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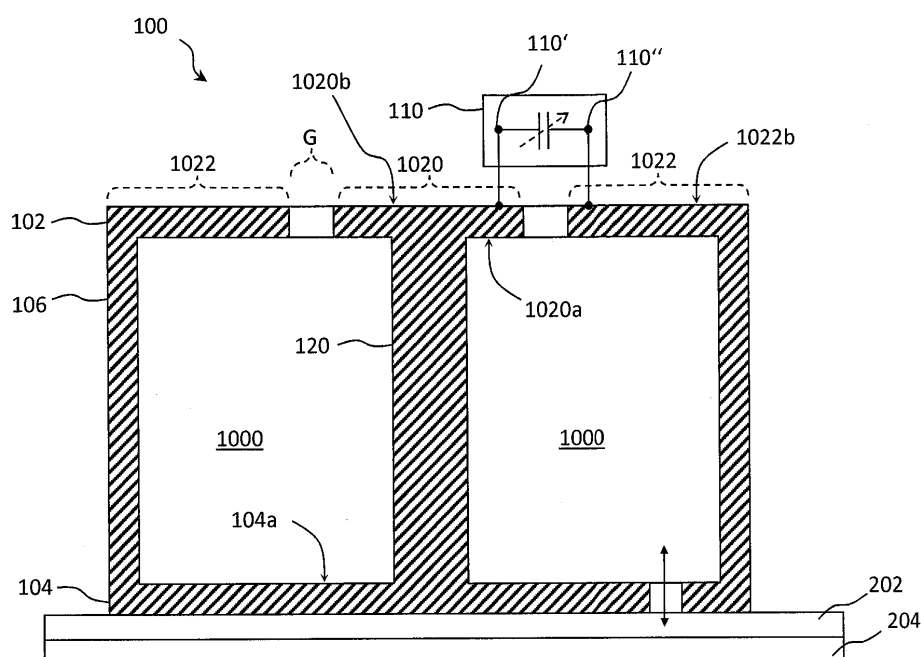
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(54) **Cavity resonator for radio frequency signals**

(57) The invention relates to a cavity resonator (100, 100a, 100b, 100c, 100d, 100e, 100f, 100g) for radio frequency signals, wherein said cavity resonator (100) comprises a basically cylindrical shape with opposing first and second axial end plates (102, 104), wherein said first axial end plate (102) comprises a first area section (1020) and a second area section (1022), wherein said first and second area sections (1020, 1022) are connected with

each other by at least one capacitive element (110), and wherein a basically cylindrical post (120) comprising an electrically conductive surface is provided in said cavity resonator (100) such that an electrically conductive connection is established between an inner surface (1020a) of said first area section (1020) of said first axial end plate (102) and an inner surface (104a) of said second axial end plate (104).

Fig. 1



Description**Field of the invention**

5 **[0001]** The invention relates to a cavity resonator for radio frequency, RF, signals. Such cavity resonators are for example used in filters for RF signals, especially microwave signals with a frequency of e.g. some GHz.

Background

10 **[0002]** It is an object of the present invention to improve cavity resonators of the above-mentioned type regarding precision and tunability of a resonance frequency.

Summary

15 **[0003]** This object is achieved by said cavity resonator comprising a basically cylindrical shape with opposing first and second axial end plates, wherein said first axial end plate comprises a first area section and a second area section, wherein said first and second area sections are connected with each other by at least one capacitive element, and wherein a basically cylindrical post comprising an electrically conductive surface is provided in said cavity resonator such that an electrically conductive connection is established between an inner surface of said first area section of said first axial end plate and an inner surface of said second axial end plate.

20 **[0004]** This configuration advantageously enables to provide a low-loss cavity resonator which offers superior tuning capabilities. Since the first axial end plate (also denoted as "cover plate" or "top cover") of the cavity resonator is partitioned into the first and second area sections, which are electrically isolated from each other apart from said at least one capacitive element, a capacitive load imposed on said electrically conductive post can be controlled by providing a corresponding capacity for the at least one capacitive element which provides the electrical (capacitive) connection between the two area sections of the first axial end plate. Thus, by providing said capacitive element, a frequency tuning of a resonance frequency of the cavity resonator may be attained.

25 **[0005]** According to one embodiment, the at least one capacitive element may comprise a constant capacitance which may e.g. be determined during manufacture of the cavity resonator. However, according to a further preferred embodiment, said at least one capacitive element comprises a variable, i.e. tunable or controllable, capacitance, which e.g. enables a resonance frequency tuning for said cavity resonator later on, e.g. during operation of the cavity resonator ("dynamic tuning").

30 **[0006]** Since the metallic post basically extends over the complete inner height of the cavity of said cavity resonator there is no requirement of performing any tuning measures inside the cavity of the cavity resonator. Instead, the tuning may solely be performed by modifying or providing a respective capacitive element which connects the first area section and the second area section of the first axial end plate with each other.

35 **[0007]** According to a preferred embodiment, at least one capacitive element is arranged inside of said cavity resonator, i.e. resides inside the cavity of the cavity resonator. Thus, said capacitive element is protected from environmental influences, and a particularly small configuration is attained.

40 **[0008]** According to a further embodiment, at least one capacitive element can be arranged outside said cavity of said cavity resonator, for example on and outer surface of the first and second area sections of the first axial end plate, whereby a particularly efficient tuning is enabled without the requirement of accessing the cavity of the cavity resonator.

45 **[0009]** According to further embodiments, a combination of both aforementioned measures is also possible. Thus, at least one capacitive element may be arranged inside the cavity, and at least one capacitive element may be arranged outside of said cavity.

50 **[0010]** According to a further preferred embodiment, at least one capacitive element is a tunable capacitive element, a capacity of which is controllable, wherein said tunable capacitive element preferably comprises at least one of a varactor diode, a micro electro mechanical system capacitor (MEMS-capacitor) or a barium strontium titanate (BST) capacitor.

55 **[0011]** According to a further embodiment, the basically cylindrical shape of said cavity resonator comprises a substantially circular cross-section.

60 **[0012]** According to a further embodiment, said post also comprises a substantially circular cross-section. However, according to further embodiments, other than circular cross-sections are possible for the cavity resonator and/or the post comprised within said cavity of the cavity resonator. I.e., according to further embodiments, the cavity resonator may comprise a basically cylindrical shape with other than circular cross-section, such as e.g. rectangular, polygonal or even arbitrary cross-section. According to further embodiments, this also applies to the side walls and/or the post.

65 **[0013]** According to a further embodiment, said first area section comprises a basically circular shape or a basically rectangular shape. Further shapes are also possible. According to a further embodiment, the first and second area sections of the first axial end plate are electrically separated from each other, i.e. isolated from each other, with the

exception of the at least one capacitive element, by means of which the capacitive tuning is enabled. According to an embodiment, the electrical separation or isolation of the first and second area sections of the first axial end plate may be achieved by providing a gap (e.g., air-filled) therebetween, and/or electrically isolating material.

[0014] According to one embodiment, a very small gap may be provided in order to avoid leakage of RF energy from the inside of the cavity to the outside of the cavity. On the other hand, the gap must be made large enough between the first and second area sections to avoid undesired bridging of the gap by e.g. dust particles or the like.

[0015] According to a further embodiment, a further capacitive element is provided on an outer surface of said first area section of said first axial end plate, wherein said further capacitive element is preferably electrically connected in series to said at least one capacitive element. Thus, a further degree of capacitive tuning for the cavity resonator is provided, which at the same time provides a rather small configuration. For example, the further capacity may also be designed to have a constant capacitance, whereas the at least one capacitive element may be configured as a tunable capacity.

[0016] According to a further embodiment, said cavity resonator is implemented by using a circuit carrier, preferably a printed circuit board, wherein said first axial end plate of said cavity resonator is implemented in a first layer of said printed circuit board, wherein said second axial end plate of said cavity resonator is implemented in a second layer of said printed circuit board, and wherein side wall portions and portions of the post are implemented in a third layer of said printed circuit board, wherein said third layer is arranged between said first and second layers. According to one embodiment, the first and second layers and/or the second and third layers may be directly adjacent to each other. According to further embodiments, further layers of the circuit carrier may be provided between said layers.

[0017] According to a further embodiment, side wall portions and/or portions of the post comprise a plurality of vias (vertical interconnect access; German:

"Durchkontaktierung") which establish an electrically conductive connection between said first and second layers through said third layer. Thereby, a particularly efficient method for providing an "electrically conductive" surface (e.g., for the side walls of the cavity and/or for the post) in the sense of the present invention is enabled using established printed circuit board manufacturing technologies. It is to be noted that in the sense of the present invention, the side wall portions of the cavity resonator as well as surface portions of the post are not necessarily closed surfaces. Rather, a sufficiently dense placement of neighbouring vias may also be considered as an "electrically conductive surface" which is capable of confining the RF energy resonating within the cavity resonator in said cavity. As is known by the skilled man, the spacing of neighbouring vias for such purpose inter alia depends on the frequency of the RF energy to be confined, and thus particularly on the resonance frequency, of the cavity resonator. The combination of the principle according to the embodiments with the first and second area sections and their capacitive connection by means of said at least one capacitive element with the usage of circuit carriers for implementing the cavity has several advantages: the placing of the at least one capacitive element and its electrical connection to the resonator (i.e., by soldering) is particularly efficient, as is the definition of a resonator cavity within the circuit carrier using metallized surfaces on the conductor layers thereof (e.g., for the axial end plates) and using e.g. vias to form electrically conductive side wall structures for said resonator.

[0018] According to a further embodiment, said at least one capacitive element is attached to said first layer, preferably directly soldered and/or glued to said first layer, whereby a particularly efficient mounting and a comparatively small form factor is attained.

[0019] According to a further embodiment, the cavity of the cavity resonator is substantially filled with a fluid, particularly with gas, preferably air. I.e., in contrast to the circuit carrier-based implementation of the embodiments, the present embodiment provides for a basically air-filled cavity of the cavity resonator. According to a further embodiment, the cavity may also be evacuated, at least to some extent, to even further reduce dielectric losses.

[0020] According to a further embodiment, said first axial end plate comprises and/or is made of a circuit carrier, preferably a printed circuit board (PCB), wherein said first and second area sections are implemented within at least one conductive layer of said printed circuit board. I.e., the complete axial end plate(s) of the cavity resonator may e.g. be manufactured by using a printed circuit board wherein electrically conductive structures required for the cavity resonator are implemented in the form of copper layers of the printed circuit board, and/or by using vias, or the like. Such printed circuit board may e.g. be clamped to and/or screwed to and/or soldered to the remaining body of the cavity resonator to the complete cavity resonator.

[0021] According to an embodiment, side wall portions of said cavity and/or at least said second axial end plate comprise material with an electrically conductive surface (e.g., any suitable type of substrate with a metallized surface or a plating). Alternatively, or in addition, said structures may also be made of electrically conductive materials such as e.g. copper. According to a preferred embodiment, at least the second axial end plate and/or the side walls and/or the post are provided together by a monolithic piece of conductive material such as e.g. copper.

Brief description of the figures

[0022] Further features, aspects and advantages of the present invention are given in the following detailed description with reference to the drawings in which:

- Figure 1 Schematically depicts a cross-sectional side view of a cavity resonator according to an embodiment,
- Figure 2 schematically depicts a cross-sectional side view of a cavity resonator according to a further embodiment,
- Figure 3a, 3b, 3c schematically depict a top view of a cavity resonator according to further embodiments,
- Figure 4 schematically depicts a side view of a circuit carrier according to an embodiment,
- Figure 5 schematically depicts a top view of a cavity resonator implemented in a circuit carrier according to a further embodiment,
- Figure 6 schematically depicts a cross-sectional side view of a circuit carrier according to a further embodiment, and
- Figure 7a, 7b schematically depict cross-sectional side views of further embodiments with capacitive elements inside and outside of a cavity.

Description of the embodiments

[0023] Figure 1 schematically depicts a cross-sectional side view of a cavity resonator 100 according to an embodiment. The cavity resonator 100 comprises a basically cylindrical shape with a first axial end plate 102 and a second axial end plate 104. According to a preferred embodiment, the basic shape of the cavity resonator 100 comprises a circular geometry. Consequently, the first and second axial end plates 102, 104 also comprise a basically circular shape.

[0024] As can be seen from figure 1, the first axial end plate 102 comprises a first area section 1020 and a second area section 1022. According to the present embodiment, the first area section 1020 is arranged at a radial inner position, whereas the second area section 1022 is arranged radially outwards of said first area section 1020. The area sections 1020, 1022 are separated electrically in the area of the end plate 102, i.e. isolated, from each other by a gap G. The only electrically conductive connection in the area of the end plate 102 between said area sections 1020, 1022 is established by at least one capacitive element 110, which is connected to respective portions of the first and second area sections 1020, 1022 in an electrically conductive manner via its terminals 110', 110". Moreover, the cavity resonator 100 comprises a post 120 which comprises a basically cylindrical shape and an electrically conductive surface. The post 120 is provided in said cavity resonator 100 such that an electrically conductive connection is established between an inner surface 1020a of said first area section 1020 of said first axial end plate 102 and an inner surface 104a of said second axial end 104. This structure enables to define a capacitive load on the cavity resonator 100, which enables the tuning of the resonance frequency of the cavity resonator 100 by means of the capacitive element 110.

[0025] According to an embodiment, the capacitive element 110 may comprise a static capacitance value. This value may e.g. be chosen during manufacture or calibration of the cavity resonator 100 to properly set the resonance frequency of the cavity resonator 100. However, according to a further preferred embodiment, the capacitive element 110 is a tunable capacitive element, a capacitance of which is controllable. According to one embodiment, the capacitive element 110 may comprise a varactor diode or MEMS capacitors or BST capacitor or the like. Thereby, a dynamic tuning of the electrical capacitance which is connecting the area sections 1020, 1022 is enabled, which may be employed to dynamically tune the resonance frequency of the cavity resonator 100 during an operation of the cavity resonator.

[0026] Thus, resonance frequency drifts, temperature dependencies or the like may be compensated over the whole life time of the cavity resonator 100 without a requirement for mechanical alterations such as tuning screws or even machining of the cavity 1000 and/or the post 120 or the like, as is required by conventional cavity resonators.

[0027] According to one preferred embodiment, the cavity resonator 100 comprises a monolithic body defining the axial end plates 102, 104, the side walls 106, and the post 120. Preferably, said monolithic body may be made of copper or another metal or another material with conductive surface like metalized plastic.

[0028] Advantageously, according to an embodiment, the capacitive element 110 may be placed on an outer surface or top surface 1022b, i.e. by gluing and/or soldering or the like. For example, a first terminal 110' of the capacitive element 110 may be soldered to the outer surface 1020b of the area section 1020, and a second terminal 110" of the capacitive element 110 may be soldered to the outer surface 1022b of the area section 1022.

[0029] Although not part of the present invention, and solely for illustrative purposes, a feeding mechanism for providing RF energy to the cavity resonator 100 is also depicted by Figure 1. The feeding mechanism comprises an RF guide 204 such as a micro-strip transmission line or the like, with a substrate layer 202 placed on top of it. Coupling of RF energy between the cavity resonator 100 and the transmission line 204 is enabled in a per se known manner by means of an opening in the axial end plate 104, cf. the double arrow (for example magnetic coupling between transmission line 204 and the cavity resonator via a coupling slot in the ground plane). This way, one or more cavity resonators 100 according to the embodiments may be connected with signal sources and/or signal sinks (not depicted), e.g. for building an RF filter comprising several cavity resonators. Other variants (not shown) for coupling RF energy with said cavity are also possible. In this case, the opening in the axial end plate 104 is not necessarily required.

[0030] Figure 2 depicts a further embodiment 100a of the cavity resonator, wherein a further capacitive element is implemented directly on the outer surface 1020b of the first area section 1020. The further capacitive element comprises a dielectric layer 1102 attached to the outer surface 1020b of the first area section 1020 and an electrically conductive layer 1104, which together with the outer surface 1020b or the first area section 1020, respectively, forms said further capacitive element. According to a preferred embodiment, this further capacitive element is connected electrically in series with the capacitive element 110 thus providing a further degree of freedom regarding capacitive tuning of the cavity resonator 100a. For example, according to an embodiment, the further capacitive element 1104, 1102, 1020b may be designed to have a constant capacitance, which may e.g. be defined during manufacture of item 100a, and which may e.g. be chosen for coarse tuning the desired resonance frequency of the cavity resonator 100a. Fine tuning of the resonance frequency of the cavity resonator 100a may be performed later on, especially also dynamically (during operation of the cavity resonator 100a), by controlling the capacitance of the capacitive element 110. For this purpose, according to an embodiment, said capacitive element 110 may comprise at least one varactor diode and/or a MEMS array or the like. Control terminals for controlling the capacitance of the capacitive element 110 are not depicted for the sake of clarity.

[0031] According to a further embodiment, a combination of solutions according to Fig. 1 and Fig. 2 are also possible.

[0032] According to an embodiment, the gap G (Fig. 1) between the elements 1020, 1022, may also be filled with an electrically isolating material, e.g. for sealing the cavity 1000 to protect it from environmental influences.

[0033] Figure 3a schematically depicts a top view of a cavity resonator 100a having a shape as e.g. depicted by figure 1. The main body comprises a circular cross-section, which also applies to the first axial end plate 102. Likewise, the post 120 comprises a circular cross-section. The first area section 1020 also comprises a circular shape, and the second area section 1022 comprises a circular ring shape as depicted by figure 3a. Thus, the basically circular-shaped gap G is defined between the area sections 1020, 1022 which effects an electric isolation between these elements, as already explained above with reference to Fig. 1. However, tuning element 110, as also already explained above, connects said elements 1020, 1022 with each other by means of its capacitance. Thus, a capacitive tuning of the cavity resonator 100a may be performed.

[0034] Figure 3b depicts a further embodiment 100b of the cavity resonator. In contrast to the figure 3a embodiment, the cavity resonator 100b depicted by figure 3b comprises three capacitive elements 110, 110a, 110b, each of which connects the elements 1020, 1022 with each other. Thus, from an electrical topology point of view, the elements 110, 110a, 110b may also be considered as being connected in parallel to each other, whereby the effective tuning capacitance between elements 1020, 1022 of the arrangement 110, 110a, 110b is defined by the sum of the individual capacitance values of the elements 110, 110a, 110b. For instance, the capacitive element 110a may comprise a rather large capacitance tuning range for coarse tuning of the effective capacitance, whereas capacitive element 110b has rather small capacitance range for fine tuning the effective capacitance. I.e., if each of the three capacitive elements 110, 110a, 110b comprises a varactor diode, three control voltages (not shown) would have to be provided to the arrangement 110, 110a, 110b for tuning. Of course, according to other embodiments, other combinations of static and controllable capacitance values are also possible.

[0035] Figure 3c depicts a further embodiment 100c of a cavity resonator, wherein the post 120 comprises circular cylinder geometry. However, the gap G1 between the area sections 1020, 1022 comprises a basically rectangular shape due to the rectangular shape of the inner section 1020. In the present configuration, the area sections 1020, 1022 are electrically conductively connected by each other by means of first capacitive element 110a and second capacitive element 110b.

[0036] Figure 4 schematically depicts a side view of a circuit carrier arrangement, for example a printed circuit board (PCB), which comprises three layers L1, L2, L3. While the layers L1, L2 are electrically conductive, e.g. copper layers, the intermediate layer L3 between the first and second layers L1, L2 comprises an electrically isolating material, e.g. composite material of the FR4-type or the like. Such printed circuit board may advantageously be used to either form a complete cavity resonator according to an embodiment, cf. figure 5, or to form a part of a cavity resonator as will be explained below with reference to figures 6 to 7b. Other multi-layer circuit carrier materials instead of PCB and/or FR4-type material may also be used, e.g. multi-layer circuit carriers based on ceramic substrates or the like.

[0037] Figure 5 schematically depicts a top view of a cavity resonator 100d according to a further embodiment. This

cavity resonator 100d is implemented within a printed circuit board, a schematic side view of which is depicted by figure 4. Electrically conductive side walls (also cf. reference sign 106 of Fig. 1) of the cavity resonator 100d according to figure 5 are implemented by a circular arrangement of a plurality of vias 1200. Likewise, an electrically conductive surface of the post 120 is attained by a circular arrangement of further vias 1202. The area sections 1020, 1022 are implemented in the form of correspondingly shaped electrically conductive elements implemented in a per se known manner within the first conductive layer L1 of the printed circuit board (figure 5). For example, layers L1, L2 of the Fig. 4 PCB may be copper layers as known in the art.

[0038] Thus, advantageously, the area sections 1020, 1022 according to the embodiments may e.g. be attained by per se known PCB manufacturing steps (e.g., by etching or milling of the copper layers L1, L2), as well as the vias 1200, 1202 (e.g., by drilling and metallizing). A gap G2 of electrically non-conductive material (the gap may comprise portions of e.g. FR-4 material of layer L3 as depicted by Fig. 4) resulting between the sections 1020, 1022 is bridged as explained above by at least one capacitive element 110 according to the embodiments.

[0039] The main advantage of the embodiment 100d according to figure 5 is a particularly small outline and particularly efficient manufacturing process. Advantageously, the capacitive element 110 (and/or further capacitive elements which are not depicted by Fig. 5 for clarity) may directly be attached to a surface of the first layer L1, i.e. by glueing and/or by soldering. For example, according to one embodiment, a variable capacitor may directly be soldered onto the copper surface of the area sections 1020, 1022.

[0040] Fig. 6 schematically depicts a cross-sectional side view of a further embodiment 100e of a cavity resonator, which is implemented by using a three layer PCB material. The first axial end plate 102 and the second axial end plate 104 of the cavity resonator 100e according to figure 6 are implemented in the form of correspondingly shaped copper layers of a printed circuit board PCB (also figure 4, copper layers L1, L2).

[0041] Tuning capacitors 110, 110a are positioned on an outer surface of the first axial end plate 102. According to an embodiment, the tuning capacitors 110, 110a may directly be soldered to said outer surface. More specifically, according to the configuration depicted by Figure 6, a first terminal of the tuning capacitor 110 is soldered to a surface portion 1020b of the first area section 1020 (Fig. 1), and a second terminal of the tuning capacitor 110 is soldered to a surface portion 1022b of the second area section 1022. In analogy, a first terminal of the further tuning capacitor 110a is soldered to said surface portion 1020b, and a second terminal of the further tuning capacitor 110a is soldered to said surface portion 1022b.

[0042] According to an embodiment, the side walls of the cavity resonator 100e may be implemented by a basically circular arrangement of a plurality of vias 1200 as depicted by Fig. 5, wherein the spacing of adjacent vias 1200 is chosen sufficiently small so as to prevent RF leakage out of the cavity 1000 to a desired degree. According to a further embodiment, the post 120 may be implemented by a basically circular arrangement of a plurality of vias 1202 as depicted by Fig. 5, wherein the spacing of adjacent vias 1200 is chosen sufficiently small so as to emulate a sufficiently "smooth" radially outer "surface" of the post 120. According to a further embodiment, the post 120 may also be provided in the form of a cylindrical piece of conductive material (or material with an electrically conductive outer surface) which is integrated into a bore hole of the PCB material, or the like.

[0043] According to the embodiment 100e of Fig. 6, the cavity 1000 of the cavity resonator 100e is filled with the material of the electrically non-conductive third layer L3 (Fig. 4) of the PCB.

[0044] Figure 7a, 7b schematically depict cross-sectional side views of further embodiments 100f, 100g with capacitive elements inside and outside of the cavity 1000. In contrast to the embodiment of Fig. 6, where the cavity resonator 100e is implemented within a PCB, the cavity resonators 100f, 100g comprise a first axial end plate which comprises a printed circuit board PCB'. The remaining body of the cavity resonators 100f, 100g may e.g. be made of metal such as copper, preferably as a monolithic unit 104, 106, 120.

[0045] As depicted by Figure 7a, on top of the monolithic unit 104, 106, 120 is arranged a three layer PCB configuration PCB' which inter alia serves to implement the first axial end plate 102 (Fig. 1) of the cavity resonator 100f.

[0046] In a first layer L1, which is a copper layer, the first area section (also cf. reference sign 1020 of Fig. 1) is formed by copper element c13, whereas the second area section (also cf. reference sign 1022 of Fig. 1) is formed by copper elements c11, c12. Additionally, in a second layer L2, which is also a copper layer, the first area section is further formed by copper element c23, which is connected in an electrically conductive fashion by means of several vias v32, only one of which is provided with a reference sign for the sake of clarity. Also, in the second layer, further copper elements c21, c22 are provided which are connected in an electrically conductive fashion by means of several vias v31 with the copper elements c11, c12 of the first copper layer L1.

[0047] Hence, copper elements c11, c12 of the first layer L1 and copper elements c21, c22 of the second layer L2 contribute to forming the second area section of the first axial end plate 102 (Fig. 1). Likewise, copper elements c13, c23 of the first and second layers L1, L2 contribute to forming the first area section of the first axial end plate 102 (Fig. 1).

[0048] As can be seen from Fig. 7a, the gaps between the area sections 1020, 1022, or the copper segments c11, c13, c12 and c21, c23, c22, respectively, are "filled" with the insulating layer material of the third layer L3 of the circuit carrier PCB'. Thus, while preventing direct electric contact between the area sections 1020, 1022, the cavity 1000 of

the cavity resonator 100f is protected against environmental influences. Advantageously, the capacitive elements 110, 110a are soldered directly onto the copper elements c11, c12, c13. According to an embodiment, the cavity 1000 may be filled with air or another fluid, which yields reduced losses as compared to the FR-4-filled cavity of the embodiment of Fig. 6.

[0049] Figure 7b depicts a further embodiment 100g, where the functionality of the first axial end plate 102 (Fig. 1) is implemented by using a circuit carrier PCB'. In contrast to the embodiment of Figure 7a, however, the capacitive elements 110, 110a are placed inside the cavity 1000, thus avoiding to lead an RF signal path outside the cavity 1000, which reduces parasitic effects. Advantageously, according to an embodiment, the capacitive elements 110, 110a may be soldered directly onto the copper elements c21, c22, c23.

[0050] A further advantage of the embodiment of Fig. 7b is a better electrical performance, e.g. higher cut-off frequency (no via holes are inserted into the signal path which connects the cavity gap).

[0051] The embodiments 100f, 100g explained above with reference to Figures 7a, 7b may advantageously be manufactured in a three-step approach: One step comprises providing the circuit carrier PCB', a further step comprises providing the remaining body parts 104, 106, 120 (preferably in form of a monolithic metal body) of the resonator, and a third step is used for attaching the circuit carrier PCB' with the attached capacitive elements 110, 110a to the remaining body parts. In this context, the shape of the copper elements c21, c22, c23 may easily be adapted when manufacturing the circuit carrier PCB', so that the circuit carrier PCB' may be used for a wide variety of resonator geometries and sizes.

[0052] In contrast to conventional cavity resonators, where mechanical dimensions have to be tuned, the proposed solution according to the embodiments allows filter tuning by means of electrical components ("adjustable capacitor" 110, 110a, ..), e.g. with tunable MEMS-capacitors, BST capacitors, switched capacitors or varactor diodes.

[0053] The principle according to the embodiments advantageously allows for different variants regarding the realization:

a) The top cover slot (i.e., the gap G between the area sections 1020, 1022, cf. Fig. 1) may have an arbitrary form (circular, rectangular, generally polygonal, curved, or any combination thereof).

b) The number of used adjustable capacitors 110, 110a, .. can be arbitrary.

[0054] According to an embodiment, when using varactor diodes as adjustable capacitors 110, additional bias capacitors (e.g., the further capacitor 1102, 1104 of Fig. 2) may be used for biasing the varactor diodes (Figure 2). According to one embodiment, all varactor diodes connected to a same bias capacitor (e.g. the further capacitor 1102, 1104 of Fig. 2) are biased with the same voltage. According to a further embodiment, using more than one bias capacitor allows to bias different varactor diodes individually.

[0055] According to a further embodiment, a combination of varactor diode characteristics (capacity range) and the capacitance value of a used bias capacitor allows to define the tuning range of the resulting capacitor and thereby the tuning frequency range of the cavity resonator 100.

[0056] According to a further embodiment, appropriate designs for the capacity elements 110, 110a, .. allow to realize tunable cavity resonators (and thus also filters) suitable for coarse tuning over the whole frequency band and for fine tuning within a limited frequency range. This also allows to increase the tuning resolution. For example, according to one embodiment, two varactor diodes may be mounted on a same bias capacitor and may be biased with the same voltage e.g. for coarse tuning, while a third varactor diode is mounted on a second bias capacitor and biased with a second voltage e.g. for fine tuning.

[0057] 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.

[0058] 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.

Claims

1. Cavity resonator (100, 100a, 100b, 100c, 100d, 100e, 100f, 100g) for radio frequency signals, wherein said cavity resonator (100) comprises a basically cylindrical shape with opposing first and second axial end plates (102, 104),
 5 wherein said first axial end plate (102) comprises a first area section (1020) and a second area section (1022), wherein said first and second area sections (1020, 1022) are connected with each other by at least one capacitive element (110), and wherein a basically cylindrical post (120) comprising an electrically conductive surface is provided in said cavity resonator (100) such that an electrically conductive connection is established between an inner surface (1020a) of said first area section (1020) of said first axial end plate (102) and an inner surface (104a) of said second axial end plate (104).
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2. Cavity resonator (100) according to claim 1, wherein at least one capacitive element (110) is arranged a) inside or b) outside a cavity (1000) of said cavity resonator (100).
- 15 3. Cavity resonator (100) according to one of the preceding claims, wherein at least one capacitive element (110) is a tunable capacitive element (110) a capacity of which is controllable, wherein said tunable capacitive element (110) preferably comprises at least one of a varactor diode, a micro-electromechanical system capacitor, BST-capacitor, MEMS-capacitor.
- 20 4. Cavity resonator (100) according to one of the preceding claims, wherein the basically cylindrical shape of said cavity resonator (100) comprises a substantially circular cross-section, and wherein said post (120) comprises a substantially circular cross-section.
- 25 5. Cavity resonator (100) according to one of the preceding claims, wherein said first area section (1020) comprises a basically circular shape or a basically rectangular shape.
6. Cavity resonator (100) according to one of the preceding claims, wherein a further capacitive element is provided on an outer surface (1020b) of said first area section (1020) of said first axial end plate (102), wherein said further capacitive element is preferably connected in series to said at least one capacitive element (110).
 30
7. Cavity resonator (100e) according to one of the preceding claims, wherein said cavity resonator (100e) is implemented by using a circuit carrier (PCB), preferably a printed circuit board, wherein said first axial end plate (102) of said cavity resonator (100e) is implemented in a first layer (L1) of said printed circuit board, wherein said second axial end plate (104) of said cavity resonator (100e) is implemented in a second layer (L2) of said printed circuit board, and wherein side wall (106) portions and portions of the post (120) are implemented in a third layer (L3) of said printed circuit board, wherein said third layer (L3) is arranged between said first and second layers (L1, L2).
 35
8. Cavity resonator (100e) according to claim 7, wherein side wall portions and/or portions of the post (120) comprise a plurality of vias (1200, 1202) which establish an electrically conductive connection between said first and second layers (L1, L2) through said third layer (L3).
 40
9. Cavity resonator (100e) according to one of the claims 7 to 8, wherein said at least one capacitive element (110) is attached to said first layer (L1), preferably directly soldered and/or glued to said first layer (L1).
- 45 10. Cavity resonator (100) according to one of the claims 1 to 6, wherein said cavity (1000) is substantially filled with a fluid, particularly with a gas, preferably air, or wherein said cavity (1000) is evacuated.
11. Cavity resonator (100, 100a, 100b, 100c, 100d, 100e, 100f, 100g) according to one of the preceding claims, wherein said first axial end plate (102) comprises and/or is made of a circuit carrier, preferably a printed circuit board (PCB'), wherein said first and second area sections (1020, 1022) are implemented within at least one conductive layer (L1, L2) of said printed circuit board (PCB').
 50
12. Cavity resonator (100) according to one of the preceding claims, wherein side wall (106) portions of said cavity (1000) and/or at least said second axial end plate (104) comprise material with an electrically conductive surface, wherein preferably side wall (106) portions of said cavity (1000) and/or at least said second axial end plate (104) are made of electrically conductive material.
 55

Fig. 1

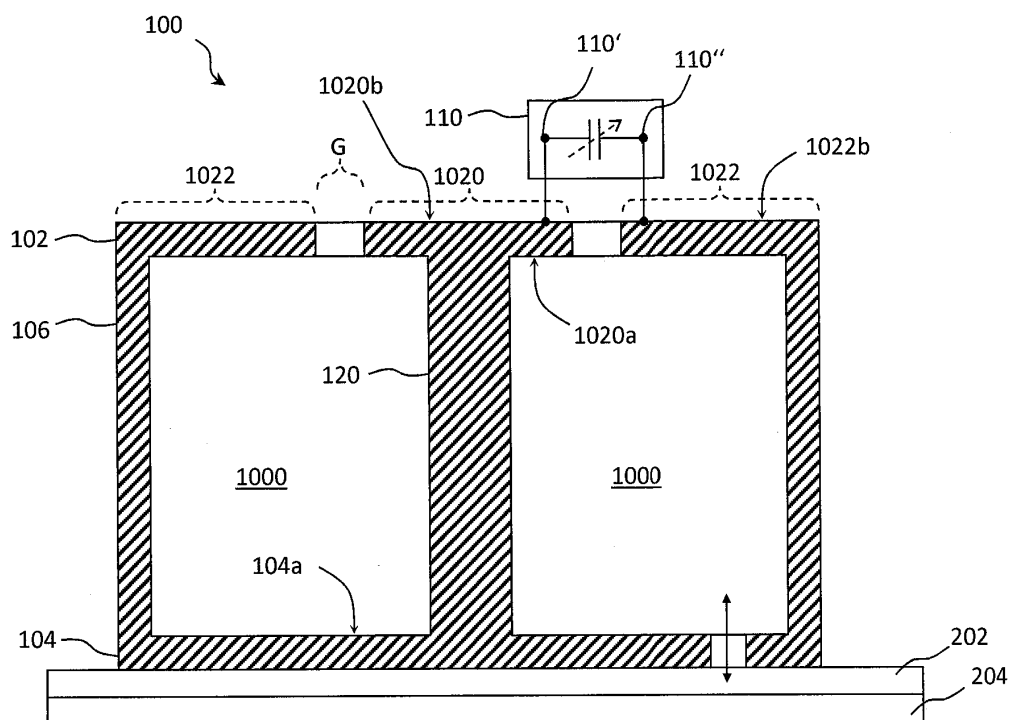


Fig. 2

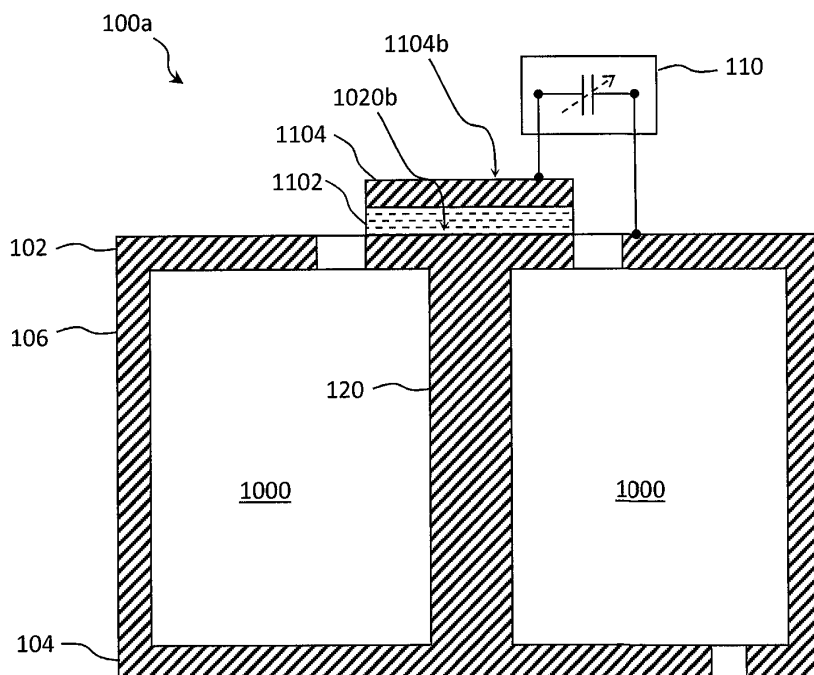


Fig. 3a

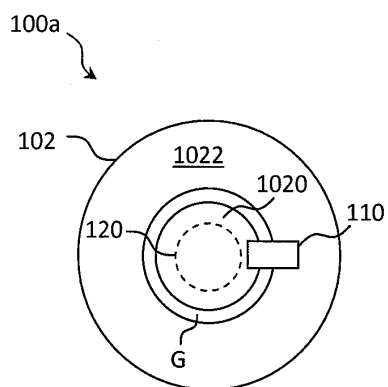


Fig. 3b

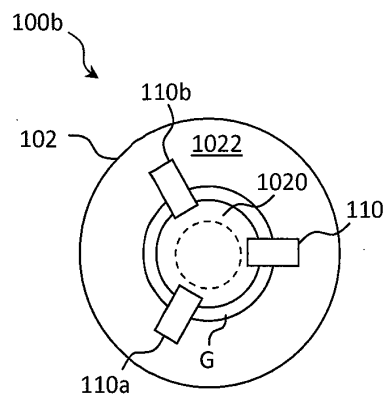


Fig. 3c

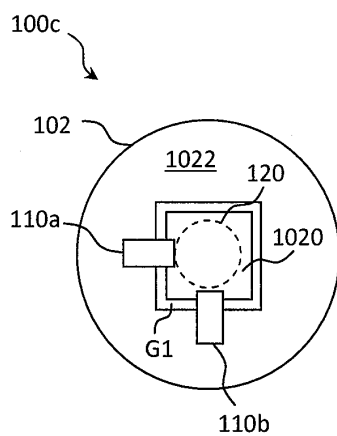


Fig. 4

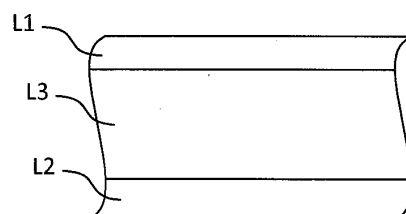


Fig. 5

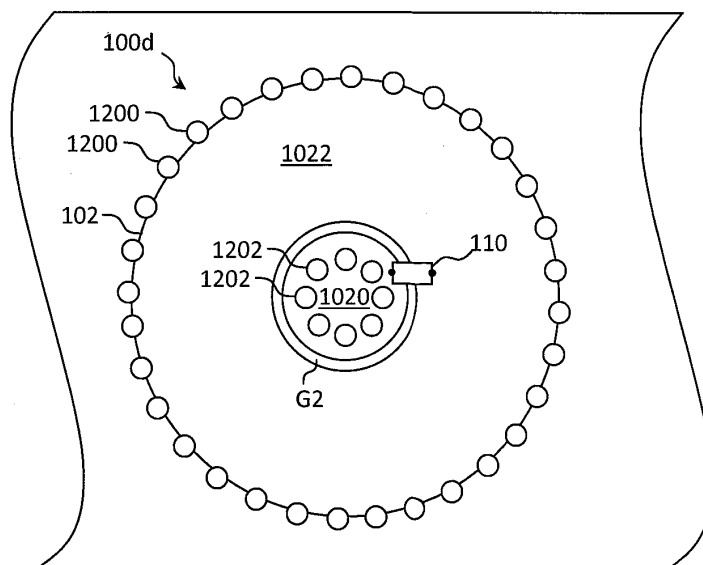


Fig. 6

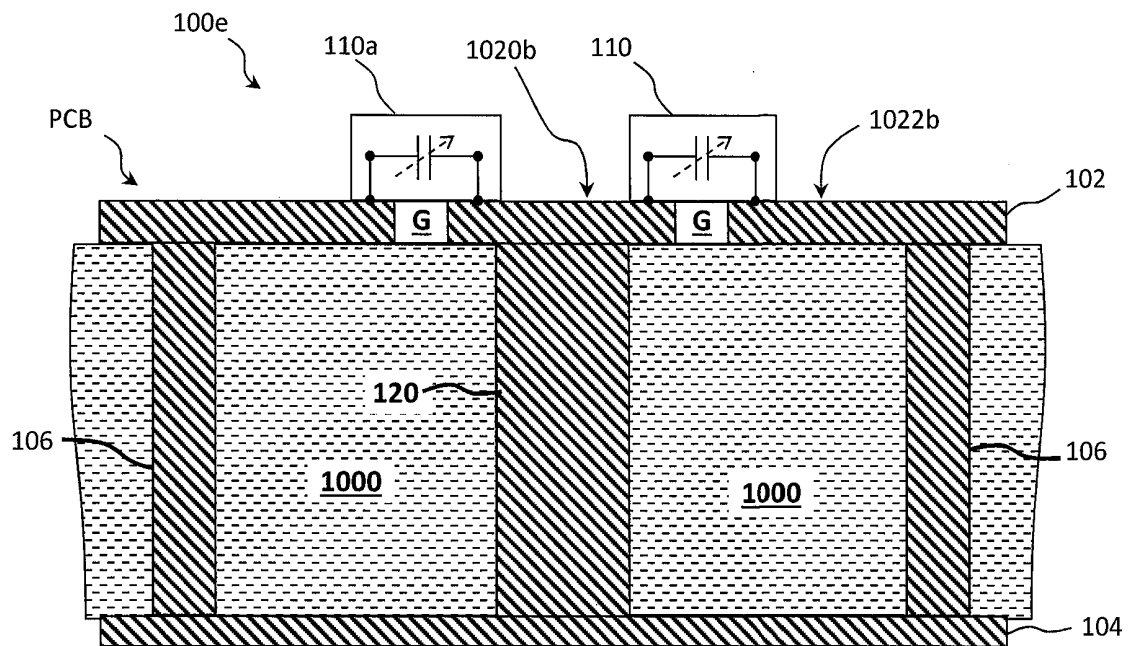


Fig. 7a

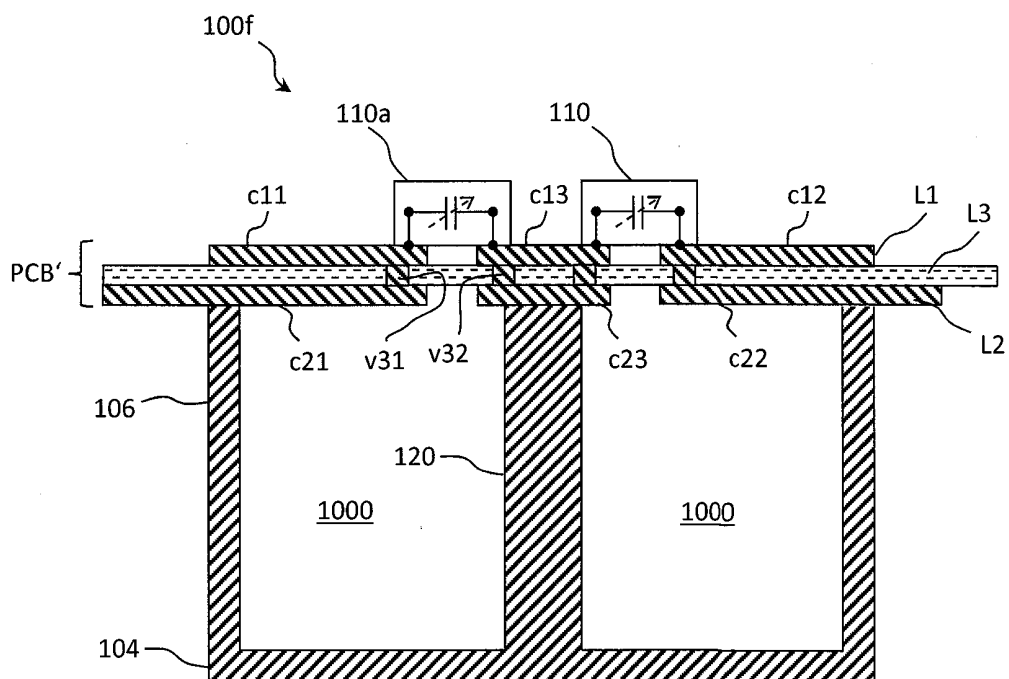
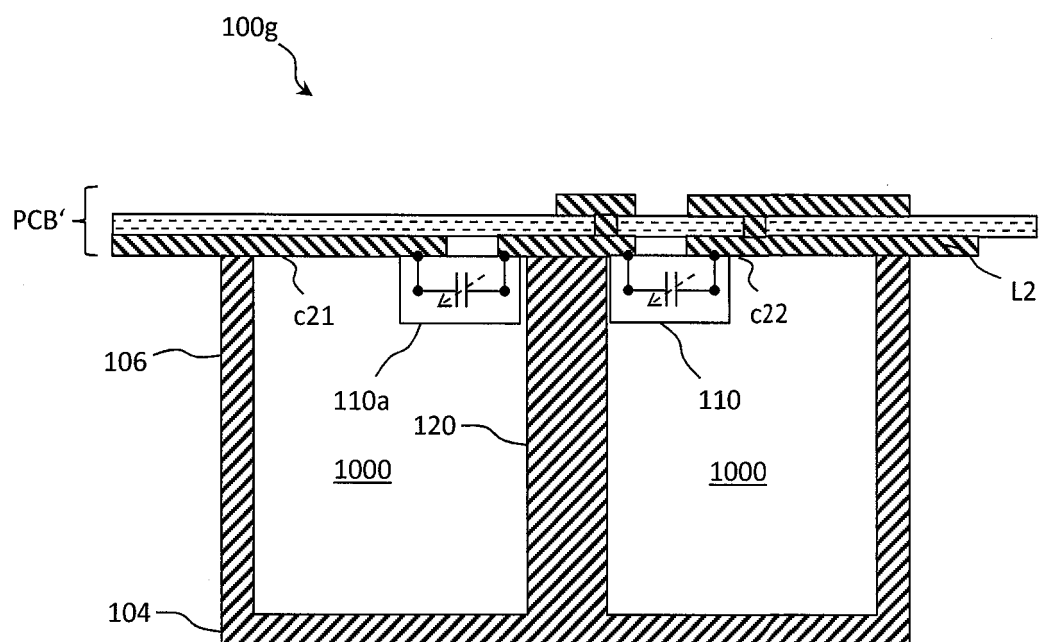


Fig. 7b





EUROPEAN SEARCH REPORT

Application Number
EP 13 19 0700

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X	DE 196 02 815 A1 (ISRAEL STATE [IL]) 8 August 1996 (1996-08-08)	1,2,4,5, 10,11	INV. H01P1/213
A	* abstract; figure 4 * * column 6, lines 4-67 *	3,6-9	H01P7/04 H01P7/06
A	US 4 249 147 A (KAEGEBEIN DANIEL P) 3 February 1981 (1981-02-03) * abstract; figure 5 *	1-11	
A	US 3 443 244 A (COOK EDWARD J) 6 May 1969 (1969-05-06) * column 3, lines 3-75; figures 1-4 *	1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC) H01P
Place of search Munich		Date of completion of the search 27 March 2014	Examiner Cordeiro, 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			

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The members are as contained in the European Patent Office EDP file on
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27-03-2014

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