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(71) Applicant: **Nokia Solutions and Networks Oy**
02610 Espoo (FI)

(72) Inventors:
- **Doumanis, Efstratios**
02610 Espoo (FI)
- **Ermutlu, Murat Emre**
02610 Espoo (FI)

(74) Representative: **DREISS Patentanwälte PartG mbB**
Friedrichstraße 6
70174 Stuttgart (DE)

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(54) RESONATOR FOR RADIO FREQUENCY SIGNALS

(57) A resonator (10; 10a; 10b; 10c) for radio frequency, RF, signals, said resonator (10; 10a; 10b; 10c) comprising a cavity (8), the cavity comprising a first wall (102), a second wall (104) opposite the first wall, and at least one side wall (106); the resonator also comprising: a resonator post (120) having a basically cylindrical body (122) with a first diameter (D1), wherein a first axial end section (122a) of said body (122) is attached to an inner surface (104a) of said second wall (104), and wherein a second axial end section (122b) of said body (122) extends into said cavity (8) and has a second diameter (D2) which is greater than said first diameter (D1), a first element (130; 1300) having a basically rotational solid shape radially surrounding at least the first axial end section (122a) of said body (122) and at least a part of an intermediate section (122c) of said body (122) which is arranged between said first and second axial end sections (122a, 122b), wherein a first axial end section (130a) of said first element (130) is attached to the inner surface (104a) of said second wall (104).

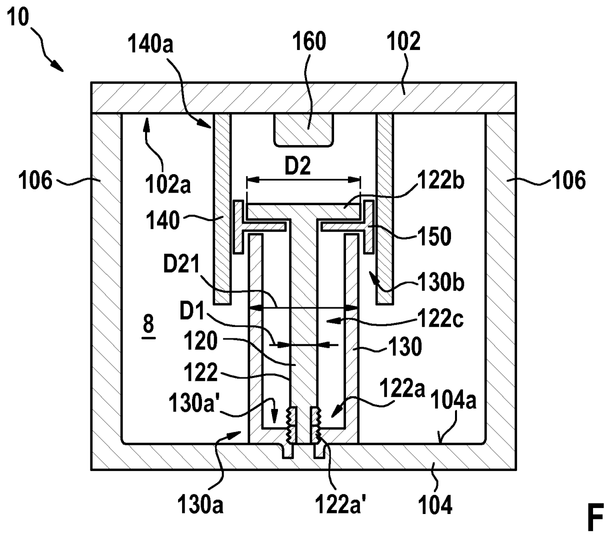

Fig. 1

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Description

Technical Field

[0001] Example embodiments relate to a resonator for radio frequency, RF, signals.

Background

[0002] In filters for use in high to medium power base stations, particularly at the lower end of the microwave frequency spectrum, for example around 700 MHz (Megahertz), the physical volume and weight of the filter is a concern. In high to medium power applications, such as those found in mobile cellular communication base stations and networks, there is still no real practical alternative to cavity filters.

[0003] That volume and weight is an issue, is a consequence of the fact that the requirements for electrical performance by the filter are stringent, for example, to provide high isolation between transmit and receive paths.

[0004] This often places practical lower limits on filter size. The choice of filter technology for a given application depends on the application specifics. However, there are certain desirable characteristics that are common to many filters. For example, insertion loss in the pass-band of a filter should be as low as possible, while the attenuation in the stop-band should be as high as possible. Furthermore, in some applications the guard band, namely the frequency separation between the pass-band and stop-band, needs to be narrow. This requires filters of high order to be implemented in order to achieve this requirement. However, the requirement for a high-order filter is accompanied by an increase in complexity (due to a greater number of components that a filter requires) and in size.

[0005] In addition to the requirement for low insertion loss (high quality factor), power handling, miniaturisation and tunability of a filter are also of importance. Power handling capability is highly dependent on the energy density of the electromagnetic (EM) fields inside the filter cavity, and, in general, the greater the energy density of the EM fields, the lower the power that can be handled.

[0006] Since the miniaturisation of a filter's cavity inherently increases the energy density of EM fields, it can be stated that, in general, miniaturisation results in reduced power handling.

Summary

[0007] Example embodiments relate to a resonator for radio frequency, RF, signals, said resonator comprising a cavity, the cavity comprising a first wall, a second wall opposite the first wall, and at least one side wall; the resonator also comprising: a resonator post having a basically (preferably circular) cylindrical body with a first diameter, wherein a first axial end section of said body is attached to an inner surface of said second wall, and wherein a second axial end section of said body extends into said cavity and has a second diameter which is greater than said first diameter, a first element having a basically rotational solid shape radially surrounding at least the first axial end section of said body and at least a part of an intermediate section of said body which is arranged between said first and second axial end sections, wherein a first axial end section of said first element is attached to the inner surface of said second wall.

[0008] In the present context, "basically cylindrical body" means that the body has a basic shape which is cylindrical, and that deviations from a strict cylindrical shape in a geometrical sense are possible. This e.g. also applies to the "basically rotational solid shape" mentioned below.

[0009] According to preferred embodiments, a second element is provided that has a basically rotational solid shape radially surrounding at least the second axial end section of said body wherein a first axial end section of said second element is attached to an inner surface of said first wall.

[0010] According to further preferred embodiments, said resonator post comprises a basically T-shaped cross-section.

[0011] According to further preferred embodiments, said first element and/or said second element has a basically hollow cylindrical shape.

[0012] According to further preferred embodiments, a third element is provided which comprises a basically rotational solid shape, wherein said third element is arranged between a second axial end section of said body and a second axial end section of said first element.

[0013] According to further preferred embodiments, said third element comprises a basically T-shaped cross-section.

[0014] According to further preferred embodiments, said third element is made of dielectric material, wherein preferably said dielectric material comprises ceramic material or polytetrafluorethylene, PTFE.

[0015] According to further preferred embodiments, said first element comprises at its first axial end section a radially inward protruding end section.

[0016] According to further preferred embodiments, said first axial end section of said body comprises a threaded portion, particularly for screwing into a respective threaded opening within said inner surface of said second wall and/or within a or said radially inward protruding end section of said first element.

[0017] According to further preferred embodiments, said first element and/or said second element has a basically conical shape, preferably substantially a right circular conical shape. According to further embodiments, the aperture (angle) of the first and second elements is substantially identical.

[0018] According to preferred embodiments, said second axial end section of the body of the resonator post comprises a basically trapezoidal cross-section.

[0019] According to further preferred embodiments, opposing surfaces of said second axial end section of said body and said second element are substantially parallel to each other.

[0020] According to further preferred embodiments, opposing surfaces of said first element and said second element are substantially parallel to each other.

[0021] According to further preferred embodiments, a tuning element is provided within said cavity, wherein said tuning element is preferably arranged on an or said inner surface of said first wall.

[0022] According to further preferred embodiments, the inner surface of said second wall comprises a protrusion to which the resonator post and/or the first element are, preferably detachably, attachable. According to further preferred embodiments, said protrusion is substantially cylindrical, preferably having a circular disc shape (with a diameter of said disc shape being greater than a height measured along an axial direction of said circular disc shape).

[0023] According to further preferred embodiments, the diameter of the disc shape of the protrusion is substantially similar or identical to an outer diameter of the first axial end section of said first element.

[0024] Further preferred embodiments relate to a filter for radio frequency, RF, signals comprising at least one resonator according to the embodiments.

[0025] Further preferred embodiments relate to a method of filtering a radio frequency, RF, signal, comprising passing said RF signal through a filter comprising at least one resonator according to the embodiments.

[0026] Exemplary embodiments may provide at least one of the following advantages: a size reduction leading to a very compact resonator, increased power handling, high performance, i.e. a high quality factor Q per volume, superior spurious-free performance, low-cost implementation, particularly enabling low-cost mass-production techniques, easy implementation, robustness, and good tunability.

Brief Description of the Drawings

[0027] Some example embodiments will now be described with reference to the accompanying drawings.

Fig. 1 schematically depicts a cross-sectional side view of an example embodiment of a resonator according to an embodiment,

Fig. 2 schematically depicts a cross-sectional side view of an example embodiment of a resonator according to a further embodiment,

Fig. 3 schematically depicts a cross-sectional side view of an example embodiment of a resonator according to a further embodiment,

Fig. 4 schematically depicts a cross-sectional side view of an example embodiment of a resonator according to a further embodiment,

Fig. 5 schematically depicts scattering parameters according to an exemplary embodiment,

Fig. 6 schematically depicts scattering parameters according to a further exemplary embodiment, and

Fig. 7 schematically depicts a detail view of Fig. 1.

Detailed Description

[0028] Figure 1 schematically depicts a cross-sectional side view of an example embodiment of a resonator 10 for radio frequency, RF, signals according to an embodiment.

[0029] The resonator 10 comprises a cavity 8 comprising a first wall 102, a second wall 104 opposite the first wall, and at least one side wall 106. Presently, the first wall 102 may form a lid that is detachably attachable to the further walls, preferably the side walls 106, of the resonator.

[0030] According to some embodiments, the side walls 106 and the first and second walls 102, 104 may form a basically cuboid shape with the first and second walls 102, 104 substantially parallel to each other and with four side walls 106 extending vertically in Fig. 1 between the first and second walls 102, 104. Note that in Fig. 1 only a left and right side wall 106 are depicted for the sake of clarity, while a front and rear side wall are not depicted.

[0031] The resonator 10 further comprises a resonator post 120 having a basically cylindrical body 122, preferably circular cylindrical body 122, with a first diameter D1, wherein a first axial end section 122a of said body 122 is attached to an inner surface 104a of said second wall 104, and wherein a second axial end section 122b of said body 122 extends into said cavity 8 and has a second diameter D2 which is greater than said first diameter D1.

[0032] The resonator 10 further comprises a first element 130 having a basically rotational solid shape radially surrounding at least the first axial end section 122a of said body 122 and at least a part of an intermediate section 122c of said body 122 which is arranged between said first and second axial end sections 122a, 122b, wherein a first axial end section 130a of said first element 130 is attached to the inner surface 104a of said second wall 104.

[0033] According to some embodiments, the resonator 10 further comprises a second element 140 surrounding at least the second axial end section 130b of the first element 130.

[0034] According to further embodiments, said second element 140 may comprise a basically rotational solid shape.

[0035] According to further embodiments, said second element 140 (which preferably has a basically rotational solid shape) is radially surrounding at least the second axial end section 122b of said body 122. Preferably, a first axial end section 140a of said second element 140 is attached to an inner surface 102a of said first wall 102.

[0036] According to some embodiments, said resonator post 120 comprises a basically T-shaped cross-section. According to further embodiments, the first element 130 comprises a basically hollow cylindrical shape and is preferably arranged coaxially with said body 122 of the resonator post 120. According to further embodiments, the second element 140 also comprises a basically hollow cylindrical shape.

[0037] According to some embodiments, during operation of the resonator, the T-shaped resonator post 120 interacts with the first element 130, which may be considered to form an inner conductor according to some embodiments. According to further embodiments, the diameter D2 of the second axial end section 122b, e.g. of the top surface of the T-shaped resonator post 120, may be chosen such that the second axial end section 122b is in close proximity to the second axial end section 130b ("open end") of the hollow cylindrical first element 130. In that way the T-shaped resonator post 120 or its second axial end section 122b, respectively, may interact particularly efficiently with the hollow cylindrical first element 130.

[0038] Fig. 7 depicts a detail view of Fig. 1 indicating an axial distance ad1 between the components 122b, 130b. According to some embodiments, said axial distance ad1 may range between about 0.5 mm (millimeter) and about 3.0 mm, preferably between about 0.5 mm and about 2.0 mm.

[0039] According to further embodiments, the T-shaped resonator post 120 or its second axial end section 122b, respectively, may at least partly overlie the first hollow cylindrical element 130. As an example, the second axial end section 122b may comprise a second diameter D2 which is substantially equal to or greater than the diameter D21 of the first hollow cylindrical element 130.

[0040] According to further embodiments, the T-shaped resonator post 120 or its second axial end section 122b, respectively, may be adjacent to said second element 140, which may be considered to form an outer conductor according to some embodiments.

[0041] According to some embodiments, a radial distance rd1, cf. Fig. 7, may range between about 0.5 mm and about 3.0 mm, preferably between about 0.5 mm and about 2.0 mm.

[0042] According to further embodiments, a third element 150 (Fig. 1) may be provided which comprises a basically rotational solid shape, wherein said third element 150 is arranged between the second axial end section 122b of said body 122 and the second axial end section 130b of said first element 130.

[0043] Preferably, according to some embodiments, said third element 150 comprises a basically T-shaped cross-section. According to further embodiments, said third element 150 is made of dielectric material, wherein preferably said dielectric material comprises ceramic material or polytetrafluorethylene, PTFE.

[0044] According to further embodiments, said third element 150 may also comprise metallic material or a metallic surface. In these cases, it may be preferable to provide mechanical means of support that do not attach / contact the remaining conductive structure such as e.g. the resonator post 120 and/or the first element 130 and/or the second element 140.

[0045] According to some embodiments, such support may e.g. be provided in the form of an additional dielectric support (not shown) e.g. fixing the third element 150 in a position relative to the components 120, 130, 140 such that there is an air gap between said third element 150 and these components 120, 130, 140. However, if - according to further embodiments - said third element 150 is made of dielectric material, an air gap is not required, but direct contact between the third element 150 and any of the components 120, 130, 140 is possible.

[0046] According to preferred embodiments, the presence of the third element 150 further improves the power handling capability of the resonator 10.

[0047] According to some embodiments, said first axial end section 122a of said body 122 comprises a threaded portion 122a', particularly for screwing into a respective threaded opening (not shown) within said inner surface 104a of said second wall 104 or another component 130a.

[0048] According to some embodiments, said first element 130 comprises at its first axial end section 130a a radially inward protruding end section 130a'. According to some embodiments, this end section 130a' may comprise a threaded hole for receiving said threaded section 122a' of the body 122. Alternatively, said end section 130a' may comprise a through hole (i.e., without threading).

[0049] In the following, examples for implementing and manufacturing components of the resonator 10 according to Fig. 1 are provided.

[0050] According to exemplary embodiments, the resonator post 120 and/or the first element 130 may be made out of electrically conductive material or a non-conductive material with a conductive surface or surface layer (e.g., metallized surface). According to further embodiments, the resonator post 120 and/or the first element 130 may also be made out of other material, e.g. ceramic or dielectric.

[0051] According to some embodiments, the first element 120 is hollow, e.g. substantially a hollow cylinder, and can be made as a deep-drawn piece. According to further embodiments, the resonator post 120 (e.g., T-shaped) may be threaded at the bottom, i.e. its first axial end section 122a may be screwed towards the inner surface 104a of the second wall 104, which may represent a ground bottom side of the cavity 8.

[0052] According to further embodiments, the resonator post 120 may be employed also as a mechanical support of the hollow cylindrical first element 130. The threaded section 122a' of the resonator post 120 may e.g. be used to screw down and lock the hollow cylindrical first element 130 to the cavity 8 or its bottom wall 104, respectively. This provides a particularly advantageous way to ease the fabrication and assembly of the resonator 10. This way, locking down/screwing of the hollow cylindrical first element 130 may be achieved (by means of the threaded section 122a') without the use of an extra screw, saving on cost and assembly. It creates a low-cost easy-to-fabricate solution for the implementation of the resonator 10 according to some embodiments. In other words, in some embodiments, the T-shaped body 122 may play a double role. With the hollow cylindrical first element 120 made in the deep-drawn technology according to some embodiments and utilizing said T-shaped body 122 for fixing said first element 120 to the second wall 104, assembly of this components within the cavity 8 is facilitated.

[0053] According to further embodiments, the second element 140 may also be a hollow cylinder and may also be deep-drawn. Alternatively, according to further embodiments, it can also be made by similar means to the making of a bushing.

[0054] According to further embodiments, the second element 140 can also be stamped on the lid 102 of the resonator 10. This approach gives a particularly compact resonator 10 that is easy to build and assemble, contributing to an increased efficiency.

[0055] According to further embodiments, an optional tuning element 160 may be provided within said cavity 8, wherein said tuning element 160 is preferably arranged on said inner surface 102a of said first wall 102 ("lid").

[0056] According to further embodiments, the wall components 102, 104, 106 of the cavity may be machined or die-casted and may preferably comprise metal material.

[0057] Figure 2 schematically depicts a cross-sectional side view of an example embodiment of a resonator 10a according to a further embodiment. In this embodiment, the cavity 8, particularly the second wall 104, is extended to form part of the first element 130. According to some embodiments, the inner surface 104a of said second wall 104 comprises a protrusion 170 to which the resonator post 120 and/or the first element 130 are, preferably detachably, attachable.

[0058] In effect, the first element 130 may be made partly out of the cavity material (wall 104, protrusion 170) and partly out of a different way, for example, a deep-drawn piece.

[0059] According to further embodiments, the T-shaped resonator post 120 enables a particularly efficient operation of the resonator 10, 10a. According to Applicant's analysis, it provides a route for the currents to run, thus increasing the overall surface area where resonant currents are running thus providing more efficient performance (higher Q-factor). The T-shaped section of the resonator post 120 is also increasing the volume area in which the electric field is stored thus reducing the operating frequency and increasing the power handling. According to some embodiments, the T-shaped section of the resonator post 120 at least partly overlies the inner hollow conductor, i.e. the first element 130, at its open end, i.e. the second axial end section 130b and is preferably adjacent to the other outer conductor, i.e. the first element 130. This way, the electric field is increased thus making the resonator 10, 10a more compact.

[0060] According to some embodiments, the third element 150, e.g. in the form of a teflon (PTFE) ring as shown in Fig. 1, 2, with T-shaped cross-section, may serve two purposes other than the immediate effect of reducing the frequency of operation: 1. to make the resonator 10 more robust, as it can be used to support mechanically the remaining elements 120, 130, 140 and 2. to increase the power handling by covering the areas where the strong electric fields are present.

[0061] According to some embodiments, the second element 140 may be employed to run currents on its surfaces and thus store the magnetic field energy inside the cavity 8 of the resonator 10, 10a.

[0062] Figure 3 schematically depicts a cross-sectional side view of an example embodiment of a resonator 10b according to a further embodiment. In contrast to the embodiments explained above with reference to Fig. 1, Fig. 2, the resonator 10b of Fig. 3 comprises a first element 1300 and a second element 1400 which each have a basically conical shape. Further, the second axial end section 122b of the body 122 of the resonator post 120 comprises a basically trapezoidal cross-section with the second diameter D2 representing the base (longer one of the two parallel sides) of the trapezoid shape, wherein preferably the first diameter D1 of the body 122 substantially corresponds with a length of the shorter one of the two parallel sides.

[0063] In other words, a cross-section or diameter of the second axial end section 122b, the first element 1300, and the second element 1400 change over a vertical coordinate of the depiction of Fig. 3. According to some embodiments, the second element 1400 may be attached with its first axial end section 1400a to the lid 102 (an inner surface of the lid 102), and the first element 1300 may be attached with its first axial end section 1300a to the (bottom) wall 104.

[0064] According to some embodiments, opposing surfaces 1222, 1400c of said second axial end section 122b of said body 122 and said second element 1400 are substantially parallel to each other. According to some embodiments, opposing surfaces 1300c, 1400d of said first element 1300 and said second element 1400 are substantially parallel to each other. This is creating a uniform area where the electric energy can be stored during operation of the resonator 10b.

[0065] Similar to Fig. 1, the resonator 10b of Fig. 3 may also comprise a body 122 with a threaded section 122a' (not shown in Fig. 3) for detachably attaching it to the wall 104 of the resonator 10b. The first and second elements 1300, 1400 may e.g. be deep-drawn or may be made similar to a bushing.

[0066] Figure 4 schematically depicts a cross-sectional side view of an example embodiment of a resonator 10c according to a further embodiment. Similar to Fig. 2, a protrusion 170 may be provided to which the elements 120, 1300 may be, preferably detachably, attached.

[0067] Similar to Fig. 1, the resonators 10a, 10b, 10c of Fig. 2 to 4 may also optionally comprise a tuning element 160 according to further embodiments.

[0068] Exemplary embodiments as inter alia explained above with reference to Fig. 1, 2, 3, 4 may provide better tolerances, ease of fabrication and compactness as well as a size reduction leading to a very compact resonator 10, 10a, 10b, 10c that may offer at least one of: increased power handling, high performance, i.e. a high quality factor Q per volume, superior spurious-free performance, low-cost implementation, particularly enabling low-cost mass-production techniques, easy implementation, robustness, and good tunability.

[0069] In the following, simulation results are discussed which have been obtained by numerical simulation with a numerical simulation tool ("Eigenmode solver") of an example resonator module similar to exemplary embodiments as explained above with reference to Fig. 1.

[0070] The example resonator on which the numerical simulation is based comprises dimensions of 2cm (centimeter) x 2cm x 0.7cm (i.e., a volume of about 2.8 cm^3). The operating frequency is 3384 MHz with a Q-factor of ~2000 (not optimized). The physical height of the resonator (internal height, corresponding to a vertical dimension of the cavity 8 of e.g. Fig. 1) is 1=0.7 cm. This represents an electrical height for the simulated resonator of 0.0886 $\lambda 0$ or ~28.4°. The first harmonic appears at 17248 MHz, thus a ratio of fundamental to harmonic of ~5.1. The surface current distribution (not shown) as obtained from the simulation shows that there is a current running along the body 122 of the resonator post 120 (Fig. 1) as well as on the elements, 130, and 140. Compared to conventional resonators, this current distribution mechanism allows for reduced losses since the surface area that the currents run is greater.

[0071] As a comparison with conventional resonators, the same dimensions for the conventional resonator leads to a simulated operating frequency of ~3802.4 MHz and a Q-factor of ~2260. Thus, employing the new resonator according to some exemplary embodiments, with the same internal dimensions for the module in the same cavity, the frequency has dropped by about ~418.42 MHz or 11% operating frequency drop. This drop enhances the compact properties of the module significantly as compared to conventional resonators making resonators according to exemplary embodiments highly desirable and efficient for size reduction.

[0072] As a further example, in comparison with further conventional resonators, a resonator according to exemplary embodiments has a maximum electric field intensity of 3.03 e+09 V/m at 3384 MHz, whereas for the conventional resonator the maximum field intensity is the same at 3802.4 MHz. In another example resonator according to exemplary embodiments, the maximum field intensity drops to 2.68 e+09 V/m (11.55 % less) at a resonant frequency of 3295.79 MHz (represents an operating frequency drop of 506.63 MHz or 13.32 %).

[0073] Fig. 5 schematically depicts scattering parameters (S-parameters) according to an exemplary embodiment along a vertical axis y1 (magnitude in dB) over a frequency axis f1. Fig. 5 has been obtained by numerical simulation of a two-pole filter for RF signals using a resonator 10a according to exemplary embodiments.

[0074] Curve C1 indicates S-parameter S2,2 (output port voltage reflection coefficient), and curve C2 indicates S-parameter S1,2 (reverse voltage gain).

[0075] Fig. 6 schematically depicts scattering parameters along a vertical axis y2 (magnitude in dB) over a frequency axis f2 according to a further exemplary embodiment. Curve C3 indicates S-parameter S1,1 (input port voltage reflection coefficient) of an exemplary conventional resonator with specific mechanical dimensions, and curve C4 indicates S-parameter S2,1 (forward voltage gain) of said exemplary conventional resonator, while curve C5 indicates S-parameter S1,1 of a resonator according to an exemplary embodiment which has the same specific mechanical dimensions as said conventional resonator, and curve C6 indicates S-parameter S2,1 of the resonator according to an exemplary embodiment. While the cavity dimensions of the conventional resonator and the resonator according to an exemplary embodiment are the same, from Fig. 6 it can be seen that the filter with the resonators according to an exemplary embodiment has a significantly reduced center frequency of about 3219.5 MHz, as compared to that of the conventional resonator filter (3615.9 MHz)(reduction of about 10,96%).

[0076] The resonators 10, 10a, 10b, 10c according to exemplary embodiments may advantageously e.g. be used for providing RF filters having one or more filter poles.

[0077] Using at least one resonator 10, 10a, 10b, 10c according to exemplary embodiments, a method of filtering an RF signal may be provided comprising passing said RF signal through a filter comprising said at least one resonator 10, 10a, 10b, 10c.

[0078] Resonators 10, 10a, 10b, 10c according to exemplary embodiments may have the following benefits: size reduction: 11 % frequency drop (as of the simplified example) of the simplified version with the same external and internal dimensions, easy to implement and robust, improved power handling, as with the same critical dimensions the electric field intensity is reduced.

[0079] The description and drawings merely illustrate the principles of exemplary embodiments. 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 exemplary embodiments 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, as well as specific examples thereof, are intended to encompass equivalents thereof.

[0080] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying exemplary embodiments. 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.

[0081] A person of skill in the art would readily recognize that steps of various above-described methods can be performed and/or controlled 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.

Claims

1. A resonator (10; 10a; 10b; 10c) for radio frequency, RF, signals, said resonator (10; 10a; 10b; 10c) comprising a cavity (8), the cavity comprising a first wall (102), a second wall (104) opposite the first wall, and at least one side wall (106); the resonator also comprising: a resonator post (120) having a basically cylindrical body (122) with a first diameter (D1), wherein a first axial end section (122a) of said body (122) is attached to an inner surface (104a) of said second wall (104), and wherein a second axial end section (122b) of said body (122) extends into said cavity (8) and has a second diameter (D2) which is greater than said first diameter (D1), a first element (130; 1300) having a basically rotational solid shape radially surrounding at least the first axial end section (122a) of said body (122) and at least a part of an intermediate section (122c) of said body (122) which is arranged between said first and second axial end sections (122a, 122b), wherein a first axial end section (130a; 1300a) of said first element (130; 1300) is attached to the inner surface (104a) of said second wall (104).

2. A resonator (10; 10a; 10b; 10c) according to claim 1, wherein a second element (140; 1400) is provided that has a basically rotational solid shape radially surrounding at least the second axial end section (122b) of said body (122) wherein a first axial end section (140a; 1400a) of said second element (140; 1400) is attached to an inner surface (102a) of said first wall (102).

3. A resonator (10; 10a) according to at least one of the preceding claims, wherein said resonator post (120) comprises a basically T-shaped cross-section.

4. A resonator (10; 10a) according to at least one of the preceding claims, wherein said first element (130) and/or said second element (140) has a basically hollow cylindrical shape.

5. A resonator (10; 10a) according to at least one of the preceding claims, wherein a third element (150) is provided which comprises a basically rotational solid shape, wherein said third element (150) is arranged between the second axial end section (122b) of said body (122) and a second axial end section (130b) of said first element (130).

6. A resonator (10; 10) according to claim 5, wherein said third element (150) comprises a basically T-shaped cross-section.

7. A resonator (10; 10) according to claim 6, wherein said third element (150) is made of dielectric material, wherein preferably said dielectric material comprises ceramic material or polytetrafluorethylene, PTFE.

8. A resonator (10; 10a) according to at least one of the preceding claims, wherein said first element (130) comprises at its first axial end section (130a) a radially inward protruding end section (130a').

9. A resonator (10; 10a) according to at least one of the preceding claims, wherein said first axial end section (122a) of said body (122) comprises a threaded portion (122a'), particularly for screwing into a respective threaded opening within said inner surface (104a) of said second wall (104) and/or within a or said radially inward protruding end section (130a') of said first element (130).

10. A resonator (10b; 10c) according to at least one of

the preceding claims, wherein said first element (1300) and/or said second element (1400) has a basically conical shape.

11. A resonator (10b; 10c) according to claim 10, wherein said second axial end section (122b) comprises a basically trapezoidal cross-section.

12. A resonator (10b; 10c) according to at least one of the claims 2 to 11, wherein opposing surfaces (1222, 1400c) of said second axial end section (122b) of said body (122) and said second element (140; 1400) are substantially parallel to each other, and/or wherein opposing surfaces (1300c, 1400d) of said first element (130; 1300) and said second element (140; 1400) are substantially parallel to each other.

13. A resonator (10; 10a; 10b; 10c) according to at least one of the preceding claims, wherein a tuning element (160) is provided within said cavity (8), wherein said tuning element (160) is preferably arranged on an or said inner surface (102a) of said first wall (102).

14. A resonator (10; 10a; 10b; 10c) according to at least one of the preceding claims, wherein the inner surface (104a) of said second wall (104) comprises a protrusion (170) to which the resonator post (120) and/or the first element (130) are, preferably detachably, attachable.

15. A filter for radio frequency, RF, signals comprising at least one resonator (10; 10a; 10b; 10c) according to at least one of the preceding claims.

16. A method of filtering a radio frequency, RF, signal, comprising passing said RF signal through a filter comprising at least one resonator (10; 10a; 10b; 10c) according to at least one of the claims 1 to 14.

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

1. A resonator (10; 10a; 10b; 10c) for radio frequency, RF, signals, said resonator (10; 10a; 10b; 10c) comprising a cavity (8), the cavity comprising a first wall (102), a second wall (104) opposite the first wall, and at least one side wall (106); the resonator also comprising: a resonator post (120) having a basically cylindrical body (122) with a first diameter (D1), wherein a first axial end section (122a) of said body (122) is attached to an inner surface (104a) of said second wall (104), and wherein a second axial end section (122b) of said body (122) extends into said cavity (8) and has a second diameter (D2) which is greater than said first diameter (D1), a first element (130; 1300) having a basically rotational solid shape radially surrounding at least the first axial end section (122a) of said body (122) and at least a part of an intermediate section (122c) of said body (122) which is arranged between said first and second axial end sections (122a, 122b), wherein a first axial end section (130a; 1300a) of said first element (130; 1300) is attached to the inner surface (104a) of said second wall (104), wherein a second element (140; 1400) is provided that has a basically rotational solid shape radially surrounding at least the second axial end section (122b) of said body (122) wherein a first axial end section (140a; 1400a) of said second element (140; 1400) is attached to an inner surface (102a) of said first wall (102).

2. A resonator (10; 10a) according to claim 1, wherein said resonator post (120) comprises a basically T-shaped cross-section.

3. A resonator (10; 10a) according to at least one of the preceding claims, wherein said first element (130) and/or said second element (140) has a basically hollow cylindrical shape.

4. A resonator (10; 10a) according to at least one of the preceding claims, wherein a third element (150) is provided which comprises a basically rotational solid shape, wherein said third element (150) is arranged between the second axial end section (122b) of said body (122) and a second axial end section (130b) of said first element (130).

5. A resonator (10; 10) according to claim 4, wherein said third element (150) comprises a basically T-shaped cross-section.

6. A resonator (10; 10) according to claim 5, wherein said third element (150) is made of dielectric material, wherein preferably said dielectric material comprises ceramic material or polytetrafluorethylene, PTFE.

7. A resonator (10; 10a) according to at least one of the preceding claims, wherein said first element (130) comprises at its first axial end section (130a) a radially inward protruding end section (130a').

8. A resonator (10; 10a) according to at least one of the preceding claims, wherein said first axial end section (122a) of said body (122) comprises a threaded portion (122a'), particularly for screwing into a respective threaded opening within said inner surface (104a) of said second wall (104) and/or within a or said radially inward protruding end section (130a') of said first element (130) .

9. A resonator (10b; 10c) according to at least one of the preceding claims, wherein said first element (1300) and/or said second element (1400) has a basically conical shape.

10. A resonator (10b; 10c) according to claim 9, wherein said second axial end section (122b) comprises a basically trapezoidal cross-section.

11. A resonator (10b; 10c) according to at least one of the preceding claims, wherein opposing surfaces (1222, 1400c) of said second axial end section (122b) of said body (122) and said second element (140; 1400) are substantially parallel to each other, and/or wherein opposing surfaces (1300c, 1400d) of said first element (130; 1300) and said second element (140; 1400) are substantially parallel to each other.

12. A resonator (10; 10a; 10b; 10c) according to at least one of the preceding claims, wherein a tuning element (160) is provided within said cavity (8), wherein said tuning element (160) is preferably arranged on an or said inner surface (102a) of said first wall (102).

13. A resonator (10; 10a; 10b; 10c) according to at least one of the preceding claims, wherein the inner surface (104a) of said second wall (104) comprises a protrusion (170) to which the resonator post (120) and/or the first element (130) are, preferably detachably, attachable.

14. A filter for radio frequency, RF, signals comprising at least one resonator (10; 10a; 10b; 10c) according to at least one of the preceding claims.

15. A method of filtering a radio frequency, RF, signal, comprising passing said RF signal through a filter comprising at least one resonator (10; 10a; 10b; 10c) according to at least one of the claims 1 to 13.

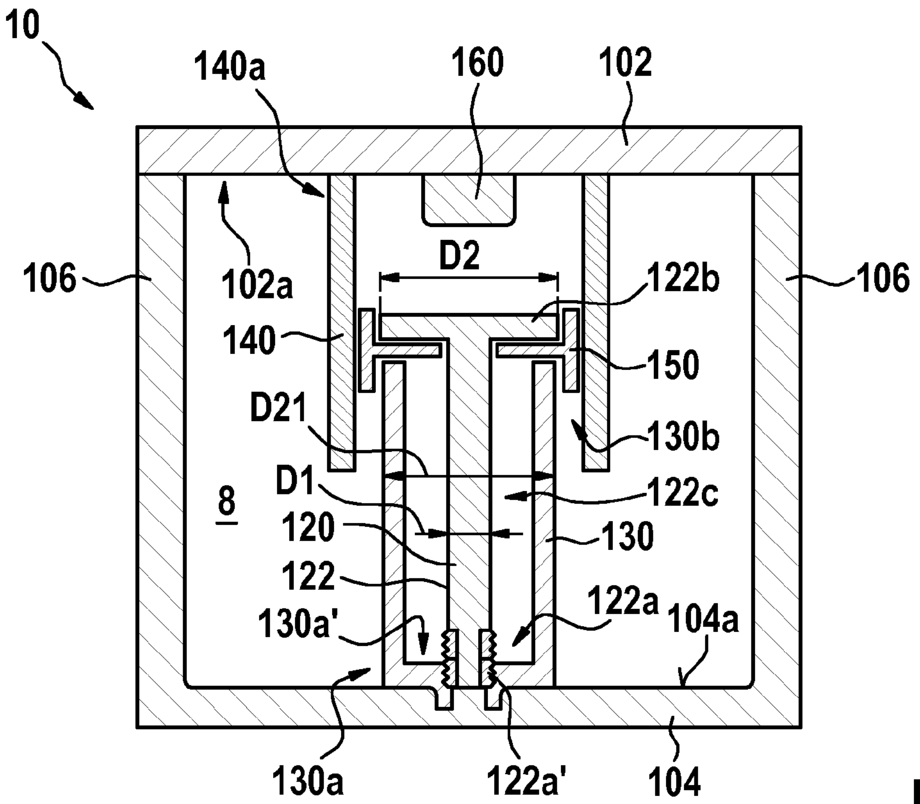
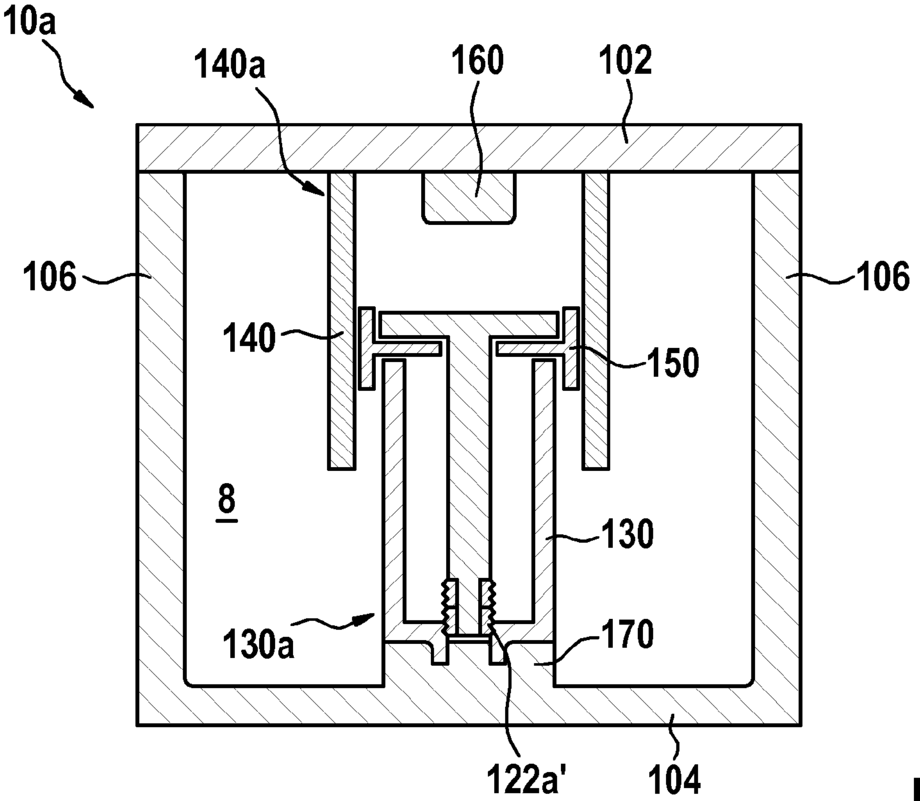

10
140a
160
102
106
102a
D2
122b
106
140
150
D21
130b
D1
122c
8
120
130
122
122a
104a
130a'
130a
122a'
104

Fig. 1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140a
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102
106
106
140
150
8
130
130a
170
122a'
104

Fig. 2

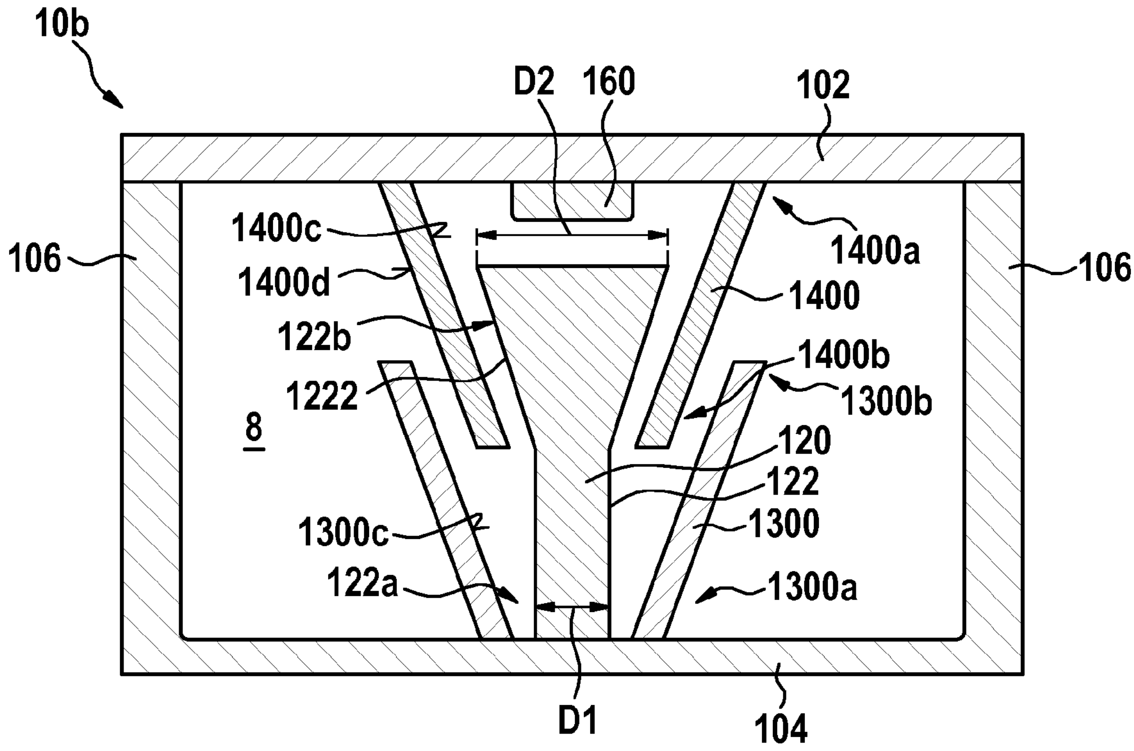

10b
D2
160
102
1400c
1400a
106
106
1400d
1400
122b
1400b
1222
1300b
8
120
122
1300c
1300
122a
1300a
D1
104

Fig. 3

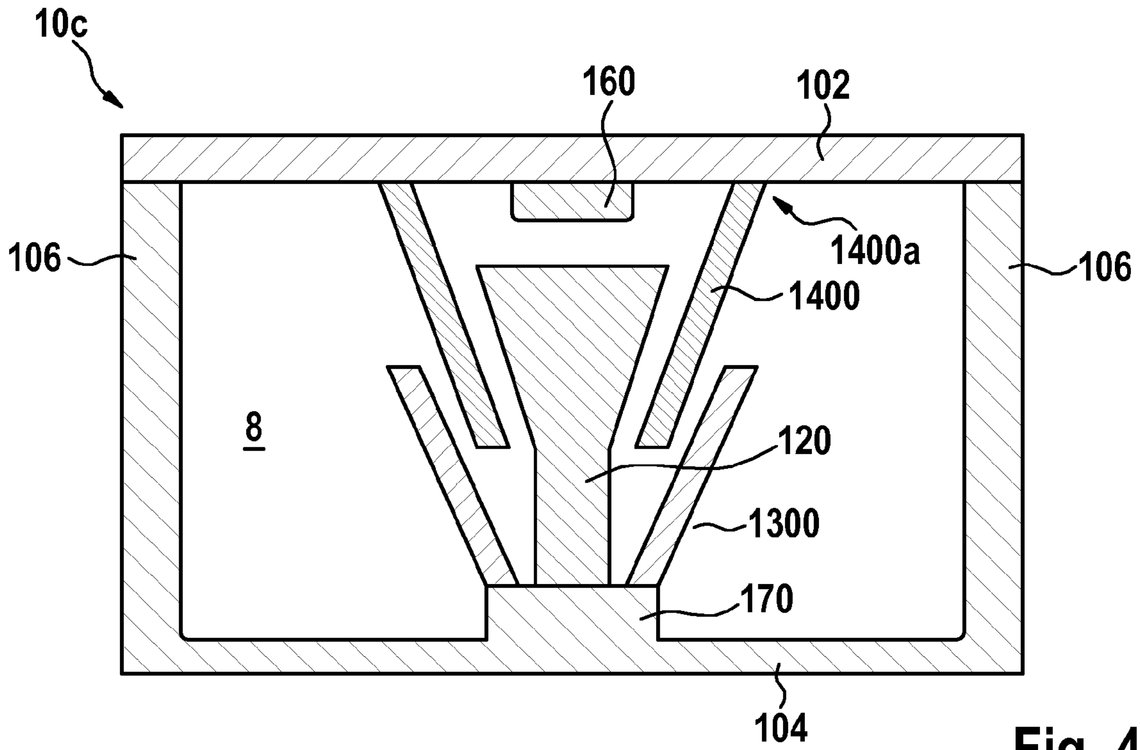

10c
160
102
1400a
106
106
1400
8
120
1300
170
104

Fig. 4

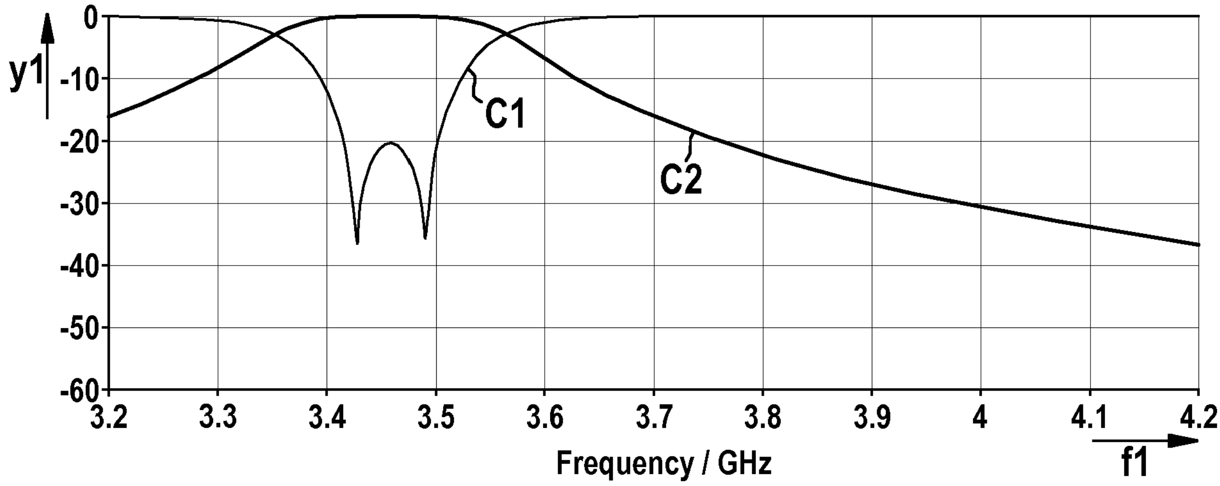
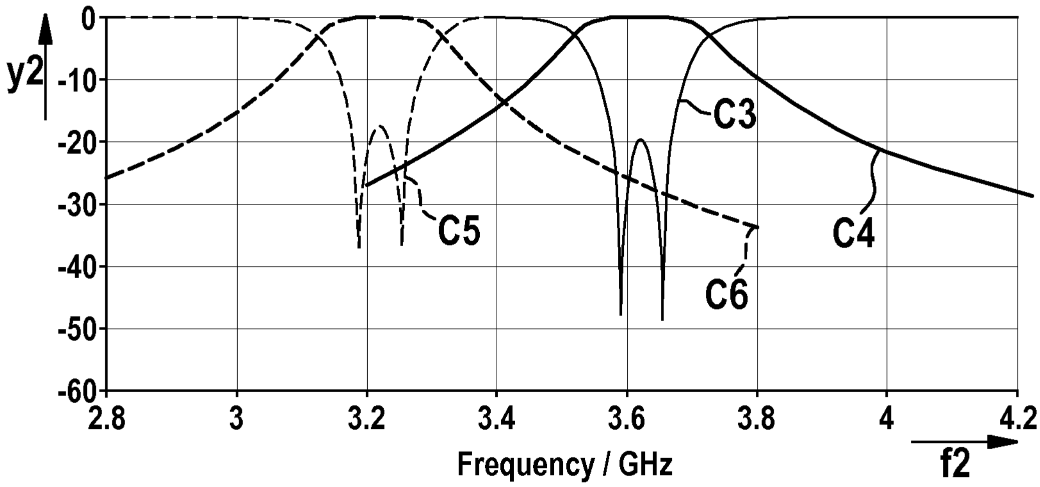

y1
0
-10
-20
-30
-40
-50
-60
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4
4.1
4.2
Frequency / GHz
f1
C1
C2

Fig. 5


y2
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-10
-20
-30
-40
-50
-60
2.8
3
3.2
3.4
3.6
3.8
4
4.2
Frequency / GHz
f2
C3
C4
C5
C6

Fig. 6

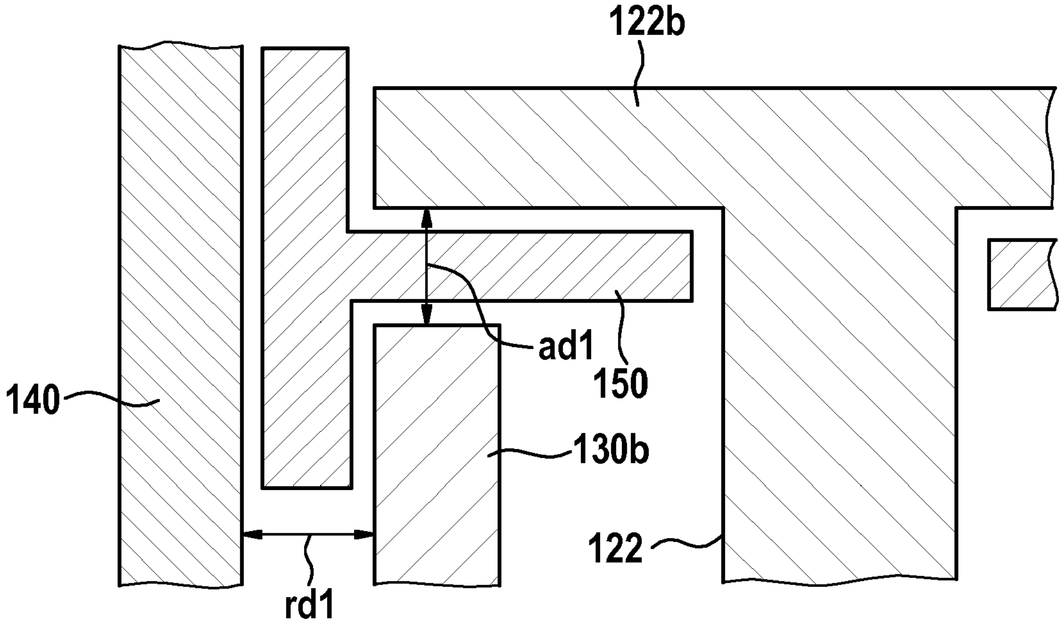

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 4328

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 760 824 A1 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 7 March 2007 (2007-03-07) * paragraphs [0044], [0063]; figure 6 * -----	1,3-6,8, 9,13-16	INV. H01P7/04
X	US 3 448 412 A (JOHNSON EINAR C) 3 June 1969 (1969-06-03) * column 2 - column 3; figure 1 * -----	1,3-7,9, 14-16	
Y	KR 101 595 551 B1 (ACE TECHNOLOGIES CORP [KR]) 22 February 2016 (2016-02-22) * paragraph [0021] - paragraph [0041]; figures 3-5 * -----	1,2,4, 10-13, 15,16	
Y	EP 3 104 453 A1 (ALCATEL LUCENT [FR]) 14 December 2016 (2016-12-14) * paragraph [0004] - paragraph [0017] * * paragraph [0039] - paragraph [0044]; figure 2 * -----	1,2,4, 10-13, 15,16	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	18 September 2018	Hueso González, J

CATEGORY OF CITED DOCUMENTS

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18-09-2018

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