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(12) # EUROPEAN PATENT APPLICATION

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

(54) **A radio frequency filter, a method of radio frequency filtering and a method of constructing a radio frequency filter**

(57) A radio frequency filter 2 is provided comprising at least one resonant chamber 20 that comprises a cavity 20 substantially filled by a granular material 6 and has a lid 10, the granular material being a dielectric material or magnetic material, in which a layer 24 of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

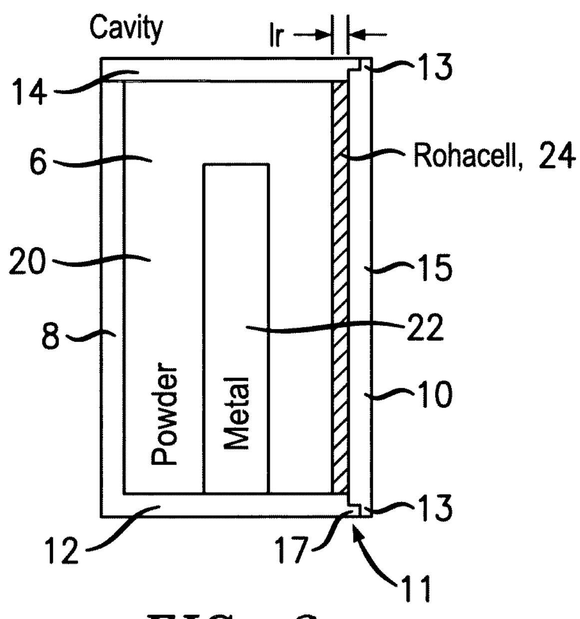

FIG. 2

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Description

Field of the Invention

[0001] The present invention relates to filters for telecommunications, in particular to radio frequency filters.

Description of the Related Art

[0002] Radio frequency filters made up of air-filled cavity resonators are known. It is also known to include posts in the cavity resonators that are loaded with rings of a high dielectric material.

Summary

[0003] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0004] An example of the present invention is a radio frequency filter comprising at least one resonant chamber that comprises a cavity substantially filled by a granular material and has a lid, the granular material being a dielectric material or magnetic material, in which a layer of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

[0005] The present invention also relates to a method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber that comprises a cavity substantially filled by a granular material and has a lid, the granular material being a dielectric material or magnetic material, in which a layer of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

[0006] The present invention also relates to a method of constructing a radio frequency filter comprising: constructing a lid and constructing a filter body comprising at least one cavity; selecting a granular material, the granular material being a dielectric material or magnetic material; filling said at least one cavity with the selected granular material; applying a layer of compressible material over the granular material; and putting the lid on over the layer of compressible material so as to apply uniform pressure to the granular material.

[0007] Preferred embodiments enable a density and packing of a powder or powder-like dielectric material in a filter cavity to be maintained and controlled. Preferred embodiments provide increased stability, uniformity and density in dielectric powder filled cavities.

[0008] Preferred embodiments enable uniform pressure to be applied to a powder or powder-like dielectric material within a metallic enclosure, specifically the cavity, so as to control the density of the dielectric material. In preferred embodiments, a small part of the cavity or a layer within the cavity is filled with an elastic, compressible and flexible material placed between the powder-filled cavity and the lid which is metallic. The compressible material is preferably of low loss and has low impact on the resonating structure.

[0009] Preferably the lid which may be metallic is shaped and configured to fit the filter body so as to provide a uniform pressure to the granular material without the granular material being squeezed out.

[0010] Preferred embodiments are suitable for use in metrocell base stations and macrocell active antenna arrays.

[0011] Preferred embodiments allow uniform pressure to be applied to the granular material in such a way that its density may be controlled and stabilised. Preferred embodiments allow powders and powder-like materials to be used efficiently in filters and other radio frequency equipment.

[0012] In some preferred embodiments, the at least one chamber houses a respective resonator post and the chamber is substantially filled by the respective resonator post and the granular material.

Brief Description of the Drawings

[0013] An embodiment of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 is a cross sectional top view of a combline filter according to a first embodiment,

Figure 2 is a cross sectional end view of a dielectric-filled cavity resonator of the combline filter shown in Figure 1,

Figure 3 is a cross sectional top view of a combline filter according to a second embodiment but in a partly constructed state in which the side lid is not in place, and

Figure 4 is a cross sectional end view of a dielectric-filled cavity resonator of the combline filter according to a third embodiment.

Detailed Description

[0014] The inventors realised that in alternative proposals it was possible to design radio frequency filters having resonant cavities of reduced size compared to air-filled resonant cavities by loading cavities with dielectric or magnetic powder. The powder would fill the cavity practically irrespective of its shape or configuration.

[0015] The inventors realised that whereas it was easy to fill the cavity with the powder through a large aperture in the cavity, this aperture must usually then be closed by a lid. The inventors realised that this was often problematic as it was hard to avoid air spaces (in other words, void areas) with the cavity and hard to ensure an equal packing density of the powder throughout the intended powder volume.

[0016] The inventors realised that it would be useful to provide a way to control the density of the powder within the entire physical space that the powder dielectric material can occupy.

[0017] The inventors realised that it would be useful to control the density of the granular dielectric material by applying a uniform pressure to the material so as to have uniform density within the metal enclosure defining the cavity.

[0018] As shown in Figure 1 and 2, a Combline filter 2 is provided made up of a connected series of resonant cavities each filled with dielectric powder 6, having a dielectric constant for example in the range 2 to 10, in particular 3 to 5, and a low dielectric loss. For example a powder may be of a dielectric constant of 3.8 and a loss tangent of 6 x 10^{-5}).

[0019] This allows the filter to be smaller in size than if air-filled, for filtering at the same radio frequency. The filter 2 includes a first side wall 8 and a corresponding removable side wall denoted side lid 10, a base plate 12, a top plate 14, and end plates 16 that define the filter. There is also a series of partial inner walls 18 parallel to the end plates 16 that define a series of the resonant cavities 20. Each resonant cavity 20 has an input port (not shown) and an output port (not shown). Within each cavity 20 extending from the base plate 12 is a respective metal post 22.

[0020] As shown in Figure 1 and 2, a small part of each cavity 20 is filled with an elastic flexible and compressible material 24 placed between the powder filled cavity 20 and the side lid 10 which is metal or metallic. That compressible material 24 is low loss and because it is thin has low impact in terms of performance in radio frequency filtering.

<u>Configuration of the side lid with respect to the rest of the filter</u>

[0021] The side lid 10 has a cut-away edge step 11 that runs along all four of its sides so that it has an edge portion 13 of less depth than the main body 15 of the side lid 10.

[0022] A corresponding lip 17 is provided that runs along the corresponding end walls 16, base plate 12 and top plate 14.

[0023] The step 11 and lip 17 are shaped and configured to fit. Specifically, the edge step 11 of the side lid 10 includes a surface 9 against which the inside surface 7 of the lip 17 can slide. Also the lip 17 is configured such that when fastened together in use by screws 19 the edge portion 13 and lip 17 abut.

[0024] In construction, each cavity 20 is filled with the dielectric powder 6 and the compressible material 24, and the side lid is fitted thereto. As the side lid is put into position then fastened, the surface 9 of the side lid 10 slides against the inside surface 7 of the lip 17, so the dielectric powder is prevented from being squeezed out.

[0025] In some similar alternative embodiments (not shown), this feature that the surface of the side lid slides against the inside surface of the lip so the dielectric powder is prevented from being squeezed out, allows dielectric powder to be heaped up then compressed by bringing the side lid into position without loss of powder. In this way extra powder can be added (or removed) so as to readily adjust the density (and hence dielectric properties) of the powder in the filter whilst the compressible material layer 24 acts to keep the density of the powder uniform within the filter.

<u>The compressible material</u>

[0026] In this example the compressible material 24 is Rohacell foam. Rohacell is understood to be a registered trademark associated with Evonik Industries AG. In an otherwise similar alternative example the compressible material is Neoprene.

[0027] In manufacture, the cavities 20 are filled with powder 6 and the compressible material 24 namely the Rohacell foam layer placed over. Doing this may be considered as overfilling the cavities. Upon the side lid 10 being put into place, the Rohacell foam layer is compressed, adjusting the total volume of the foam layer and providing even compression on the powder 6 that fills the cavities 20.

<u>Some details</u>

[0028] Taking the Rohacell material as having a dielectric constant (real relative dielectric permittivity) of 1.067 and a loss tangent of 0.0041, it was calculated that altering the height lr from 2mm to 1 mm, (see Figure2) altered the resonant frequency of a resonant cavity by approximately less than 0.4%. The parameter values assumed were that the resonant cavity had an internal height of 120mm, an internal width of 70mm, a resonator post height of 93mm, and a post cross section diameter of 20.4mm. The dielectric powder was assumed to be fused quartz material having a permittivity of 3.8 and a loss tangent of 6x10-5. These calculations were performed using known High Frequency Structure Simulator (HFSS) software, version 15.0, provided by Ansoft (<u>Http://www.ansys.com/Products/Simulation+Technology/Electromagnetics/HighPerf ormance+Electronic+Design/ANSYS+HFSS).</u> An alteration in the resonant frequency of approximately 0.4% can be readily accommodated by the use a tuning screw (not shown) through the top plate 14 opposite the top of the post 22.

<u>Further Examples</u>

[0029] As shown in Figure 3, a basically similar alternative embodiment is provided, in which the side lid 10" is flat rather than having edge steps. In manufacture, the cavities 20" are filled with powder 6" and the compressible material 24" namely the Rohacell foam layer. Doing this may be considered as overfilling the cavities. Upon the side lid 10" being put into place, the Rohacell foam layer is compressed, adjusting the total volume of the foam layer and providing even compression on the powder 6" that fills the cavities 20".

[0030] As shown in Figure 4, in another basically similar alternative embodiment, in each resonant cavity 20' there is a tuning screw 26 which is located in a hole 28 through the top plate 14' so as to be adjustable in distance from the top of the metal post 22'. Each cavity 20' is filled with the powder 6' then a Rohacell layer 24' is applied and the top plate 14' secured in position. The foam layer 24' is thereby compressed, adjusting the total volume of the foam layer and providing even compression on the powder 6' that fills the cavities 20'. The foam layer 24' has holes 30 cut so as to correspond to the tuning screw positions, and it is through those holes that the tuning screws 26 may penetrate the foam layer 24'.

[0031] The present invention may be embodied in other specific forms without departing from its essential characteristics. For example a granular magnetic material may be used instead of a granular dielectric material.

[0032] The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0033] A person skilled in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Some embodiments relate to 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. Some embodiments involve computers programmed to perform said steps of the above-described methods.

Claims

1. A radio frequency filter (2) comprising at least one resonant chamber (20) that comprises a cavity (20) substantially filled by a granular material (6) and has a lid (10), the granular material being a dielectric material or magnetic material, in which a layer (24) of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

2. A radio frequency filter according to claim 1, in which the compressible foam material (24) is one of the Rohacell range of foam materials.

3. A radio frequency filter according to claim 1, in which the compressible foam material is Neoprene.

4. A radio frequency filter according to any preceding claim, in which the lid (10) has a cut-away edge step (11) that runs along its sides so that the lid has an edge portion (13) of less depth than its main body (15), the step being configured to fit a corresponding lip (17) that runs along corresponding walls of the filter.

5. A radio frequency filter according to claim 4, in which the edge step (11) of the lid (10) includes a surface (9) against which the inside surface (7) of the lip (17) is slidable.

6. A radio frequency filter according to claim 4 or claim 5, in which the lip (17) is configured such that when the lid is fastened in place the edge portion |(13) and lip (17) abut.

7. A radio filter according to any preceding claim, in which the at least one chamber (20) houses a respective resonator post (22) and the chamber is substantially filled by the respective resonator post (22) and the granular material (6).

8. A method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber (20) that comprises a cavity (20) substantially filled by a granular material (6) and has a lid(10), the granular material being a dielectric material or magnetic material, in which a layer (24) of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

9. A method of radio frequency filtering according to claim 8, in which the compressible foam material is one of the Rohacell range of foam materials.

10. A method of radio frequency filtering according to claim 8, in which the compressible foam material is Neoprene.

11. A method of radio frequency filter according to any of claims 8 to 10, in which the lid (10) has a cut-away edge step (11) that runs along its sides so that the lid has an edge portion (13) of less depth than its main body (15), the step being configured to fit a corresponding lip (17) that runs along corresponding walls of the filter.

12. A method of radio frequency filter according to any of claims 8 to 11, in which the edge step (11) of the lid (10) includes a surface (9) against which the inside surface (7) of the lip (17) is slidable.

13. A method of radio frequency filtering according to

claim 11 or claim 12, in which the lip (17) is configured such that when the lid is fastened in place the edge portion (13) and lip (17) abut, the lid having been pressed into position such that a side surface (9) of the lid (10) slides against the inside surface (7) of the lip (17) extending from the filter body, so that the granular dielectric material is prevented from being squeezed out.

14. A method of constructing a radio frequency filter comprising:

constructing a lid (10) and constructing a filter body (8, 12,14,16,20) comprising at least one cavity(20) ;
selecting a granular material (6), the granular material being a dielectric material or magnetic material;
filling said at least one cavity (20) with the selected granular material;
applying a layer (24) of compressible material over the granular material; and
putting the lid (10) on over the layer of compressible material so as to apply uniform pressure to the granular material.

15. A method of constructing a radio frequency filter according to claim 8, in which the step of bringing the lid (10) into position over the layer of compressible material comprises:

placing the lid on top, and
pressing the lid into position such that a side surface (9) of the lid (10) slides against the inside surface (7) of a lip (17) extending from the filter body, so that the granular dielectric material is prevented from being squeezed out.

16. A method of constructing a radio frequency filter according to claim 8 or claim 9, in which the amount of granular material (6) is adjusted before compression by bringing the lid into position, so as to adjust the density of the granular material in the filter.

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

1. A radio frequency filter (2) comprising at least one resonant chamber (20) that comprises a cavity (20) substantially filled by a granular material (6) and has a lid (10), the granular material being a dielectric material or magnetic material, in which a layer (24) of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

2. A radio frequency filter according to claim 1, in which the compressible foam material (24) is one of the Rohacell range of foam materials.

3. A radio frequency filter according to claim 1, in which the compressible foam material is Neoprene.

4. A radio frequency filter according to any preceding claim, in which the lid (10) has a cut-away edge step (11) that runs along its sides so that the lid has an edge portion (13) of less depth than its main body (15), the step being configured to fit a corresponding lip (17) that runs along corresponding walls of the filter.

5. A radio frequency filter according to claim 4, in which the edge step (11) of the lid (10) includes a surface (9) against which the inside surface (7) of the lip (17) is slidable.

6. A radio frequency filter according to claim 4 or claim 5, in which the lip (17) is configured such that when the lid is fastened in place the edge portion |(13) and lip (17) abut.

7. A radio filter according to any preceding claim, in which the at least one chamber (20) houses a respective resonator post (22) and the chamber is substantially filled by the respective resonator post (22) and the granular material (6).

8. A method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber (20) that comprises a cavity (20) substantially filled by a granular material (6) and has a lid(10), the granular material being a dielectric material or magnetic material, in which a layer (24) of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

9. A method of radio frequency filtering according to claim 8, in which the compressible foam material is one of the Rohacell range of foam materials.

10. A method of radio frequency filtering according to claim 8, in which the compressible foam material is Neoprene.

11. A method of radio frequency filtering according to any of claims 8 to 10, in which the lid (10) has a cut-away edge step (11) that runs along its sides so that the lid has an edge portion (13) of less depth than its main body (15), the step being configured to fit a corresponding lip (17) that runs along corresponding walls of the filter.

12. A method of radio frequency filtering according to any of claims 8 to 11, in which the edge step (11) of the lid (10) includes a surface (9) against which the inside surface (7) of the lip (17) is slidable.

13. A method of radio frequency filtering according to claim 11 or claim 12, in which the lip (17) is configured such that when the lid is fastened in place the edge portion (13) and lip (17) abut, the lid having been pressed into position such that a side surface (9) of the lid (10) slides against the inside surface (7) of the lip (17) extending from the filter body, so that the granular dielectric material is prevented from being squeezed out.

14. A method of constructing a radio frequency filter according to any of claims 1 to 7 comprising:

constructing the lid (10) and constructing a filter body (8, 12,14,16,20) comprising at least one cavity(20) ;
selecting the granular material (6), the granular material being a dielectric material or magnetic material;
filling said at least one cavity (20) with the selected granular material;
applying the layer (24) of compressible material over the granular material; and
putting the lid (10) on over the layer of compressible material so as to apply uniform pressure to the granular material.

15. A method of constructing a radio frequency filter according to claim 14, in which the step of bringing the lid (10) into position over the layer of compressible material comprises:

placing the lid on top, and
pressing the lid into position such that a side surface (9) of the lid (10) slides against the inside surface (7) of a lip (17) extending from the filter body, so that the granular dielectric material is prevented from being squeezed out.

16. A method of constructing a radio frequency filter according to claim 14 or claim 15, in which the amount of granular material (6) is adjusted before compression by bringing the lid into position, so as to adjust the density of the granular material in the filter.

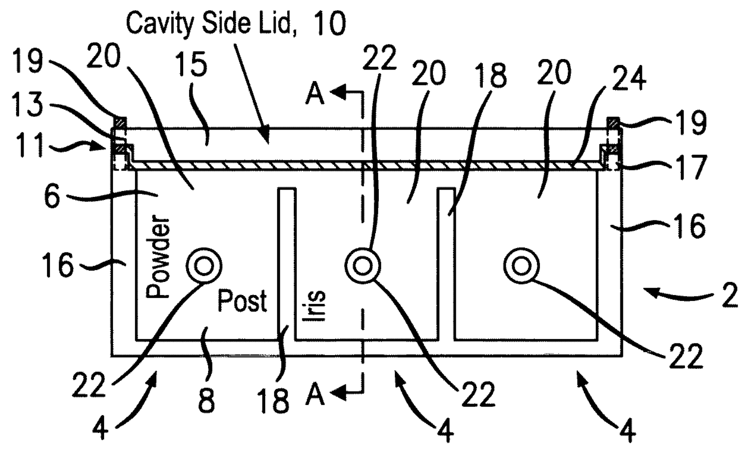

FIG. 1

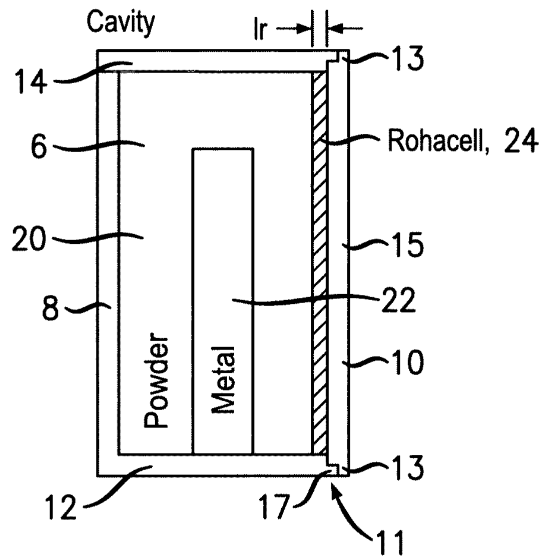

FIG. 2

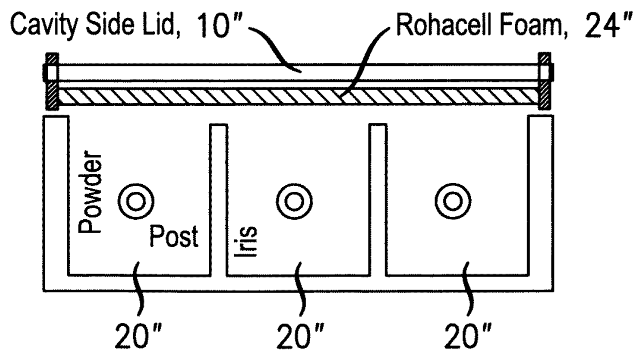

FIG. 3

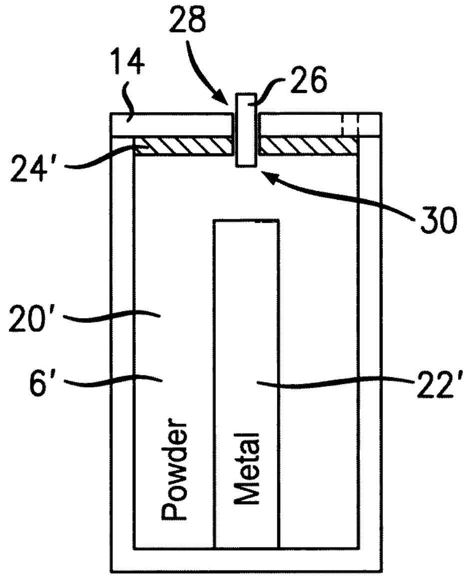

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 13 29 0142

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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
Munich	8 November 2013	Köppe, Maro

CATEGORY OF CITED DOCUMENTS

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