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

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

(57) A radio frequency filter is provided comprising at least one resonant chamber (2'') that comprises a respective tuning assembly, in which the resonant chamber (2'') is at least partially filled by the respective tuning assembly and a granular dielectric material (3), and in which the tuning assembly comprises a tuning screw (14'') within an enclosure comprising dielectric material, the enclosure providing an air pocket (23) in the granular dielectric material (3) within which the tuning screw (14'') is movable. In this way, the electrical or mechanical performance of the resonator is not compromised due to a non-uniform density of dielectric powder as would otherwise occur due to the screw pressing the powder. In consequence, the electrical performance of the filter is not compromised.

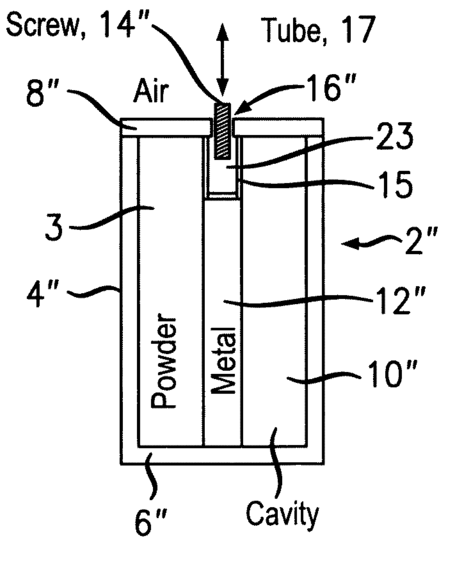

FIG. 3

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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 are known made up of air-filled cavity resonators. It is also known to include posts in the resonators that are loaded with rings of a high dielectric material (not shown). An example of a known air-filled resonator, for use in a radio frequency filter is shown in Figure 1.

[0003] As shown in Figure 1, a resonator 2 includes side walls 4, a base plate 6 and a top plate 8 that define a cavity 10. The resonator has an input port (not shown) and an output port (not shown). Within the cavity 10 extending from the base plate 6 is a metal post 12. There is a tuning screw 14 which is extending into the cavity through a hole 16 in the top plate 8 so as to be adjustable in distance from the top 18 of the metal post 12.

Summary

[0004] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0005] An example of the present invention is a radio frequency filter comprising at least one resonant chamber that comprises a respective tuning assembly, in which the at least one resonant chamber is at least partially filled by a granular dielectric material, and in which the tuning assembly comprises a tuning screw within an enclosure comprising dielectric material, the enclosure providing an air pocket in the granular dielectric material within which the tuning screw is movable.

[0006] 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 respective tuning assembly and is at least partiallyfilled by a granular dielectric material, and in which the tuning assembly comprises a tuning screw within an enclosure of dielectric material, the enclosure providing an air pocket in the granular material within which the tuning screw is movable, and the resonant chamber is tuned by adjusting the depth of penetration of the tuning screw into the chamber.

[0007] Preferably methods and means for the tuning of powder-filled cavity resonators are provided. Preferably tuning mechanisms are provided for dielectric powder cavity resonators allowing good electrical performance.

[0008] In preferred embodiments a tube or cap of dielectric material is provided over the tuning screw, keeping a space surrounding the tuning screw free of dielectric material, allowing mechanical movement of the tuning screw through air. In this way, the electrical or mechanical performance of the resonator is not compromised due to a non-uniform density of dielectric powder as would otherwise occur due to the screw pressing the powder. In consequence, the electrical performance of the filter is not compromised.

[0009] Preferably, the filters are usable in metrocell base stations and macrocell active antenna arrays, for example.

Brief Description of the Drawings

[0010] 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 front view illustrating a known cavity resonator of a known combline filter (PRIOR ART)

Figure 2 are front views illustrating (a) a dielectric powder filled cavity resonator of a combline filter (ALTERNATIVE PROPOSAL) and (b) a dielectric powder part-filled resonator (ALTERNATIVE PROPOSAL),

Figure 3(a) is a front view of a dielectric filled cavity resonator according to a first embodiment having a tube in which the tuning screw may be moved,

Figure 4 shows (a) a front view of a known air-filled cavity resonator for comparison, and (b) a front view of a dielectric filled cavity resonator according to the first embodiment having a tube in which the tuning screw may be moved,

Figure 5 is a graph showing tuning screw performance for the resonators shown in Figure 4, and

Figure 6 is a front view of a dielectric filled cavity resonator according to a second embodiment having a cap in which the tuning screw may be moved.

Detailed Description

[0011] Having described prior art with reference to Figure 1, we next describe an alternative proposal. After that, preferred embodiments of the present invention are described.

[0012] As shown in Figure 2(a), in an alternative proposal a cavity resonator 2' is filled with dielectric powder 3 , having a dielectric constant for example in the range 2 to 10 or 3 to 5, and a low dielectric loss. This allows the filter to be smaller in size than if air-filled for filtering at the same radio frequency. The resonator 2' includes side walls 4', a base plate 6' and a top plate 8' that define a cavity 10'. The resonator has an input port (not shown) and an output port (not shown). Within the cavity extending from the base plate is a metal post 12'. There is a tuning screw 14' which is located in a hole 16' through the top place 8' so as to be adjustable in distance from the top 18' of the metal post 12'. All the empty space in the cavity 10' is filled with the powder 3 which is intended to be of a uniform and constant density as required for stable electrical and mechanical performance.

[0013] The inventors realised that this alternative proposal has disadvantages. Specifically, they realised that movement of the tuning screw presses the powder so affects the density of the powder in a critical region of the cavity resonator 2' leading to deviations in electrical performance. They realised that depending on the density of the powder, it may not even be possible to screw the tuning screw into the powder.

[0014] They realised that, as shown in Figure 2(b), in a modified alternative proposal an air gap 11 may be included so that the powder does not fully fill the cavity, but then any mechanical movement of the powder may result in the uncontrolled disposition of powder within the cavity and hence undesirable and uncontrolled changes to the electrical performance of the resonator 2', specifically in its radio frequency filtering function. Also, as shown in Figure 2(b), as the cavity is only part-filled with dielectric powder, the potential of using powder to allow the filter to be made smaller is not made good use of.

Resonator with tube

[0015] As shown in Figure 3, a cavity resonator 2" is provided substantially filled with dielectric powder 3', having a dielectric constant for example in the range 2 to 10 or 3 to 5, and a low dielectric loss. This allows the filter to be smaller in size than if air-filled for filtering at the same radio frequency. The resonator 2" includes side walls 4", a base plate 6" and a top plate 8" that define a cavity 10". The resonator has an input port (not shown) and an output port (not shown). Within the cavity extending from the base plate is a metal post 12". There is a tuning screw 14" which is located in a hole 16" through the top plate 8' so as to be adjustable in distance from the top 18" of the metal post 12". There is a tube 19 which extends between the top 18" of the metal post 12" and the top plate 8" and defines a cylindrical space 23 within which the screw can be moved. The tube 19 is of a dielectric material, for example having a permittivity in the range of 2 to 10 or 3 to 5, and a low dielectric loss. In this example the tube may be of fused quartz.

[0016] The rest of the otherwise empty space in the cavity 10" is filled with the powder 3 which is intended to be of a practically uniform and constant density as required for stable electrical and mechanical performance.

[0017] A particular example was considered as shown in Figure 4(b), having an internal height of 120mm, an internal width of 70mm, a post height of 93mm, a post cross section diameter of 20.4mm, a screw cross section diameter of half that of the post namely 10.2mm. The depth of penetration of the screw into the cavity is b1 where b1 varies between 10mm and 22mm. The wall thickness of the tube is 2mm. The cavity is filled with fused quartz material having a permittivity of 3.8 and a loss tangent of $6x10^{-5}$. A known air-filled cavity resonator is shown for comparison in Figure 4 (a).

[0018] Referring now to Figure 5, for each of these two resonators, the normalised filtering frequency is shown as a function of screw penetration. It is seen that the dielectric powder filled resonator with the tube provides a resonator that can be appropriately tuned. Specifically, it is seen that approximately 20% additional screw penetration is required as compare to the prior art resonator in order to achieve the same level of frequency tuning. Furthermore, the dielectric powder filled resonator with tube shows similar sensitivity to screw penetration.

Resonator with cap

[0019] An alternative embodiment is shown in Figure 6.

[0020] As shown in Figure 6, a cavity resonator 2a is provided substantially filled with dielectric powder 3 a, having a dielectric constant for example in the range 2 to 10 or 3 to 5, and a low dielectric loss. This allows the filter to be smaller in size than if air-filled for filtering at the same radio frequency. The resonator 2a includes side walls 4a, a base plate 6a and a top plate 8a that define a cavity 10a. The resonator has an input port (not shown) and an output port (not shown). Within the cavity extending from the base plate is a metal post 12a. There is a tuning screw 14a which is located in a hole 16a through the top plate 8a so as to be adjustable in distance from the top 18a of the metal post 12a. There is a cap 21 which extends downwards from the top plate 8a around the hole 16a so as to define an air space 23a within which the screw can be moved. The rest of the otherwise empty space in the cavity 10a is filled with the powder 3 a which is intended to be of a practically uniform and constant density as required for stable electrical and mechanical performance.

[0021] The cap is of a dielectric material, for example having a permittivity in the range of 2 to 10, and a low dielectric loss. In this example the tube may be of fused quartz.

[0022] The cap differs from the tube in that it need not be of substantially the same inner diameter as the metal post and need not extend all the way to the top surface of the metal post. In other words there may be a dielectric powder filled portion between the top surface of the metal post and the tuning screw. This portion is indicated by the reference numeral 25 in Figure 6.

[0023] The present invention may be embodied in other specific forms without departing from its essential characteristics. For example, although resonator elements in the form of resonator posts have been specifically described in some examples, resonator elements can take other shapes and forms. 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.

[0024] 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 comprising at least one resonant chamber that comprises a respective tuning assembly, in which the at least one resonant chamber is at least partially filled by a granular dielectric material, and in which the tuning assembly comprises a tuning screw within an enclosure comprising dielectric material, the enclosure providing an air pocket in the granular dielectric material within which the tuning screw is movable.

2. A radio frequency filter according to claim 1, in which the resonant chamber is substantially filled by a respective resonator post and the granular dielectric material.

3. A radio frequency filter according to claim 1 or claim 2, in which the enclosure comprises a tube of dielectric material providing the air pocket.

4. A radio frequency filter according to claim 3, in which the tube extends to the top of the resonator post so as to provide the air-filled pocket defined by the tube and the top of the resonator post.

5. A radio frequency filter according to claim 1 or claim 2, in which the enclosure comprises a cap of dielectric material providing the air pocket.

6. A radio frequency filter according to claim 5 as dependent upon claim 2, in which the cap provides the air-filled pocket in the vicinity of the resonator post.

7. A method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber that comprises a respective tuning assembly and is at least partially filled by a granular dielectric material, in which the tuning assembly comprises a tuning screw within an enclosure comprising dielectric material, the enclosure providing an air pocket in the granular dielectric material within which the tuning screw is movable, and the resonant chamber is tuned by adjusting the depth of penetration of the tuning screw into the chamber.

8. A method of radio frequency filter according to claim 7, in which the resonant chamber is substantially filled by a respective resonator post and the granular dielectric material.

9. A method of radio frequency filtering according to claim 7 or claim 8, in which the enclosure comprises a tube of dielectric material providing the air pocket.

10. A method of radio frequency filtering according to claim 9 as dependent on claim 8, in which the tube extends to the top of the resonator post so as to provide the air-filled pocket defined by the tube and the top of the resonator post.

11. A method of radio frequency filtering according to claim 7 or claim 8, in which the enclosure comprises a cap of dielectric material providing the air pocket.

12. A method of radio frequency filtering according to claim 11, in which the cap provides the air-filled pocket in the vicinity of the resonator post.

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

1. A radio frequency filter comprising at least one resonant chamber (2",10",2a) that comprises a respective tuning assembly, in which the tuning assembly comprises a tuning screw (14") within an enclosure (19,21) comprising dielectric material,
<u>characterised in that</u>
the at least one resonant chamber is at least partially filled by a granular dielectric material (3), and the enclosure provides an air pocket (23) in the granular dielectric material within which the tuning screw is movable.

2. A radio frequency filter according to claim 1, in which the resonant chamber is substantially filled by a respective resonator post (12",12a) and the granular dielectric material.

3. A radio frequency filter according to claim 1 or claim 2, in which the enclosure comprises a tube (19) of dielectric material providing the air pocket.

4. A radio frequency filter according to claim 3, in which the tube extends to the top (18") of the resonator post so as to provide the air-filled pocket defined by the tube (19) and the top of the resonator post (12").

5. A radio frequency filter according to claim 1 or claim 2, in which the enclosure comprises a cap (21) of dielectric material providing the air pocket (23a).

6. A radio frequency filter according to claim 5 as dependent upon claim 2, in which the cap (21) provides the air-filled pocket in the vicinity of the resonator post.

7. A method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber (2",10",2a) that comprises a respective tuning assembly, in which the tuning assembly comprises a tuning screw (14") within an enclosure (19,21) comprising dielectric material, and the resonant chamber is tuned by adjusting the depth of penetration of the tuning screw into the chamber,
characterised in that
the respective tuning assembly is at least partially filled by a granular dielectric material (3), and the enclosure provides an air pocket (23) in the granular dielectric material within which the tuning screw is movable.

8. A method of radio frequency filter according to claim 7, in which the resonant chamber (2",2a) is substantially filled by a respective resonator post (12",12a) and the granular dielectric material (3,3a).

9. A method of radio frequency filtering according to claim 7 or claim 8, in which the enclosure comprises a tube (19) of dielectric material providing the air pocket.

10. A method of radio frequency filtering according to claim 9 as dependent on claim 8, in which the tube (19) extends to the top (18") of the resonator post (12") so as to provide the air-filled pocket defined by the tube and the top of the resonator post.

11. A method of radio frequency filtering according to claim 7 or claim 8, in which the enclosure comprises a cap (21) of dielectric material providing the air pocket.

12. A method of radio frequency filtering according to claim 11, in which the cap (21) provides the air-filled pocket in the vicinity of the resonator post.

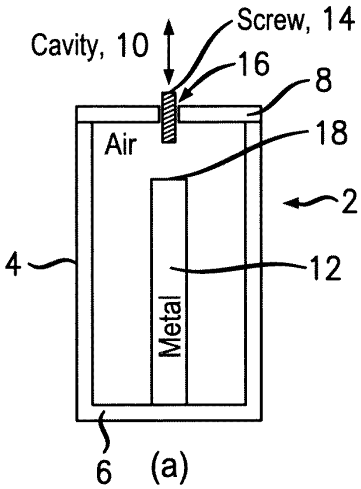


FIG. 1

PRIOR ART

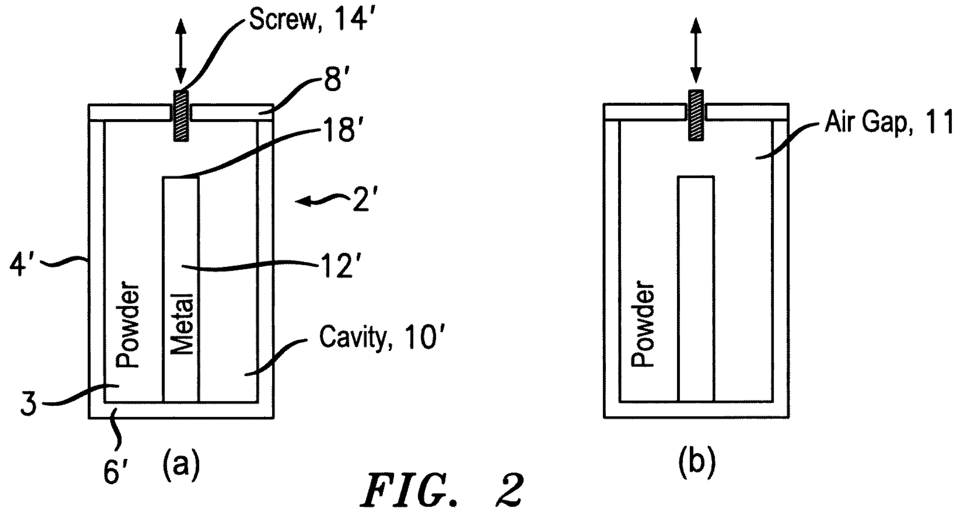


FIG. 2

ALTERNATIVE PROPOSAL

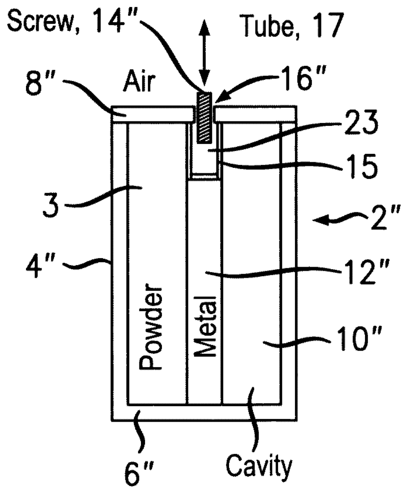
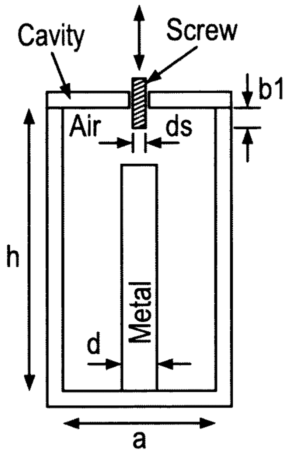


FIG. 3



(a)
PRIOR ART
FOR COMPARISON

(b)
DIELECTRIC POWDER
FILLED WITH TUBE

FIG. 4

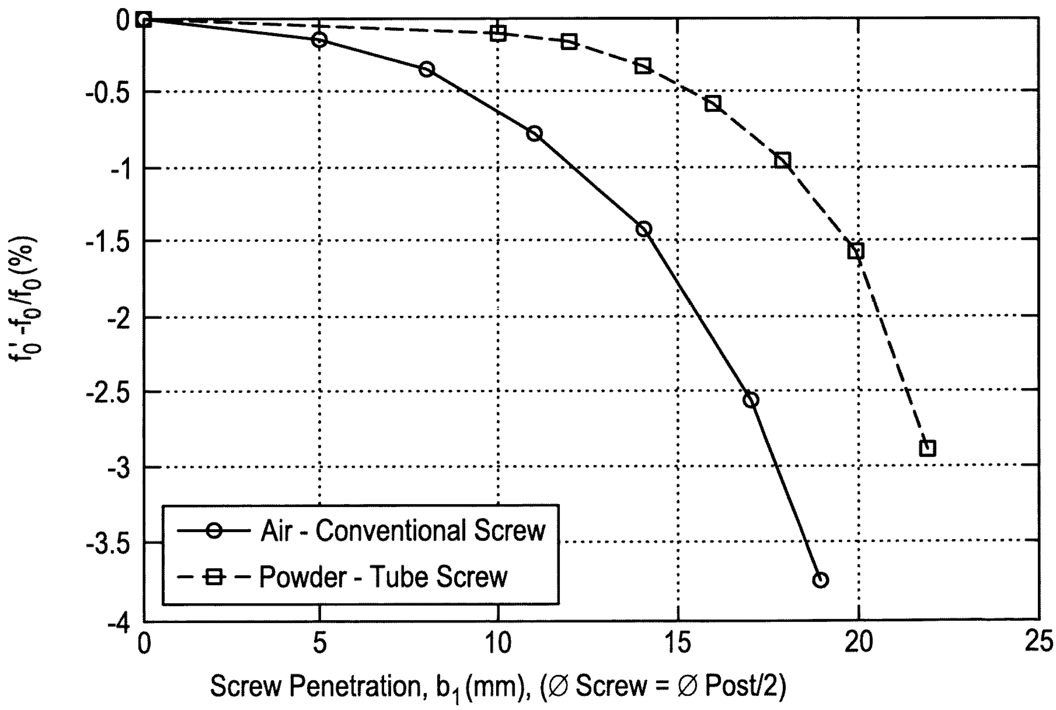


FIG. 5

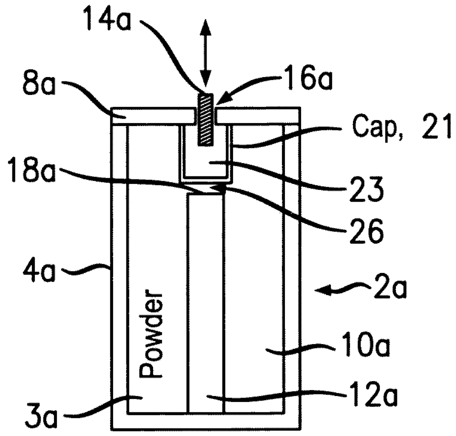


FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 13 29 0141

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 1 755 189 A1 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 21 February 2007 (2007-02-21) * column 8, line 58 - column 11, line 3 * * figures 1-3 *	1-12	INV. H01P1/205 H01P7/04
Y	DE 35 41 585 A1 (SIEMENS AG [DE]) 27 May 1987 (1987-05-27) * column 2, line 24 - column 2, line 63 *	1-12	
Y	JP S55 85101 A (NIPPON ELECTRIC CO) 26 June 1980 (1980-06-26) * the whole document *	1,2,5-8, 11,12	
A	US 4 166 256 A (SHISHIDO TSUNEO [US]) 28 August 1979 (1979-08-28) * the whole document *	1-12	

TECHNICAL FIELDS SEARCHED (IPC)

H01P

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	13 November 2013	Köppe, Maro

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 29 0141

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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13-11-2013

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82