant assembly is disclosed. The resonator assembly, comprises: a resonator having a conductive resonance post surrounded by a conductive enclosure defining a cavity, the conductive resonance post being operable to filter a signal within a first frequency band, and a conductive resonance ring element positioned around the conductive resonance post, the conductive resonance ring element being operable to filter a signal within a second frequency band concurrently with the conductive resonance post filtering the signal within the first frequency band. Through this approach, it is possible to provide a single device which implements more than one independent resonance or filtering at the same time within the same cavity volume, allowing significantly smaller cavity filters to be built, which avoids the need to provide separate devices, one for each frequency. This is particularly convenient in resonant assemblies used in RF front ends which will often be required to receive signals at two or more different frequencies.



DescriptionFIELD OF THE INVENTION

5 **[0001]** The present invention relates to a resonant assembly.

BACKGROUND

10 **[0002]** Resonant devices are known. In low-frequency electronics, a resonant circuit contains a capacitor and a coil. The capacitor is used to store electrical energy and the coil stores magnetic energy. At resonance, energy stored in the resonant circuit is continuously converted between two states, swapping between capacitor and coil over time. At higher frequencies, transmission lines can resonate. A quarter-wavelength transmission line with one end grounded and the other end open can be seen as a combination of a capacitor and coil. Increasing the permittivity of the transmission line by using, for example, ceramic materials reduces the size of the resonant device. Resonant devices are often used in radio-frequency (RF) front ends. Each resonant device has its own characteristics, including its own resonance frequency. The resonance frequency is dependent on the characteristics of the device and, in particular, on the characteristics of the mixtures of various materials making up the device.

15 **[0003]** It is desired to provide an improved resonant device.

20 SUMMARY

[0004] According to a first aspect, there is provided a resonator assembly, comprising: a resonator having a conductive resonance post surrounded by a conductive enclosure defining a cavity, the conductive resonance post being operable to filter a signal within a first frequency band, and a conductive resonance ring element positioned around the conductive resonance post, the conductive resonance ring element being operable to filter a signal within a second frequency band concurrently with the conductive resonance post filtering the signal within the first frequency band.

25 **[0005]** The first aspect recognizes that conventional resonators such as, for example, a transverse electromagnetic (TEM) combine resonator consist of a metallic cavity enclosure (with a generally circular shaped or rectangular shaped cross section) with a cylindrically-shaped metallic post at the centre of the circular/rectangular cavity grounded at one side and open-circuit at the opposite side. Each of these resonators is dimensioned to provide a resonance at a particular desired frequency. However, the first aspect recognizes that it is possible to reuse the cavity in order to provide a resonator which resonates at more than one particular desired frequency so that more than one resonance can be achieved concurrently or simultaneously.

30 **[0006]** Accordingly, a resonator assembly may be provided. The resonator assembly may comprise a resonator. The resonator may have a conductive resonance post. The conductive resonance post may be surrounded by a conductive enclosure which defines a cavity. The conductive resonance post may filter a signal at a first frequency band. That is to say, the conductive resonance post may resonate at a frequency within a first frequency band, thereby attenuating frequencies of the signal outside of the first frequency band. The resonator may also have a conductive resonance ring element. The conductive resonance ring element may be positioned or located around the conductive resonance post. The conductive resonance ring may filter a signal within a second frequency band. That is to say, the second conductive resonance ring may resonate at a frequency within the second frequency band, thereby attenuating frequencies of the signal which fall outside of the second frequency band. The filtering of the signals within the first frequency band and the second frequency band may occur simultaneously or concurrently so that the filtering within the two frequency bands occurs at the same time using a single resonator. Through this approach, it is possible to provide a single device which implements more than one independent resonance or filtering at the same time within the same cavity volume, allowing significantly smaller cavity filters to be built, which avoids the need to provide separate devices, one for each frequency. This is particularly convenient in resonant assemblies used in RF front ends which will often be required to receive signals at two or more different frequency bands.

35 **[0007]** In one embodiment, the conductive resonance ring element is electrically isolated from the conductive enclosure. Hence, the conductive resonance ring element may be insulated from the conductive enclosure. This facilitates the resonance of the conductive resonance ring element.

40 **[0008]** In one embodiment, the resonator comprises an insulating mounting operable to retain the conductive resonance ring element within the conductive enclosure. It will be appreciated that a variety of different mounting structures may be utilized to retain the conductive resonance ring element in place.

45 **[0009]** In one embodiment, the conductive resonance ring element has a length corresponding to a wavelength and/or less at a frequency within the second frequency band. Accordingly, the conductive resonance ring element is dimensioned to have an effective electrical length of a single wavelength at a selected frequency within the second frequency band. This enables a stationary standing wave at the selected frequency to be established within the conductive enclosure

for the conductive resonance ring element. The length can be adjusted to less than a wavelength by capacitively loading the conductive resonance post.

[0010] In one embodiment, the conductive resonance post upstands from a first face of the conductive enclosure, other faces of the conductive enclosure upstand from the first face and the conductive resonance ring element extends between the other faces. Accordingly, the conductive resonance post may extend from one face of the conductive enclosure. The conductive resonance post may be electrically connected to the conductive enclosure. Other faces of the conductive enclosure may also upstand from the first face and the conductive resonance ring may extend or be dimensioned between those other faces.

[0011] In one embodiment, the conductive resonance post upstands from a first face of the conductive enclosure, other faces of the conductive enclosure upstand from the first face and the conductive resonance ring element extends between the other faces. Accordingly, the conductive resonance ring element may be orientated or positioned transversely to the elongate access of the conductive resonance post.

[0012] In one embodiment, the plane is orientated orthogonally to the first axis. Accordingly, the conductive resonance ring may be positioned or orientated orthogonally with respect to the elongate axis of the conductive resonance post. It will be appreciated that the orientation may not need to be completely normal to the elongate axis but may also be orientated at non-normal angles.

[0013] In one embodiment, the conductive resonance ring element is located concentrically with the conductive resonance post. Accordingly, the conductive resonance ring element may at least partially surround the conductive resonance post. In one embodiment, the conductive resonance ring element is located coaxially with the conductive resonance post.

[0014] In one embodiment, the conductive resonance ring element comprises at least a portion of one of an annulus, a torus and a polyhedron. Accordingly, the conductive resonance ring element may comprise a portion, sector or segment of an annulus, a torus or other ring-shaped polyhedron structure.

[0015] In one embodiment, the conductive resonance post is electrically connected with the conductive enclosure.

[0016] In one embodiment, the conductive resonance post has a length corresponding to a quarter-wavelength and/or less at a frequency within the first frequency band. Accordingly, the conductive resonance post is dimensioned to have an effective electrical length of a quarter wavelength at a selected frequency within the first frequency band. This enables a stationary standing wave at the selected frequency to be established within the conductive enclosure for the conductive resonance post. The length can be adjusted to less than a quarter wavelength by capacitively loading the conductive resonance post.

[0017] In one embodiment, frequencies within the second frequency band are greater than frequencies within the first frequency band. Accordingly, the second frequency band encompasses frequencies which are higher than the frequencies in the first frequency band.

[0018] In one embodiment, harmonics of the frequencies within the first frequency band fail to coincide with the frequencies within the second frequency band. By preventing the harmonics of the different frequency bands from overlapping, coupling between the conductive resonance post and the conductive ring is reduced. This helps to improve isolation between the two filtered signals. For example, 700MHz and 2100 MHz are used, the harmonics of the 700 MHz can coincide with the usable second frequency band. Also, coupling between the first frequency band elements and the second frequency band elements can occur.

[0019] In one embodiment, the conductive resonance ring element is operable to filter two signals within a second frequency band concurrently with the conductive resonance post filtering the signal within the first frequency band. Accordingly, the conductive resonance ring may filter one signal in a first mode, whilst concurrently filtering another signal at a second mode. Hence, three signals can be filtered concurrently.

[0020] In one embodiment, the resonator comprises a pair of feeds positioned orthogonally with respect to each other, each operable to convey one of the two signals to the conductive resonance ring element.

[0021] In one embodiment, the resonator comprises at least one further conductive resonance ring element positioned around the first conductive resonance post, each further conductive resonance ring element being operable to filter a signal within a respective frequency band concurrently with the conductive resonance post filtering the signal within the first frequency band. Accordingly, the additional conductive resonance ring elements may be provided, each of which may also filter signals concurrently within associated frequency bands. This enables yet more filtering to occur within the same resonator space.

[0022] In one embodiment, each further conductive resonance ring element is operable to filter a signal within one of the second frequency band and another frequency band concurrently with the conductive resonance post filtering the signal within the first frequency band.

[0023] In one embodiment, the resonator assembly comprises a plurality of the resonators adjacently located and having shared portions of the conductive enclosure. Accordingly, individual resonators may be positioned together to provide a resonant assembly having desired filtering characteristics.

[0024] In one embodiment, the shared portions of the conductive enclosure comprise at least one aperture to facilitate

coupling between adjacent resonators.

[0025] In one embodiment, one of the plurality of resonators comprises a first signal feed operable to convey its signal to the resonance post of that resonator and another of the plurality of resonators comprises a second signal feed operable to convey its signal to the conductive resonance ring element. By providing individual signal feeds in different cavities, the isolation between the signals is improved.

[0026] 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.

[0027] 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

[0028] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 illustrates the arrangement of a resonator according to one embodiment;

Figures 2A to 2C illustrate the electric field intensity distribution at resonance;

Figures 3A and 3B illustrate the surface current density distribution at resonance;

Figure 4 illustrates the arrangement of coupling feeding pins used to couple signals to or from the resonator;

Figure 5 illustrates a plurality of resonators arranged together as a first filter; and

Figure 6 illustrates a plurality of resonators arranged together as a second filter.

DESCRIPTION OF THE EMBODIMENTS

Overview

[0029] Before discussing the embodiments in any more detail, first an overview will be provided. Embodiments provide a resonator assembly having one or more resonators or filters. Each of the resonators or filters is a dual-frequency resonator or filter which is able to concurrently or simultaneously filter signals within different frequency bands. For example, in a dual-frequency arrangement, the same or different signals may be provided to the resonator and the signals are filtered to exclude or reject all but a first frequency band which passes through, whilst the same or another signal is filtered simultaneously or concurrently to exclude or reject all but another frequency band which passes through.

[0030] The resonator comprises a conductive enclosure within which is provided with a conductive resonance post which filters within the first frequency band as well as a conductive resonant ring element which filters within a second frequency band. The conductive resonance post may have any suitable cross-section which need not be circular. Typically, the conductive resonance post is dimensioned to have a length which matches a quarter of the wavelength of a frequency within the first frequency band such that a standing wave is established within the structure at the selected resonant frequency. The conductive resonance ring element is typically positioned around the first conductive resonance post in order to re-use the same space within the conductive enclosure to perform the dual-frequency filtering, which provides for a smaller and more lightweight arrangement than would be required if two different resonator or filter assemblies were provided, one for each filtering function. Typically, the conductive resonance ring element is dimensioned to have a length which matches the wavelength of a frequency within the second frequency band such that a standing wave is established within the structure at the selected resonant frequency. This length of the conductive resonance ring element provides for an improved Q-factor of the device compared to other arrangements, which significantly reduces insertion losses resulting from use of the device.

[0031] In embodiments where the configuration of the resonator is symmetric in multiple planes, the opportunity for coupling between adjacent resonators is increased, which simplifies the construction of the device and provides increased opportunities for the location of tuning mechanisms which are used to calibrate the resonance characteristics of the conductive resonance structures and control the resultant filtering characteristics.

Resonator Configuration

[0032] Figure 1 illustrates the arrangement of a resonator, generally 10, according to one embodiment. An enclosure 20 is provided which defines a cavity 30. In this example, the enclosure 20 is a cuboid having six faces. However, it will be appreciated that the enclosure 20 may have any suitable configuration and may be a non-cuboid. The enclosure 20 is made of a conductive material, such as a metal, or may be made of another material which is then coated with a conductive material.

[0033] A conductive resonance post 40 is provided which extends into the cavity 30 from a face of the conductive enclosure 20. The conductive resonance post 40 is electrically connected to the conductive enclosure 20. The conductive resonance post 40 is dimensioned to have a length b_1 which corresponds with a half wavelength of a frequency within the frequency band to be filtered and may have any suitable cross-section. In other words, the length b_1 is selected to have an effective electrical length which corresponds to a quarter of the wavelength of a frequency within the frequency band to be filtered. A tuning screw 50 is provided which is coaxially located, aligned with an elongate access of the conductive resonance post 40, and retained by and protruding from a face of the conductive enclosure 20. Rotation of the tuning screw 50 adjusts its length LS_1 within the cavity 30, which provides for fine-tuning of the resonance frequency of the conductive resonance post 40.

[0034] A conductive resonance ring 60 is provided which is placed around the conductive post 40. The conductive resonance ring 60 again may be metallic or coated with a conductive coating. The conductive resonance ring 60 is dimensioned to have a circumference which matches a wavelength of a frequency within a second frequency band. Typically, the second frequency band encompasses frequencies which are higher than those of the first frequency band. In a similar manner to the conductive resonance post 40, a tuning screw is provided (not shown) which is used to provide fine adjustment of the resonance frequency of the conductive resonance ring 60.

[0035] A mounting (not shown) is provided in order to retain the conductive resonance ring 60 in place. This is typically achieved by a non-conductive pin or clip which mounts the conductive resonance ring 60 using either or both of a face of the conductive enclosure 20 or the conductive post 40. Alternatively, the conductive ring 60 may be mounted on plastic and the plastic may be retained as mentioned above.

[0036] Hence, this arrangement utilises the physical space provided by the single rectangular cavity 30 of a coaxially cavity resonator to include an additional metallic torus which operates at a full-wavelength resonance at the middle of the rectangular cavity 30. It will be appreciated that the vertical position of the conductive resonance ring 60 can be varied. Providing the conductive resonance ring 60 introduces an additional electromagnetic resonance at a higher frequency.

[0037] It will be appreciated that the conductive resonance ring 60 and the conductive resonance post 40 may also be formed from dielectric high permittivity material. Also, although the conductive resonance ring 60 is shown as a torus, it will be appreciated that other configurations are possible, such as a ring of fixed thickness (an annular ring), or even a square, rectangular, hexagonal or other (typically regular) polyhedral ring may be provided. Also, although a complete ring is shown it will be appreciated that less than a complete ring may be provided. For example, a segment of the ring may be omitted, provided that the resultant structure was still dimensioned to resonate at a full wavelength.

[0038] Typical dimensions (in mm) of the resonator 10 are: $2a=72$, $h=120$, $b_1=93$, $d_1=20.4$, $1s_1=13$, $sd=d_1/2$, $h_2=b_1/2$, $d_2=7.7$, $d_{2e}=44.5$, $d_{2i}=36.8$.

[0039] In embodiments, additional conductive resonant rings may be provided, each of which is positioned around the conductive post 40. Those additional conductive resonant rings may be dimensioned identically or differently to the conductive resonant ring mentioned above. This enables additional frequencies to be filtered (where the conductive rings are dimensioned differently) or multiple signals to be simultaneously filtered at the same frequency (where the conductive rings are identical). Again, appropriate apertures and feeds will be provided in order to achieve a filter having the desired characteristics.

Operation

[0040] The structural arrangement of the resonator 10 undergoes two electromagnetic resonances at two distinct frequency bands. The conductive resonance post 40 resonates at a lower frequency band (f_1) and the conductive resonance ring 60 resonates at a higher frequency band (f_2). The combination of the conductive resonance post 40 and the conductive resonance ring 60 means that the conductive post resonance 40 and the conductive resonance ring 60 resonate at slightly different frequencies than if they were alone within the cavity 30. However, this slight change in frequency can be accommodated by the dimensioning of these structures and by the tuning screws.

[0041] This basic structure, therefore, is able to receive one or more signals to be filtered concurrently. For example, a signal may be provided which is coupled to the conductive resonance post 40 which then filters that signal to reject those frequencies which are outside of its resonant frequency or its harmonics. Likewise, the same or one or more different signals may be provided to the conductive resonance ring 60 which again rejects those frequencies which are outside of its resonant frequency or its harmonics.

[0042] Due to the symmetric nature of the conductive resonance ring 60, the conductive resonance ring 60 is able to receive two signals (provided that the signal feeds are located orthogonally with respect to each other) in order to operate the conductive resonance ring 60 in a dual mode. This enables the conductive resonance ring 60 to receive two independent signals and to filter them concurrently.

[0043] Figures 2A to 2C illustrate the electric field intensity distribution at resonance at the lower frequency (shown in Figure 2A) and at the two degenerate modes (mode 1 and mode 2) at the higher frequency (Figures 2B and 2C). As

can be seen, the electric fields for the two higher frequency modes are orthogonal and so this can be exploited to provide simultaneous dual-mode filtering using a single conductive resonance ring 60.

[0044] Figures 3A and 3B illustrate the surface current density distribution at resonance at the higher frequency wavelength. Figure 3A illustrates mode 1, whilst Figure 3B illustrates mode 2. Again, it can be seen that the current density distribution is again orthogonal for the two modes.

Operational Performance

[0045] An Eigenmode analysis tool was used to calculate the resonant frequency and Q-factor of the resonator 10. Ohmic losses are included in these simulations; aluminium was simulated for the cavity walls and copper for the conductive resonance post 40 and conductive resonance ring 60. The dimensions of the simulated structures are those mentioned above. Table 1 shows the results.

Table 1

Resonator	Mode 1 f_o (MHz)	$Qu(Cu)$	Mode 2 f_o (MHz)	$Qu(Cu)$
Conductive resonance post 40	695.200	6390	2004.570	11095
Conductive resonance ring 60	694.778	5901	1796.65/1796.84	7913/7943

[0046] As can be seen, for a resonator having the conductive resonance post 40 alone, this resonates at 695.200 MHz and has a harmonic at 2004.570 MHz. For the conductive resonance post 40 and conductive resonance ring 60 arrangement, the resonant frequency of the conductive resonance post 40 remains virtually unchanged at 694.778 MHz, whilst the first mode of the conductive resonance ring 60 resonates at 1796.65 MHz, with the second mode of the conductive resonance ring 60 resonating at 1796.84 MHz. The resonant frequency of the conductive resonance ring 60 (around 1.8 GHz) differs sufficiently from the harmonic frequency of the conductive resonance post 40 (around 2 GHz) sufficiently enough to prevent resonant coupling between the two structures.

[0047] Hence, it can be seen that the results demonstrate that two resonant modes can be supported and that these closely correspond to the resonant modes of the individual standalone resonant modes of the low band and high band resonators. Although the Q-factor of the low-frequency resonance is decreased (by around 7.7%) the resonance frequency of the conductive resonance post 40 remains substantively unchanged. The Q-factor of the high frequency resonance is very high (almost 8000). This is due to the large electrical size of the cavity and the large area/ volume provided by the conductive resonance ring 60 that is used to store energy.

[0048] One limitation of this arrangement is that the ratio of the low and high frequencies cannot be close to unity (i.e., the two frequencies cannot be very similar) since under those circumstances the resonance of the two structures will begin to interact and cannot be decoupled as required for the distinct filtering functions to be achieved.

Signal Feed

[0049] Figure 4 illustrates the arrangement of coupling feeding pins used to couple signals to or from the conductive resonance post 40 and the conductive resonance ring 60. As can be seen in Figure 4A, a capacitive coupling 70 is provided to couple the signal to the conductive resonance post 40. Likewise, a capacitive coupling 80 is provided to couple the signal to the conductive resonance ring 60. As shown in Figure 4B, in an alternative configuration, a direct coupling 90 is provided to couple the signal to the conductive resonance post 40. As also shown in Figure 4B, a direct coupling 100 may be provided alternatively or in addition to the capacitive coupling 80, in order to couple the same or another signal to the conductive resonance ring 60 which will then resonate in the alternate mode to that caused by the signal coupled from the capacitive coupling 80.

High Order Filter - First Arrangement

[0050] In order to produce a high order filter with the required filtering characteristics, a plurality of resonators may be arranged together, as shown in Figure 5. As can be seen, four resonators are provided which are arranged adjacent to each other. A first resonator 10A comprises an arrangement similar to that described above, with a conductive resonance post 40 surrounded by a conductive resonance ring 60. A conductive feed 90 couples with the conductive resonance post 40, whilst a capacitive feed 80 couples with the conductive resonance ring 60. A tuning screw (not shown) is provided to control the resonant frequency of the conductive resonance post 40, whilst a tuning screw 110 is provided for controlling the resonant frequency of the conductive resonance ring 60.

[0051] Another resonator 10A' is provided which has a mirror configuration to that of resonator 10A.

[0052] Interposed between resonators 10A and 10A' are two resonators 10B. These are of identical configuration to the resonators 10A and 10A', but without the couplings 80 and 90.

[0053] Apertures (not shown) are formed in the walls of the conductive enclosure to facilitate electromagnetic coupling between adjacent resonators.

[0054] In operation, a signal can be provided to one of the two capacitive feeds 80 and a filtered signal is provided by the other. The signal couples from the capacitive feed 80 into the adjacent conductive resonance ring 60 and this induces resonance in the conductive resonance ring 60 of the adjacent resonator 10B, which induces resonance in the conductive ring of the adjacent resonator 10B, which induces resonance in the conductive ring of the adjacent resonator 10A' and a filtered signal is provided out of the capacitive feed 80.

[0055] Likewise, a signal may be provided via the conductive feed 90 to the conductive resonance post 40 and a filtered signal is provided by the other conductive feed 90.

[0056] It will be appreciated that the filter may be bi-directional, in that the signal may be fed into either coupling and the filtered signal obtained from the other coupling. This arrangement enables simultaneous filtering at two frequency bands to be achieved either on the same or different signals.

High Order Filter - Second Arrangement

[0057] Figure 6 illustrates an example arrangement of a high order filter. This arrangement illustrates how the resonators can be arranged as an array and shows how the filtered signals can follow different paths through the high order filter. For example, assuming that the signal to be filtered at the low frequency is provided via the conductive feed 90 to the conductive resonant post labelled 1, apertures are formed in the conductive enclosure so that coupling occurs in the sequence illustrated by the numbering of the conductive posts; namely, that the signal passes from the conductive resonant post labelled 1 to the conductive resonant post labelled 2, then 3, then 4, then 5 and then 6. The filtered signal is then retrieved via the conductive feed 90.

[0058] Likewise, a signal is provided by the capacitive feed 80 to the conductive ring labelled 1, and then apertures in the conductive enclosure then facilitate coupling in the order 1, 2, 3, 4, 5, with the filtered signal being provided via the capacitive feed 80.

[0059] Providing the couplings for the different frequencies in the cavity of different resonators helps to improve the isolation or decoupling between the resonators.

[0060] It will be appreciated that, again, conductive couplings may be provided to the conductive rings in order to support the second mode, thereby enabling a further signal to be filtered at the high frequency concurrently with the other two signals.

[0061] Hence, it can be seen that these arrangements enable two electromagnetic resonances to be achieved concurrently at distinct frequencies in a single physical volume within a single metallic enclosure using coaxial cavity filter technology. A conductive post and conductive ring are provided in a single cavity. The centre post resonates at a quarter wavelength for the low frequency resonance, and the conductive ring resonates at full wavelength for the high frequency resonance. The spatial separation of the resonance field distribution allows for independent control of input/ output coupling/tuning/inter-resonator coupling. The arrangement is fully symmetric in two orthogonal planes which provides for full physical symmetry of the structure which provides for increased flexibility when building a filter by locating individual resonant devices adjacent each other.

[0062] Hence, it can be seen that these arrangements provide for a reduced physical size compared to providing two sets of filters, one for each frequency, since the two distinct resonant frequencies can co-exist within the same resonator at the expense of slightly higher manufacturing costs and design complexity. Arrangements support very high Q-factor filtering at the high frequency, which helps to minimise insertion losses. This arrangement provides for cost reduction compared to the cost of the design and fabrication of two separate filters. Also, size reduction is achieved since no additional physical space is required for a second filter. Instead, the two filters can be incorporated into the space already used for the low frequency filtering.

[0063] Further, these arrangement provide the following benefits and advantages:

1. Cost reduction. The additional cost of design and fabrication (in same or other implementation technology, e.g., microstrip) for two separate high frequency filters as compared to the proposed solution is significantly higher.
2. Size reduction. No additional physical space is required for the second high frequency filter (f2). It can be incorporated in the low band resonant structure (at f1) without any additional physical space requirement.
3. High Q-factor (at f2) with no additional physical space. The additional physical space of the combined resonant structure allows for increase in the quality factor at the high frequency regime (f2). This can allow for high performance filtering; required for narrow-band filter wireless telecommunication applications. The quality factors of the high frequency resonant structures are higher (represent lower ohmic losses) as compared with the standalone high

filtering quality factors in the conventional filtering solution.

4. In the conventional coaxial cavity technology, to achieve the two filtering functions two distinct physical cavities are required. A cavity is required to support the high frequency, f_2 . This cavity is conventional in the same technology substantially smaller than the cavity at f_1 . Thus, and due to the fact that additional physical space is inherent to the new resonant structure (as compared to the conventional case) at the high frequency, increase in the high power handling capabilities for terrestrial communication systems can be pursued.

[0064] Advantages as compared to an arrangement of dual quarter wavelength conductive resonant posts within the same cavity:

1. Increased Q-factor and thus minimized ohmic loss for the high frequency filtering (as high as 82 %). This is due to the fact that equal amount of electromagnetic energy is stored in larger physical area (volume).
2. Symmetric topology. This can support topologies (physical structural configuration of the resonant cavities) for high order filters due to the fact that it is feasible to couple simultaneously on all sides of the cavity as opposed to prior art (i.e., grounded post at the corner of the rectangular cavity).
3. Enhanced coupling capability. It allows to couple simultaneously from all sides of a single cavity to the neighbouring cavities. Does not require additional coupling elements (e.g., coupling wires).
4. It involves tuning screws that are easier to realize since the metallic post is exposed simultaneously to all of the neighbouring cavities.
5. Enhanced flexibility of achieving independent control of coupling for the two distinct filtering functions when we utilize a dual-slot de-coupling iris.
6. It is easier to physically realize this dual-frequency resonance in a circular cavity. This is due to the fact that the high frequency post in the former case is placed at a corner of the rectangular cavity. There is physical space limitation when the cavity is of circular cross section.
7. Improved power handling. This is due to the fact that the energy stored at f_2 in the new structure is stored at a greater physical volume thus minimizing the risks for high power discharge phenomena.

[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 resonator having a conductive resonance post surrounded by a conductive enclosure defining a cavity, said conductive resonance post being operable to filter a signal within a first frequency band, and a conductive resonance ring element positioned around said conductive resonance post, said conductive resonance ring element being operable to filter a signal within a second frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

2. The resonator assembly of claim 1, wherein said conductive resonance ring element has a length corresponding to no more than a wavelength at a frequency within said second frequency band.

3. The resonator assembly of claim 1 or 2, wherein said conductive resonance post comprises an elongate member extending along a first axis and said conductive resonance ring element comprises at least a portion of a ring-shaped member extending across a plane, said plane being orientated transversely to said first axis.

4. The resonator assembly of any preceding claim, wherein said conductive resonance ring element is located concentrically with said conductive resonance post.

5. The resonator assembly of any preceding claim, wherein said conductive resonance post is electrically connected with said conductive enclosure.

6. The resonator assembly of any preceding claim, wherein said conductive resonance post has a length corresponding to no more than a quarter-wavelength at a frequency within said first frequency band.

7. The resonator assembly of any preceding claim, wherein frequencies within said second frequency band are greater than frequencies within said first frequency band.

8. The resonator assembly of any preceding claim, wherein harmonics of said frequencies within said first frequency band fail to coincide said frequencies within said second frequency band.

9. The resonator assembly of any preceding claim, wherein said conductive resonance ring element is operable to filter two signals within a second frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

10. The resonator assembly of any preceding claim, comprising a pair of feeds positioned orthogonally with respect to each other, each operable to convey one of said two signals to said conductive resonance ring element.

11. The resonator assembly of any preceding claim, comprising at least one further conductive resonance ring element positioned around said first conductive resonance post, each further conductive resonance ring element being operable to filter a signal within a respective frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

12. The resonator assembly of any preceding claim, wherein each further conductive resonance ring element is operable to filter a signal within one of said second frequency band and another frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

13. The resonator assembly of any preceding claim, comprising a plurality of said resonators adjacently located and having shared portions of said conductive enclosure.

14. The resonator assembly of claim 13, wherein said shared portions of said conductive enclosure comprise at least one aperture to facilitate coupling between adjacent resonators.

15. The resonator assembly of any preceding claim, wherein one of said plurality of resonators comprises a first signal

feed operable to convey its signal to said resonance post of that resonator and another of said plurality of resonators comprises a second signal feed operable to convey its signal to said conductive resonance ring element.

Amended claims in accordance with Rule 137(2) EPC.

1. A resonator assembly, comprising:

a resonator (10; 10A; 10A'; 10B) having a conductive resonance post (40) surrounded by a conductive enclosure (20) defining a cavity (30), said conductive resonance post being operable to filter a signal within a first frequency band (f1), and a conductive resonance ring element (60) positioned around said conductive resonance post, said conductive resonance ring element being operable to filter a signal within a second frequency band (f2) concurrently with said conductive resonance post filtering said signal within said first frequency band.

2. The resonator assembly of claim 1, wherein said conductive resonance ring element has a length corresponding to no more than a wavelength at a frequency within said second frequency band.

3. The resonator assembly of claim 1 or 2, wherein said conductive resonance post comprises an elongate member extending along a first axis and said conductive resonance ring element comprises at least a portion of a ring-shaped member extending across a plane, said plane being orientated transversely to said first axis.

4. The resonator assembly of any preceding claim, wherein said conductive resonance ring element is located concentrically with said conductive resonance post.

5. The resonator assembly of any preceding claim, wherein said conductive resonance post is electrically connected with said conductive enclosure.

6. The resonator assembly of any preceding claim, wherein said conductive resonance post has a length corresponding to no more than a quarter-wavelength at a frequency within said first frequency band.

7. The resonator assembly of any preceding claim, wherein frequencies within said second frequency band are greater than frequencies within said first frequency band.

8. The resonator assembly of any preceding claim, wherein harmonics of said frequencies within said first frequency band fail to coincide said frequencies within said second frequency band.

9. The resonator assembly of any preceding claim, wherein said conductive resonance ring element is operable to filter two signals within a second frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

10. The resonator assembly of any preceding claim, comprising a pair of feeds (80, 100) positioned orthogonally with respect to each other, each operable to convey one of said two signals to said conductive resonance ring element.

11. The resonator assembly of any preceding claim, comprising at least one further conductive resonance ring element positioned around said first conductive resonance post, each further conductive resonance ring element being operable to filter a signal within a respective frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

12. The resonator assembly of any preceding claim, wherein each further conductive resonance ring element is operable to filter a signal within one of said second frequency band and another frequency band concurrently with said conductive resonance post filtering said signal within said first frequency band.

13. The resonator assembly of any preceding claim, comprising a plurality of said resonators adjacently located and having shared portions of said conductive enclosure.

14. The resonator assembly of claim 13, wherein said shared portions of said conductive enclosure comprise at least one aperture to facilitate coupling between adjacent resonators.

- 15.** The resonator assembly of any preceding claim, wherein one of said plurality of resonators comprises a first signal feed operable to convey its signal to said resonance post of that resonator and another of said plurality of resonators comprises a second signal feed operable to convey its signal to said conductive resonance ring element.

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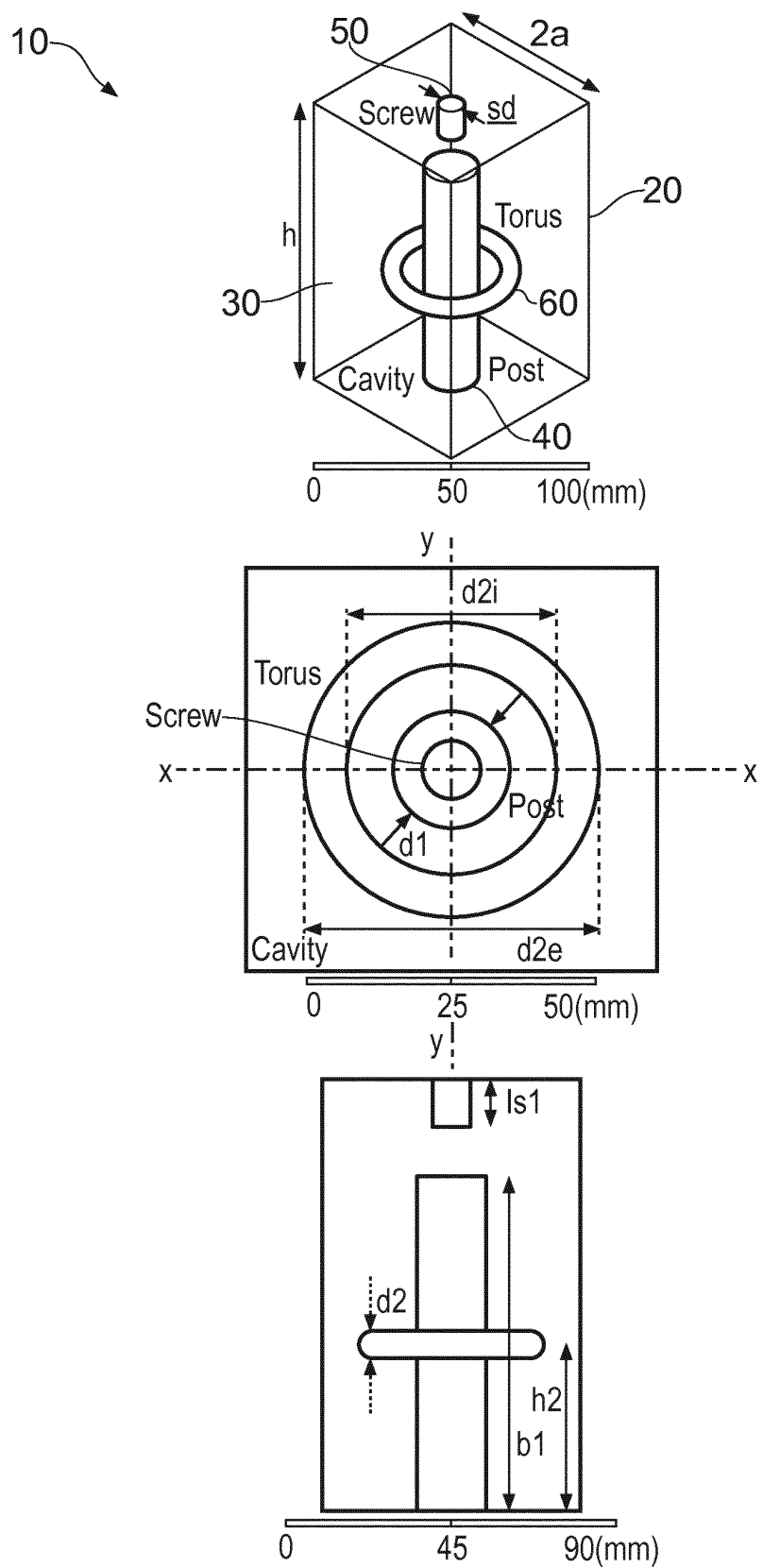
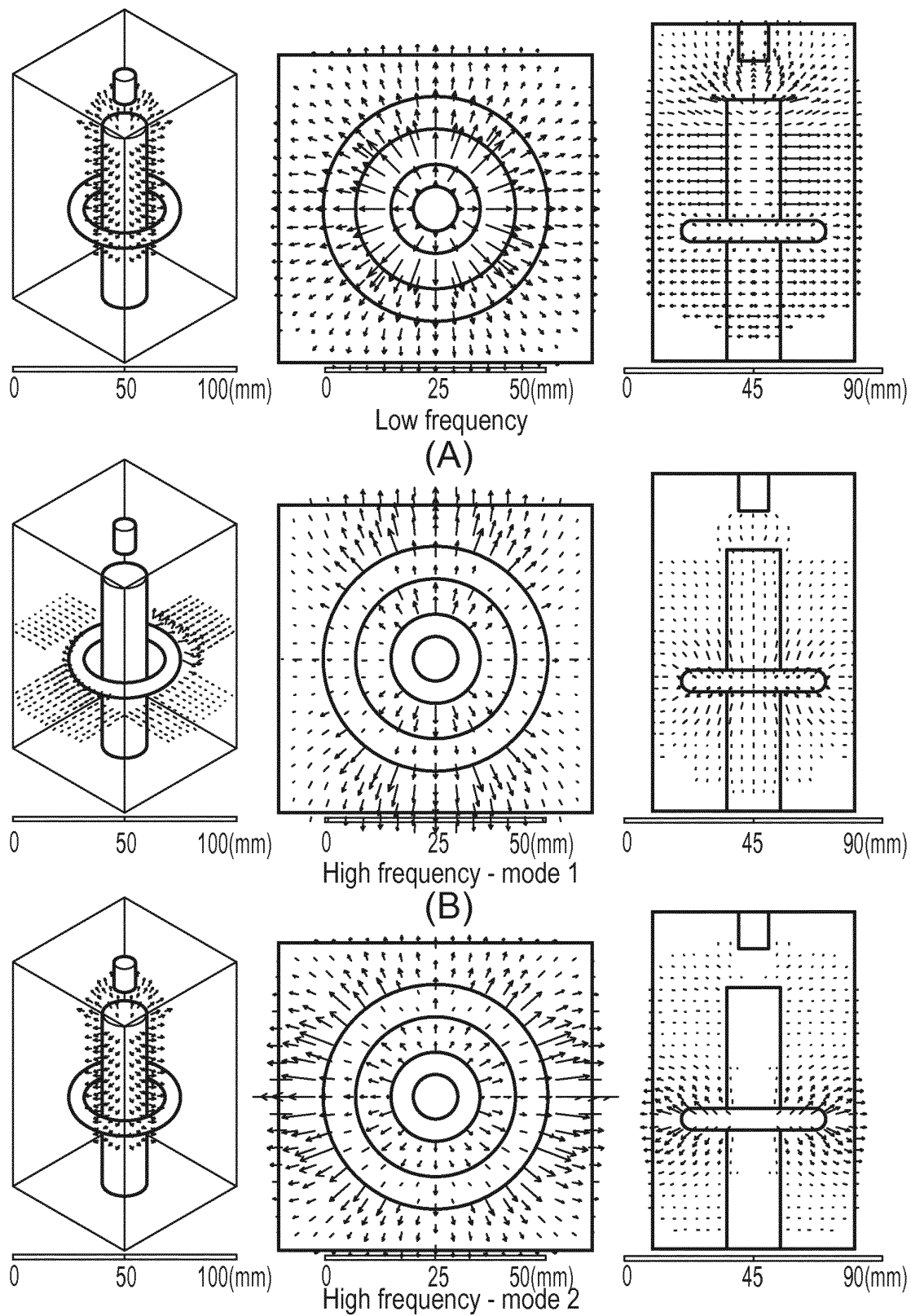


FIG. 1



(C)
FIG. 2

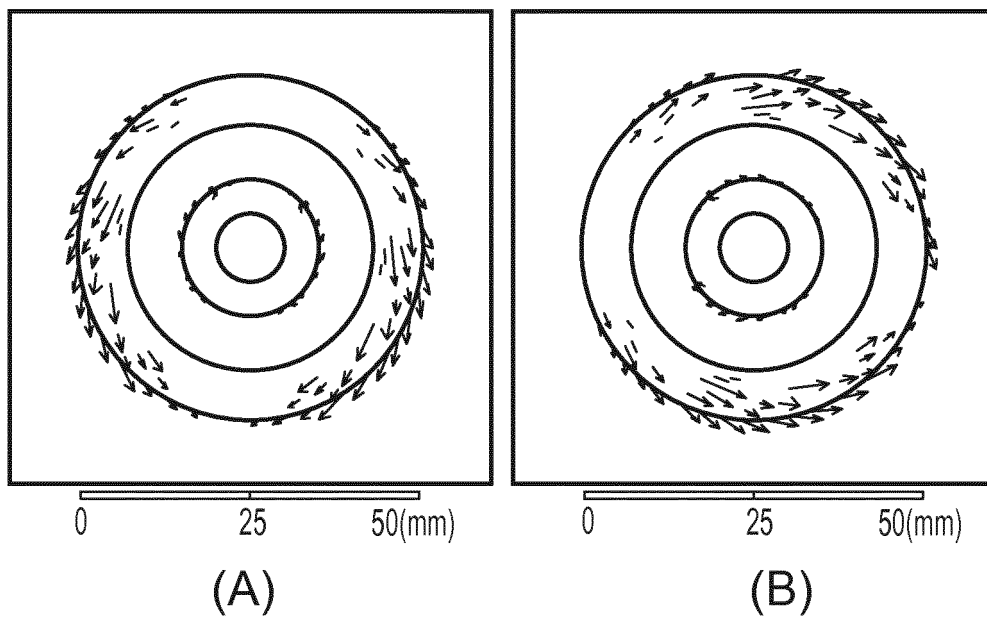


FIG. 3

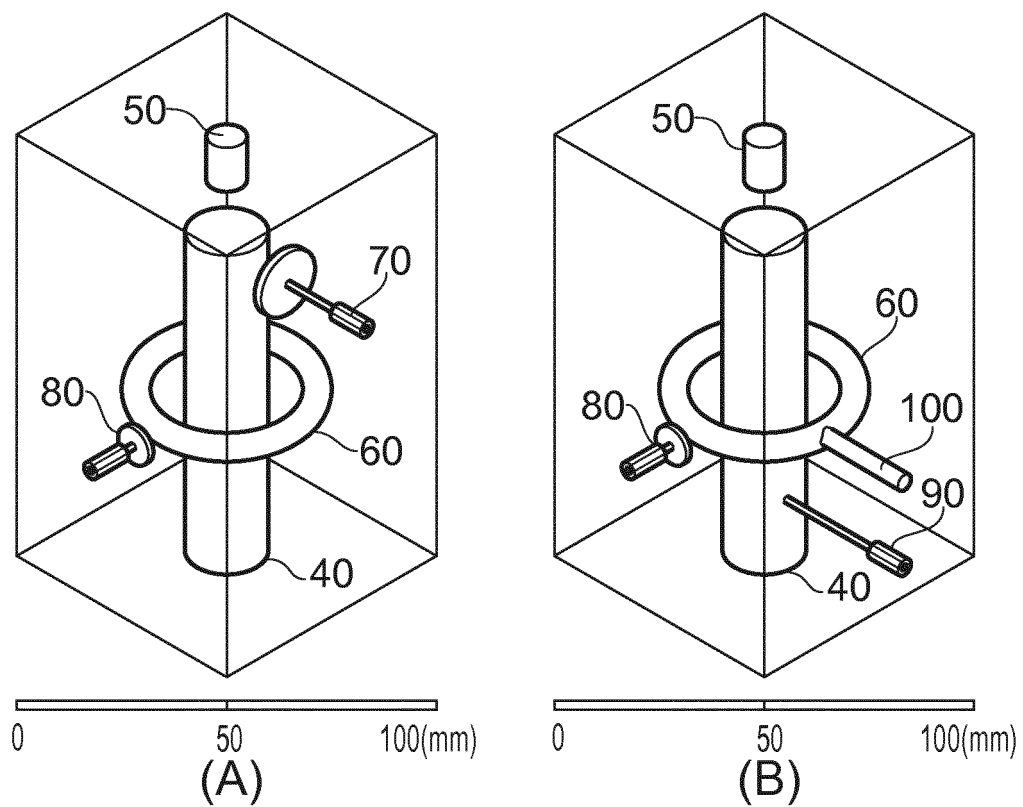


FIG. 4

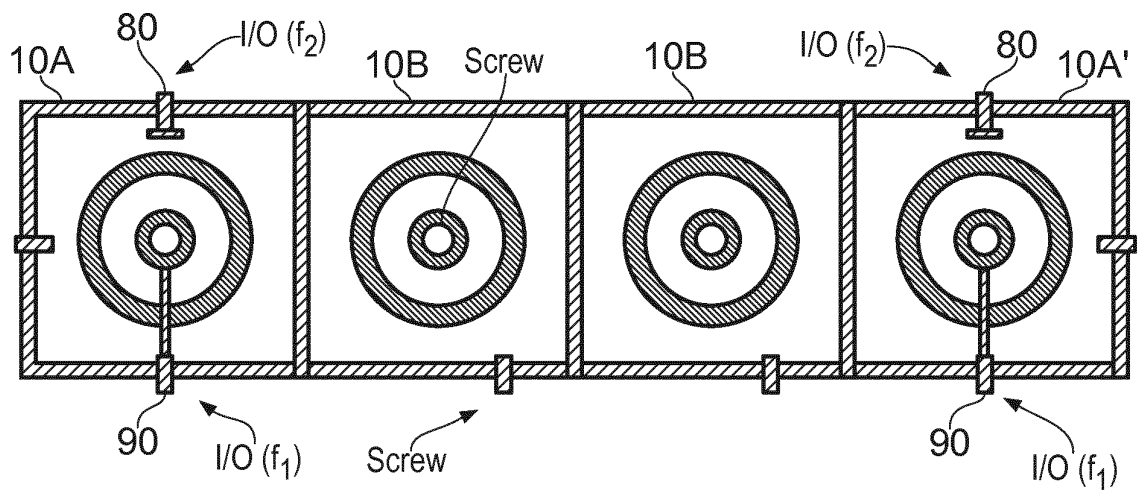


FIG. 5

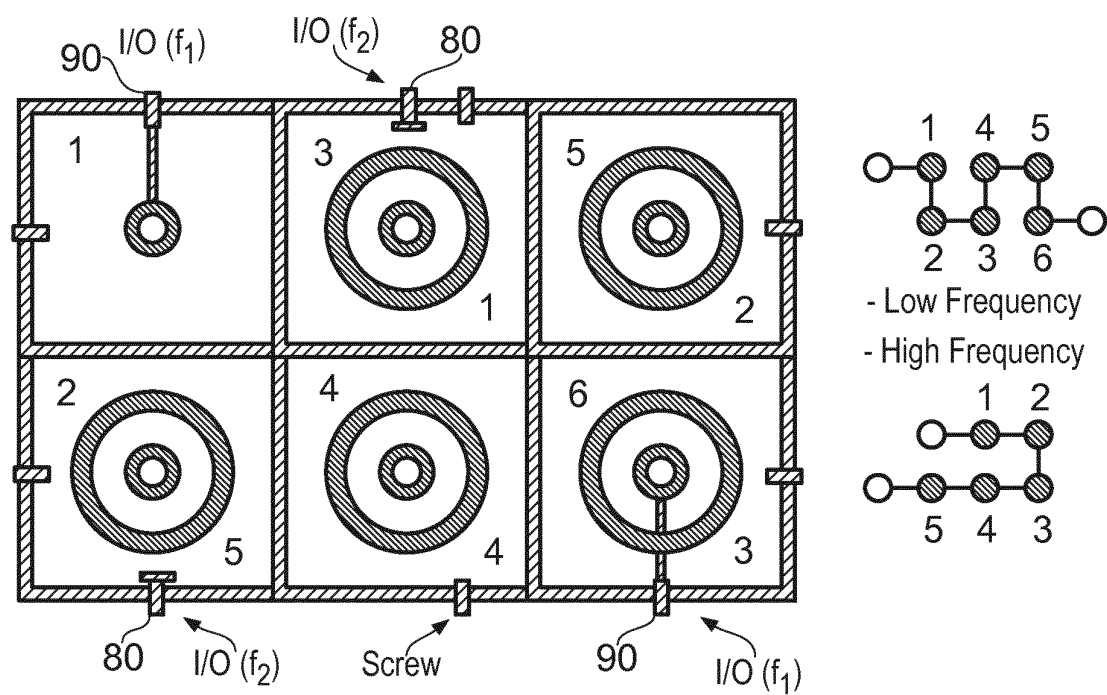


FIG. 6



EUROPEAN SEARCH REPORT

 Application Number
 EP 14 30 5032

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A	WO 2009/067056 A1 (ERICSSON TELEFON AB L M [SE]; LINDELL PATRIK [SE]) 28 May 2009 (2009-05-28) * page 5, line 8 - page 7, line 3; figure 1 *	1-15	
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Place of search Munich	Date of completion of the search 6 May 2014	Examiner La Casta Muñoa, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		



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The members are as contained in the European Patent Office EDP file on
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