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

(72) Inventors:
• **DOUMANIS, Efstratios**
DUBLIN, 15 (IE)
• **BULJA, Senad**
DUBLIN, 15 (IE)

(74) Representative: **Sarup, David Alexander**
Alcatel-Lucent Telecom Ltd
Intellectual Property Business Group
Christchurch Way
Greenwich
London SE10 0AG (GB)

(54) **A RESONATOR, A MICROWAVE FREQUENCY FILTER AND A METHOD OF RADIO FREQUENCY FILTERING**

(57) A resonator for a filter is provided comprising a resonant chamber, the resonant chamber comprising a first wall, a second wall opposite the first wall, and side walls. The resonator also comprises: a resonator post which is grounded so as to extend into the chamber on the first wall or the second wall; a first cylinder grounded on the second wall so as to extend into the chamber and

having an open end which is distal from the second wall; a second cylinder grounded on the first wall so as to extend into the chamber and having at its open end which distal from the first wall an inner diameter wider than the outer diameter of the open end of first cylinder. The resonator is configured so that at least an end portion of the first cylinder lies within the second cylinder.

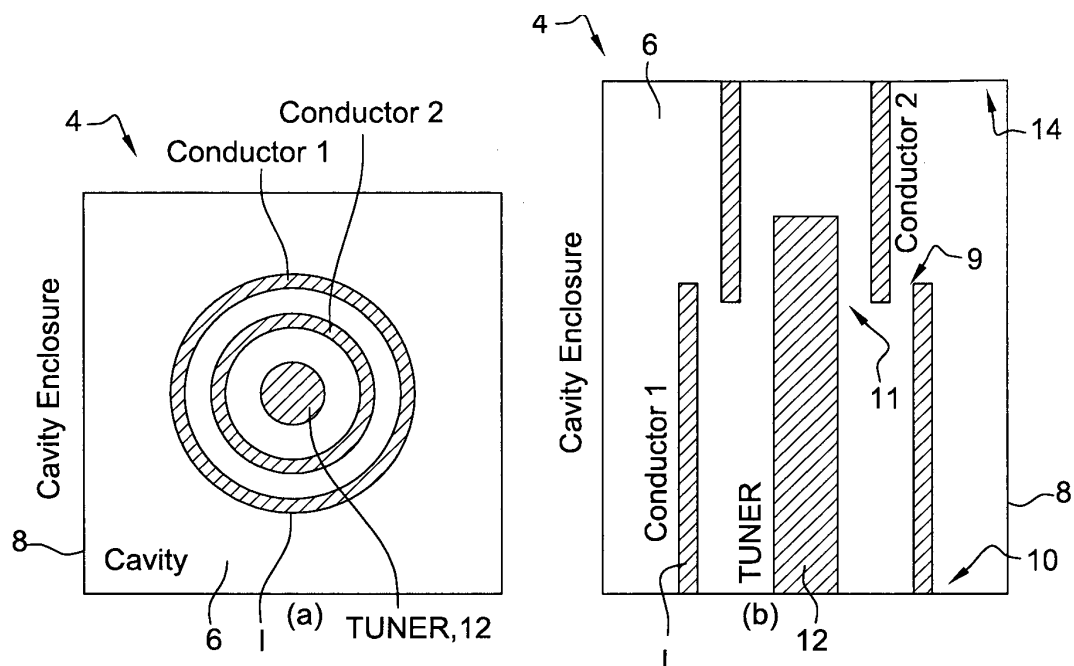


Fig. 3

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] 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, 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 well-defined and stringent, for example, to provide high isolation between transmit and receive paths. This often places practical lower limits on filter size.

[0004] The choice of filter technology for a given application depends on the application specifics. However, there are certain desirable characteristics that are common to all 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 always accompanied by an increase in complexity (due to a greater number of components that a filter requires) and in size. Furthermore, increasing the order of the filter inevitably increases the losses in the pass-band (as explained for example in J.S. Hong and M.J. Lancaster. Microstrip Filters for RF/Microwave Applications. John Wiley & Sons, ISBN: 0-471-38877-7 (Hardback), 2001).

[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.

[0007] Tunability, i.e. the ability of a filter to vary its frequency of operation and percentage bandwidth, is very desirable in filter design, especially if variations of the operating frequency and the bandwidth of the filter do not significantly deteriorate other important filter parameters, for example pass-band loss and frequency rejection.

[0008] Filters of various types and shape/configuration are possible, although no single particular cavity filter is ideal in addressing all four requirements. For example, high quality factors and high power handling are usually obtained at the expense of miniaturization, while tunability is, usually, obtained at the expense of high quality factors and power handling. For printed-circuit-board (PCB) filtering applications, electronic tunability can be achieved using a varactor diode suitably connected to the open-ended part of a resonator. However, that comes at a heavy cost: power handling of such a resonator/filter is greatly reduced due to the poor intermodulation performance of the varactor diode and, at the same time, the insertion loss of such a resonator/filter is significantly increased (giving low quality factors), due to the parasitic resistance of the diode.

[0009] The building block of cavity filters is a combine resonator, depicted in its basic form in Figure 1 consisting of a resonator post within a cavity. The resonator post resonates at a frequency at which the resonator post's height is one quarter-wavelength of the electric current, I , induced on the surface of the resonator post. Since no manufacturing is perfect, the typical practical realization of the resonator includes a tuning screw inserted from the top of the cavity toward the resonator's open (i.e. ungrounded) end. The tuning screw effectively balances the undesired effects caused by manufacturing tolerances. Put another way, the screw allows the resonator to be tune to the designed-for resonant frequency. Naturally, the same mechanism can be utilized to retune the resonator. The range of tunability achievable this way in practice, however, is only a few per cent, primarily limited by to the following consideration: the volume of space between the cavity top and the ungrounded end of the resonator is the region within the entire cavity where, at resonance, the electric field in the cavity is the strongest, meaning that this region is very susceptible to arcing. The tuning screw further reduces the size of the gap between the cavity top and the ungrounded end of the resonator, thus reducing the power-handling capability of the resonator. For reasons of power handling, the minimum size of the gap found in practical filters for wireless cellular-communication applications is about 1 mm.

[0010] Furthermore, the change of resonant frequency achieved by tuning the resonator of Fig. 1 varies nonlinearly with the intrusion depth of the tuning screw into the cavity. In particular, the larger the intrusion depth the more rapidly the resonant frequency varies. Consequently, finely tuning the conventional resonator is difficult and time-consuming.

[0011] A slightly larger tunability range is achieved by enlarging the surface area through which the tuning screw

electromagnetically interacts with the resonator. As shown in Figure 2, this may be achieved by hollowing the top part of the resonator and allowing the tuning screw to protrude slightly into the hollow.

Summary

[0012] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0013] The present invention provides a resonator for a filter comprising a resonant chamber, the resonant chamber comprising a first wall, a second wall opposite the first wall, and side walls;
the resonator also comprising:

a resonator post which is grounded so as to extend into the chamber on the first wall or the second wall;
a first cylinder grounded on the second wall so as to extend into the chamber and having an open end which is distal from the second wall;
a second cylinder grounded on the first wall so as to extend into the chamber and having at its open end which is distal from the first wall an inner diameter wider than the outer diameter of the open end of first cylinder;
the resonator being configured so that at least an end portion of the first cylinder lies within the second cylinder.

[0014] Preferred embodiments provide a high quality factor, good power handling, small size ('miniaturization'), and good tunability.

[0015] Preferred embodiments simultaneously provides for (A) reduced physical dimensions of cavity filters and (B) an extended frequency-tunable range of cavity filters. Both qualities are valued in industrial applications.

[0016] Regarding (A), filters are typically the bulkiest and heaviest subsystems in mobile cellular base stations (rivalled only by power-amplifier heatsinks). Therefore filter miniaturization is always desirable.

[0017] Regarding (B), a typical envisioned application scenario includes a mobile cellular operator, who has a plan to transition its services to a different frequency band sometime in the future, procuring cavity filters for his base stations. If the operator purchases conventional filters, transitioning to the new frequency band will require a second set of filters to be purchased. In contrast, the present invention eliminates the need to purchase the second set of filters, by providing for simple retuning of filters.

[0018] In another application scenario, manufacturers of mobile cellular base stations tend to stockpile cavity filters, rather than procure them in a build-to-order fashion. Filters according to preferred embodiments may be stock-piled and are readily retunable without the need to open the filter up.

[0019] A preferred embodiment is a miniaturised coaxial resonator for a filter that simultaneously achieves size reduction, frequency tunability, and retention of high quality factors and high power handling.

[0020] Preferably a part of the post lies within the first cylinder and the second cylinder.

[0021] Preferably, the first cylinder and the second cylinder are coaxial with each other and the resonator post.

[0022] Preferably, the resonator post is grounded on the first wall. Alternatively preferably, the resonator post is grounded on the second wall. Preferably the resonator post is of adjustable length within the cavity for tuning. Preferably the resonator post is the shaft of a tuning screw.

[0023] Preferably, the first cylinder is an inner cylinder, and the second cylinder is an outer cylinder having an inner diameter wider than the outer diameter of the first cylinder.

[0024] Alternatively preferably the main part of the first cylinder and the main part of the second cylinder are of least substantially the same diameter, and the end of the second cylinder distal from the first wall has an inner diameter wider than the outer diameter of the end of first cylinder distal from the second wall. Preferably the distal end of the first cylinder comprises an extending cylindrical wall thinner than the wall thickness of the main part of the first cylinder, and the distal end of the second cylinder comprises an extending cylindrical wall thinner than the wall thickness of the main part of the second cylinder.

[0025] Preferably at least one of the first and second cylinders comprises a respective end wall for ease of mounting to the first wall or the second wall.

[0026] The present invention also provides a radio frequency filter comprising at least one resonator as outlined above.

[0027] The present invention also provides a method of radio frequency filtering comprising passing a radio frequency signal for filtering through a filter comprising a resonant chamber, the resonant chamber comprising a first wall, a second wall opposite the first wall, and side walls;
the resonator also comprising:

a resonator post which is grounded so as to extend into the chamber on the first wall or the second wall;
a first cylinder grounded on the second wall so as to extend into the chamber and having an open end (9) which is distal from the second wall;

a second cylinder grounded on the first wall so as to extend into the chamber and having at its open end which is distal from the first wall an inner diameter wider than the outer diameter of the open end of first cylinder; the resonator being configured so that at least an end portion of the first cylinder lies within the second cylinder.

Brief Description of the Drawings

[0028] Embodiments of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 is a diagram illustrating a known resonator for a known combline filter (PRIOR ART),
 Figure 2 is a diagram illustrating another known resonator for a known combline filter (PRIOR ART), and
 Figure 3 is a diagram illustrating (a) a cross-sectional top view and (b) a cross-sectional side view of a miniaturized coaxial resonator according to a first embodiment,
 Figure 4 is a diagram illustrating the cross-sectional side view of the miniaturized coaxial resonator shown in Figure 3 with current directions indicated,
 Figure 5 is a diagram illustrating the cross-sectional top view of the miniaturized coaxial resonator shown in Figure 3 with some dimensions indicated,
 Figure 6 is a diagram illustrating the cross-sectional side view of the miniaturized coaxial resonator shown in Figure 3 with some dimensions indicated,
 Figure 7 are graphs showing (Left) resonant frequency and (Right) Q-factor of the resonator according to the first embodiment (example 1) as the tuner penetration is changed,
 Figure 8 are graphs showing (Left) resonant frequency and (Right) Q-factor of a resonator according to a second embodiment (example 2) as the tuner penetration is changed,
 Figure 9 is a diagram illustrating a cross-sectional side view of a miniaturized coaxial resonator according to a further embodiment,
 Figure 10 is a diagram illustrating a cross-sectional side view of a miniaturized coaxial resonator according to a further embodiment, and
 Figure 11 is a diagram illustrating a cross-sectional side view of a miniaturized coaxial resonator according to a further embodiment.

Detailed Description

[0029] The inventors realised that in known cavity filters, modest frequency tunability is achievable by a tuning screw, positioned as shown in Figures 1 and 2. Some other approaches involve incorporating an electronically controllable device inside the cavity of the filter. The electronically controllable device is usually a varactor diode (in which case the resulting filter has the same technical limitations as its Printed Circuit Board (PCB) counterpart) or a microelectromechanical system (MEMS). MEMS-based cavity filters are substantially similar to their counterparts having varactor diodes, with the exception that for the MEMS-based cavity filter, power handling capability is increased to some extent, while its tunable range is decreased due to the existence of stray capacitance between metallic contacts of the MEMS switch.

[0030] The inventors considered that a miniaturized, tunable RF resonator with high power handling and low insertion loss is desirable, and provided a mechanically tunable RF resonator that meets these four requirements.

First Example

[0031] As shown in Figure 3, the cavity resonator 4 includes a cavity 6 within a conductive enclosure 8. Extending into the cavity 6 from one wall 10 is a first tubular conductor 1 which has an open end 9. From that same wall 10, a tuner 12 also extends into the cavity 6. The tuner is a cylindrical metallic post, of adjustable length, which lies coaxially along the central longitudinal axis within the tubular conductor 1. From the wall 14 that is opposite the wall 10, a second tubular conductor 2 extends into the cavity 6. The second tubular conductor has an open end 11. The second tubular conductor 2 has a diameter less than that of the first tubular conductor 1 but more than that of the tuner 12.

[0032] The two tubular conductors 1, 2 and the tuner 12 are in close proximity with each other. The conductors 1, 2 and the tuner 12 are both electrically and mechanically connected to the respective wall 10, 14 on which mounted.

[0033] Specifically the two tubular conductors are hollow and of different widths (radii) so as to allow the second tubular conductor 2 to be inserted into the hollow space defined by the first tubular conductor 1. In other words, a portion of the second tubular conductor 2 lies within the first tubular conductor 1. The extent of the intrusion, in other words the extent of overlap, determines the extent of electromagnetic coupling between the two conductors.

[0034] The tuner 12 is provided for additional electromagnetic coupling with the second tubular conductor 2. In consequence the resonator 4 may be considered a three-element distributed resonator where the three elements are the

two tubular conductors 1,2 and the tuner 12. This resonator may also be considered a miniaturised coaxial resonator.

[0035] The tuner 12 is, in this example, a tuning screw which can be screwed in or out via a correspondingly threaded hole (not shown) in the first wall 10 of the enclosure 8 so as to adjust the length of the screw that resides within the cavity 6, in other words the extent of intrusion into the cavity 6.

Operation

[0036] In use, the current flows are as indicated in Figure 4.

[0037] Assuming that say conductor 1 is excited first, at the fundamental resonant frequency of this conductor 1, the electric current flow on the conductor 1 surface is such that the current density is highest at the area of contact with the wall 10 on which the conductor 1 is mounted. The wall 10 may be considered the ground plane of the conductor 1. The direction of propagation of the current is as shown in Figure 4.

[0038] By virtue of Faraday's law, electric current on conductor 1 induces electric currents on conductor 2 and the tuner 12, with the main directions of current flow being as shown in Figure 4. The directions of the induced currents are always so as to reduce the magnetic fields that created the induced currents. However, due to the unusual nature of the structure in that the resonators 1,2,12 are sequentially mounted on opposite walls 10,14 of the resonant cavity 6, the resultant magnetic field in the inter-resonator regions, in other words in the volumes of space between conductor 1 and conductor 2, and between conductor 2 and the tuner 12, is not net-zero but has a non-zero value.

[0039] This resultant magnetic field value is non-zero because the resonators, namely conductor 1, conductor 2 and tuner 12, are interacting with each other and the intensities of the resultant interacting magnetic fields in the inter-resonator regions are dependent on the separation between the respective resonators. In general, the smaller the separation is, the greater is the interacting magnetic field and, hence, the interaction between the respective resonators is greater. Since the level of interaction among the resonators determines the effective electrical length that the combined electric current depicted in Figure 4 needs to travel, it follows that closely coupled resonators of Figure 4 offer a reduction of frequency of operation compared to that of a single resonator in isolation.

[0040] Furthermore, the resonator which is the tuner 12 is, in this example, in the form of a screw, whose intrusion into the cavity 8 can be variably adjusted. This means, there is frequency tunability as well as the reduction in the frequency of operation.

[0041] Another important aspect of the miniaturized resonator arises from the rotational symmetry of the three resonators 1,2, 12 and the overall cavity resonator assembly 4. This is that as a direct consequence of the symmetries, at any point along the length of the individual resonators 1,2,12, the surface current density along the perimeter of each resonator is equally distributed. As a result, no surface current "hot spots" are created in this process of miniaturization, giving high power-handling capability.

Example Dimensions

[0042] In this example, the particular dimensions selected are as indicated in Figures 5 and 6 and are as shown in Table 1:

Table1 : Resonator dimensions Example 1

Resonator	Example 1
Cavity (W x W x L) where W denotes width and L denotes length	2.0cmx2.0cmx4.0cm (16 cm ³)
OuterDia1 which denotes the outer diameter of conductor 1	4.63 mm
OuterDia2 which denotes the outer diameter of conductor 2	3.95 mm
L1/ t1 where L1 is the length in the cavity of the conductor 1 and t1 is the thickness of the cylindrical wall of conductor 1	20.03 mm/0.43 mm
L2/ t2 where L2 is the length in the cavity of the conductor 2 and t2 is the thickness of the cylindrical wall of conductor 2	26.74 mm/0.43 mm
Lt/TunerDia where Lt is the length in the cavity of the tuner and TunerDia is the diameter of the tuner	15.00 mm/0.81 mm

Second Example

[0043] The second example is similar in structure to the first example except for having different dimensions, as follows:

Table 2: Resonator dimensions Example 2

Resonator	Example 1
Cavity (W x W x L) where W denotes width and L denotes length	2.3cmx2.3cmx3.0cm (15.87 cm ³)
OuterDia1 which denotes the outer diameter of conductor 1	6.1 mm
OuterDia2 which denotes the outer diameter of conductor 2	5.51 mm
L1/ t1 where L1 is the length in the cavity of the conductor 1 and t1 is the thickness of the cylindrical wall of conductor 1	14.77 mm/0.45 mm
L2/ t2 where L2 is the length in the cavity of the conductor 2 and t2 is the thickness of the cylindrical wall of conductor 2	19.08 mm/0.45 mm
Lt/TunerDia where Lt is the length in the cavity of the tuner and TunerDia is the diameter of the tuner	27.54 mm/1.94 mm

Performance of Example 1 and Example 2

[0044] Based on the basic idea epitomized in Figure 4, the two example resonators were simulated using CST microwave studio software.

[0045] Table 3 shows the simulated performance of the two example resonators.

[0046] Furthermore, Figure 7 (Left) and Figure 8 (Left) demonstrate the variation of resonant frequency as a function of the tuner penetration in the cavity for resonator example 1 and 2, respectively.

[0047] Furthermore Fig. 7 (Right) and Fig. 8 (Right) demonstrate the variation of the q-factor as a function of the tuner penetration in the cavity for resonator example 1 and 2, respectively.

[0048] The results demonstrate a smooth variation of resonant frequency (desirable for post-fabrication tuning of filters) and a minimized effect on the Q-factor of the resonator assembly.

[0049] It has been found that for basically the same volume as known resonators depicted in Figures 1 and 2, the two example embodiments of the miniaturised coaxial resonator achieve the reduction of frequency of operation of over two times, with a frequency tunability of over 7%.

Table 3: Simulated performance of the two example resonators (CST Eigenmode solver)

Resonator	Electrical Length @700MHz (428.6 mm)	Gap Size/Overlap	Resonant frequency	Q-Factor (Au/Au) 5.4x10 ⁰⁷ S/m	Q/Vol (1/cm ³)
Example 1	~33.6 deg	0.27/6.71 (mm)	709.6 MHz	1812	113.3
Example 2	~25.2 deg	0.14/4.31 (mm)	700.9 MHz	1809	114

[0050] In a first instance, the power handling capability of the resonator 4 is strongly dependent on the overlap gap distance and length between the two main conductors, conductor 1 and conductor 2. It follows that these dimensions determine both the power handling capacity of the resonator 4, and the amount of miniaturization (size as compared to a corresponding known resonator). Thus, there is a trade-off to consider: the more we miniaturize, the less the handling capacity is going to be. It has been shown that changes to size can be made, for example to the overlap gap distance and length, without greatly affecting electrical performance. See for example Table 2, where the two examples have similar electrical performance, i.e. resonant frequency and Q-factor.

Some other Examples

[0051] Figure 9 shows an alternative example in which the cylindrical conductors 1', 2' mounted on opposite walls 10', 14' are equal in radius save at their open ends 1a', 2a' where the extended rim portion 2b' of second conductor 2' fits in a non-contacting way within the extended rim portion 1b' of first conductor 1'.

[0052] Figure 10 shows another example in which the cylindrical conductors 1" and 2" include respective end wall portions 1c, 2c for ease of mounting to cavity end walls 10", 14".

[0053] Figure 11 shows an example in which the tuner post 12' is mounted on the wall 14a on which the smaller radius cylindrical conductor 2 instead of on the wall 10a on which the larger radius cylindrical conductor 1 is mounted.

[0054] The present invention may be embodied in other specific forms without departing from its essential character-

istics. 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.

[0055] 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.

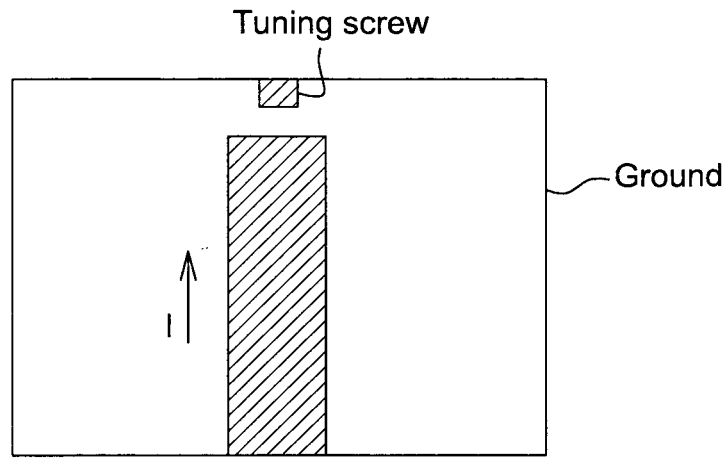
Claims

1. A resonator for a filter comprising a resonant chamber (8), the resonant chamber comprising a first wall (10), a second wall (14) opposite the first wall, and side walls;
the resonator also comprising:
 a resonator post (12) which is grounded so as to extend into the chamber on the first wall or the second wall;
 a first cylinder (2) grounded on the second wall (14) so as to extend into the chamber and having an open end (9) which is distal from the second wall;
 a second cylinder (1) grounded on the first wall (10) so as to extend into the chamber and having at its open end (11) which is distal from the first wall an inner diameter wider than the outer diameter of the open end (9) of first cylinder;
 the resonator being configured so that at least an end portion of the first cylinder (2) lies within the second cylinder (1).
2. A resonator according to claim 1, in which a part of the post (12) lies within the first cylinder (2) and the second cylinder (1).
3. A resonator according to claim 1, in which the first cylinder (2) and the second cylinder (1) are coaxial with each other and the resonator post.
4. A resonator according to claim 1 or claim 2, in which the resonator post is grounded on the first wall (10).
5. A resonator according to claim 1 or claim 2, in which the resonator post is grounded on the second wall (14).
6. A resonator according to any preceding claim, in which the resonator post is of adjustable length within the cavity for tuning.
7. A resonator according to claim 6, in which the resonator post is the shaft of a tuning screw.
8. A resonator according to any preceding claim, in which the first cylinder (2) is an inner cylinder, and the second cylinder (1) is an outer cylinder having an inner diameter wider than the outer diameter of the first cylinder.
9. A resonator according to any of claims 1 to 7, in which the main part of the first cylinder (2') and the main part of the second cylinder (1') are of least substantially the same diameter, and the end portion (1b') of the second cylinder distal from the first wall (10') has an inner diameter wider than the outer diameter of the end portion (2b') of first cylinder distal from the second wall (14').
10. A resonator according to any preceding claim, in which the distal end of the first cylinder comprises an extending cylindrical wall (2b') thinner than the wall thickness of the main part of the first cylinder (2'),
the distal end of the second cylinder (1b') comprises an extending cylindrical wall thinner than the wall thickness of the main part of the second cylinder (1').
11. A resonator according to any preceding claim, in which at least one of the first and second cylinders comprises a respective end wall (1c,2c) for ease of mounting to the first wall (10") or the second wall (14").

12. A radio frequency filter comprising at least one resonator according to any preceding claim.

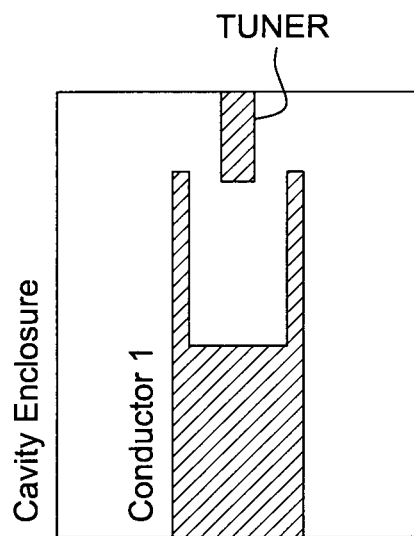
13. A method of radio frequency filtering comprising passing a radio frequency signal for filtering through a filter comprising a resonant chamber (8), the resonant chamber comprising a first wall (10), a second wall (14) opposite the first wall, and side walls;
the resonator also comprising:

a resonator post (12) which is grounded so as to extend into the chamber on the first wall or the second wall;
a first cylinder (2) grounded on the second wall so as to extend into the chamber and having an open end (9) which is distal from the second wall;
a second cylinder (1) grounded on the first wall (10) so as to extend into the chamber and having at its open end (11) which is distal from the first wall an inner diameter wider than the outer diameter of the open end (9) of first cylinder;
the resonator being configured so that at least an end portion of the first cylinder (2) lies within the second cylinder (1).



PRIOR ART

Fig. 1



PRIOR ART

Fig. 2

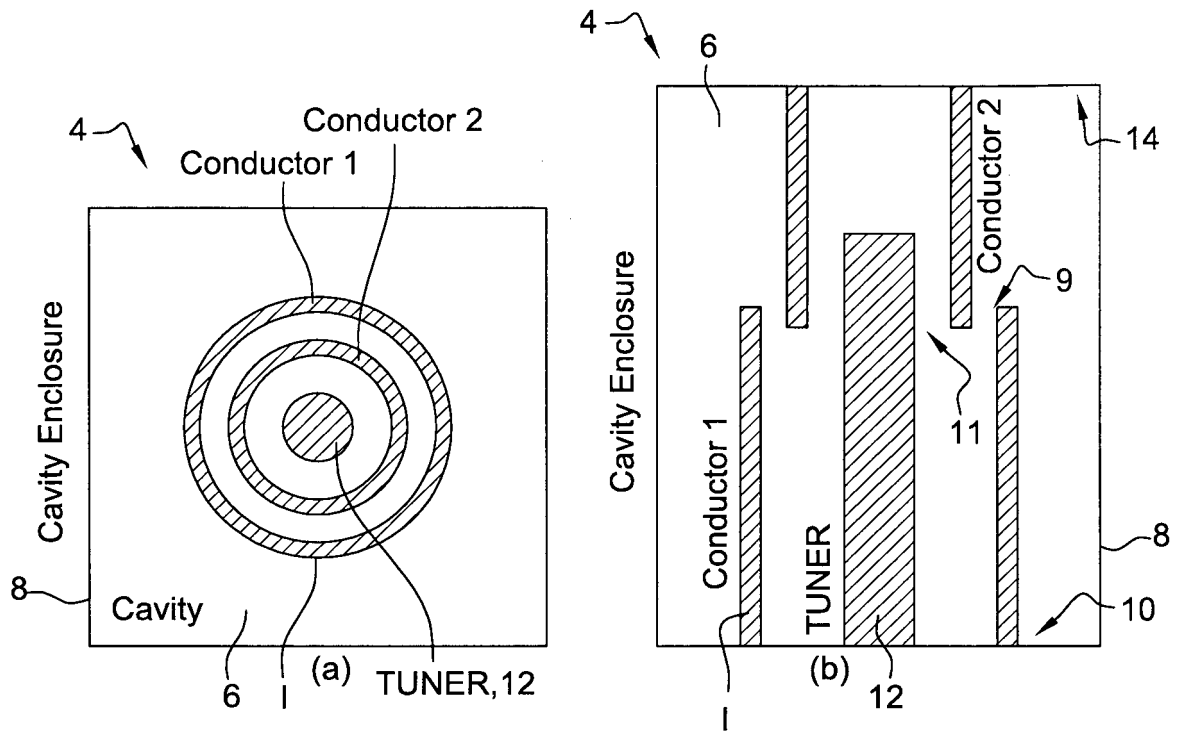


Fig. 3

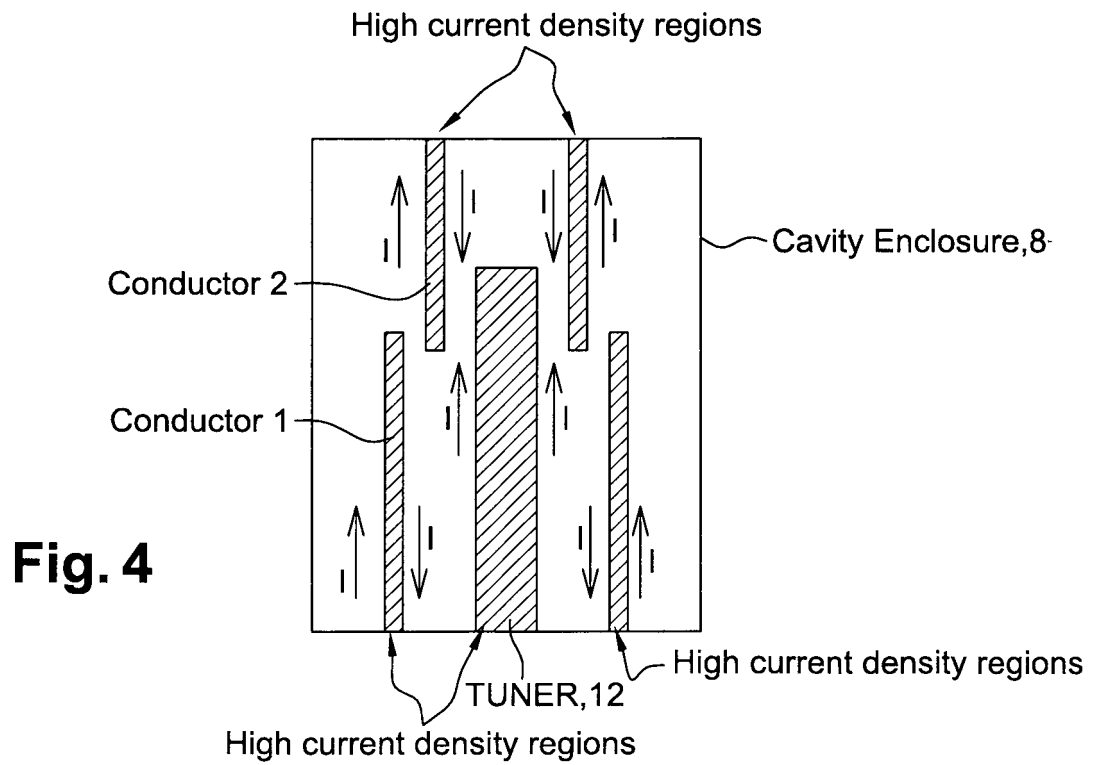


Fig. 4

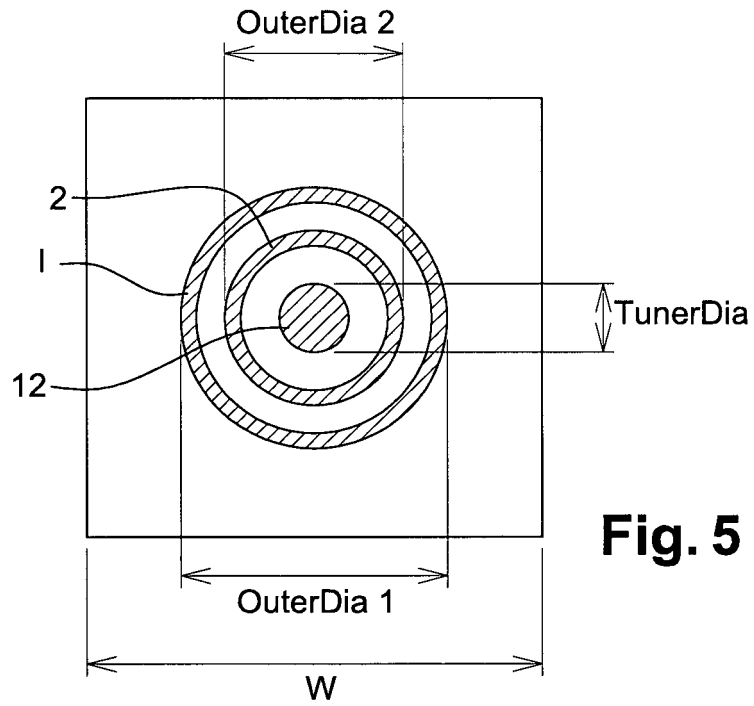


Fig. 5

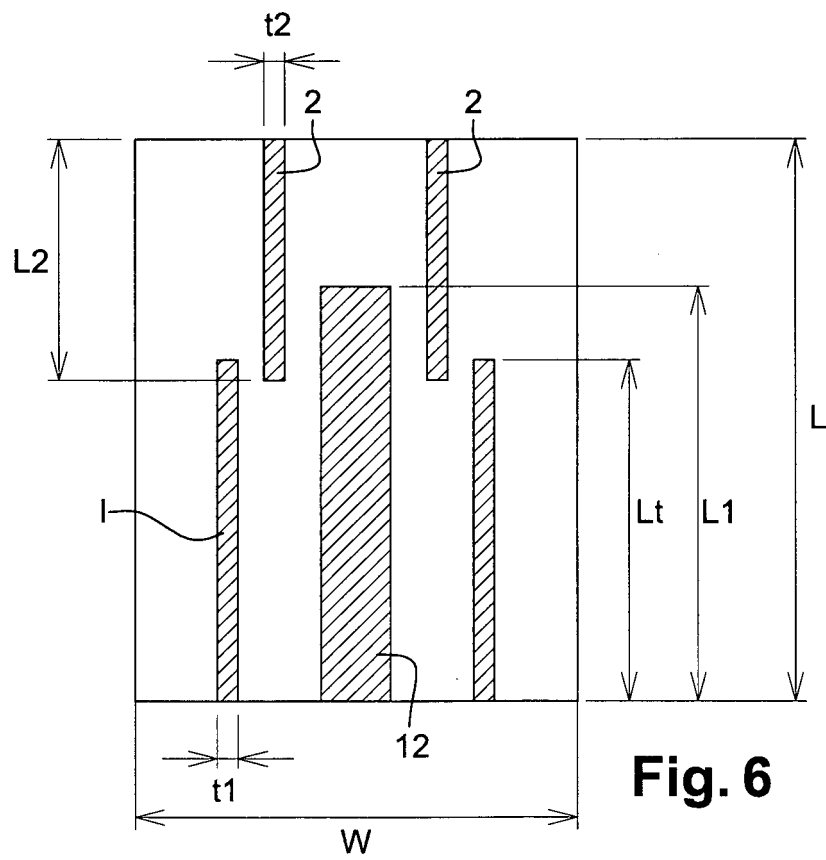


Fig. 6

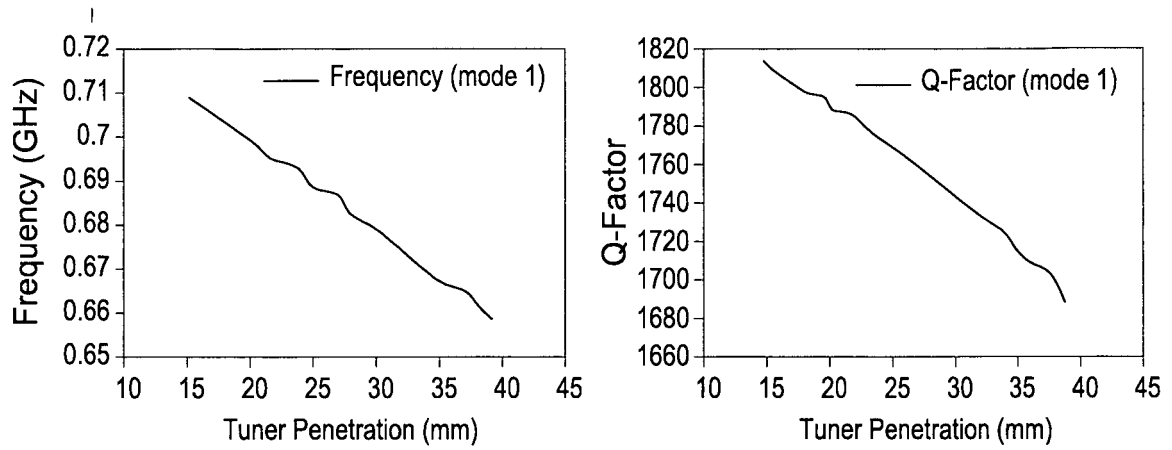


Fig. 7

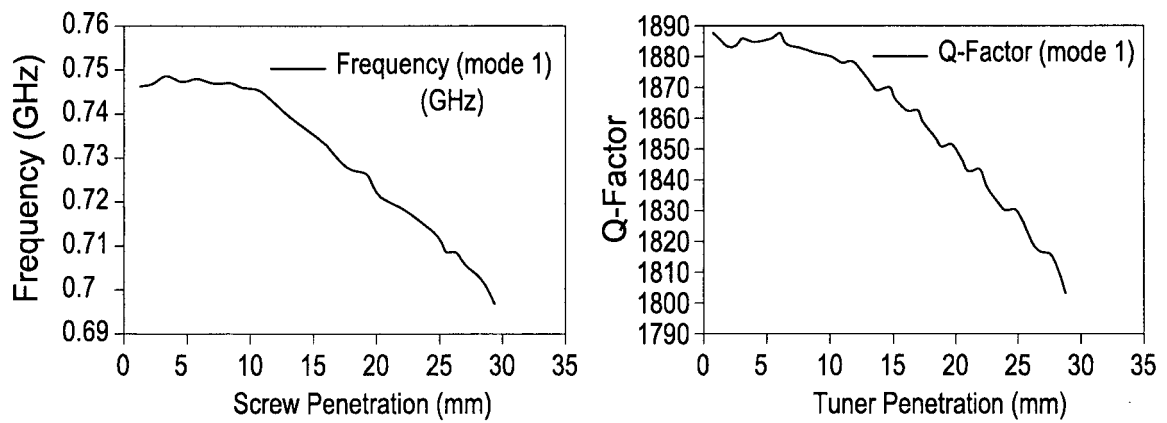


Fig. 8

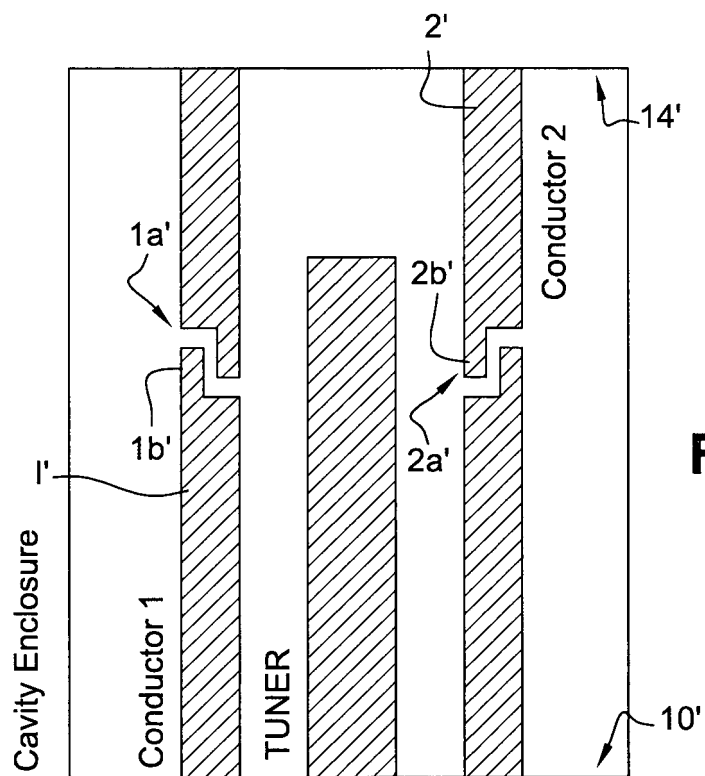


Fig. 9

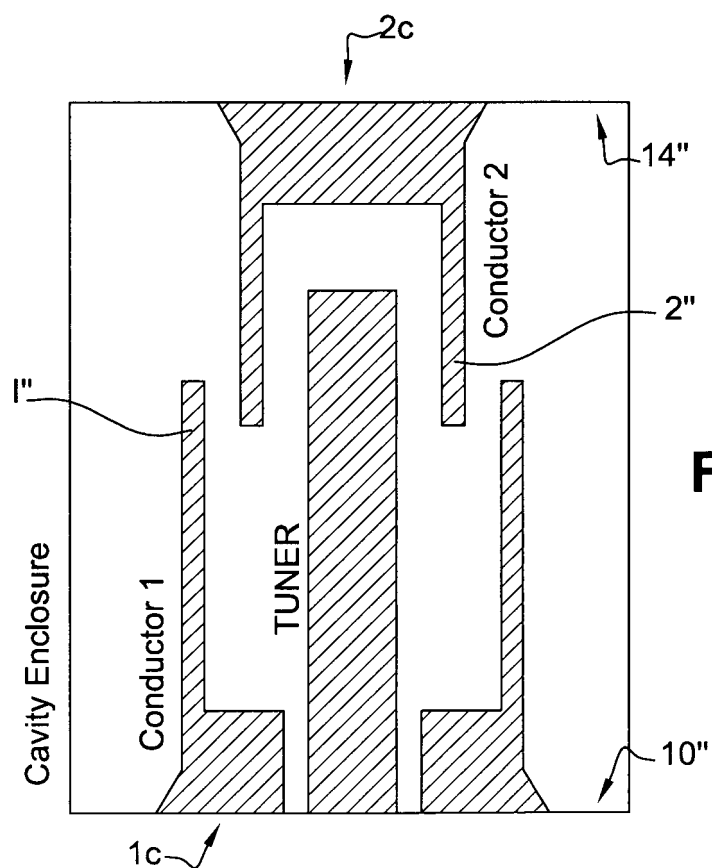


Fig. 10

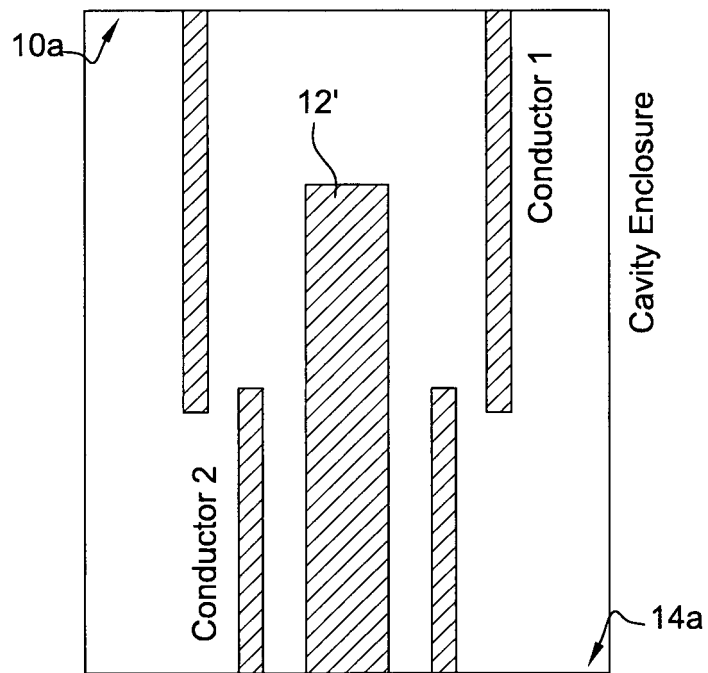


Fig. 11



EUROPEAN SEARCH REPORT

Application Number
EP 15 30 5879

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EPO FORM 1503 03.82 (P04C01)

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	US 2 181 901 A (LINDENBLAD NILS E) 5 December 1939 (1939-12-05)	1-9, 11-13	INV. H01P7/04
Y	* page 1, line 35 - page 2, line 17; figures 1,2 *	10	
Y	----- US 5 867 076 A (TADA HITOSHI [JP] ET AL) 2 February 1999 (1999-02-02) * column 6, line 23 - column 7, line 13; figures 1-3 *	10	
A	----- US 3 448 412 A (JOHNSON EINAR C) 3 June 1969 (1969-06-03) * column 2, line 20 - line 70; figures 1,2 *	1-13	
A	----- EP 2 533 356 A1 (POWERWAVE FINLAND OY [FI]) 12 December 2012 (2012-12-12) * paragraph [0023] - paragraph [0026]; figures 6,7 * * paragraph [0034] - paragraph [0035]; figure 10 *	1-13	
A	----- US 2014/347148 A1 (RUIZ-CRUZ JORGE A [ES] ET AL) 27 November 2014 (2014-11-27) * paragraph [0002] * * paragraph [0034] - paragraph [0040]; figures 4-8 *	1-13	TECHNICAL FIELDS SEARCHED (IPC) H01P
	----- -/--		
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 3 December 2015	Examiner Pastor Jiménez, 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	



EUROPEAN SEARCH REPORT

Application Number
EP 15 30 5879

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40

45

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	MUSONDA EVARISTO ET AL: "Microwave Bandpass Filters Using Re-Entrant Resonators", IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 63, no. 3, 1 March 2015 (2015-03-01), pages 954-964, XP011574138, ISSN: 0018-9480, DOI: 10.1109/TMTT.2015.2389216 [retrieved on 2015-03-03] * page 954, left-hand column, line 1 - page 955, left-hand column, line 12; figures 1-3 *	1-13	
A	JP 2002 076709 A (SHIMADA PHYSICAL CHEM IND CO) 15 March 2002 (2002-03-15) * abstract; figures 1,3 *	9	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 3 December 2015	Examiner Pastor Jiménez, 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	

 1
EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 15 30 5879

5

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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03-12-2015

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20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2181901 A	05-12-1939	FR 831568 A	08-09-1938
		GB 489598 A	29-07-1938
		NL 50891 C	03-12-2015
		US 2181901 A	05-12-1939
US 5867076 A	02-02-1999	JP 3344428 B2	11-11-2002
		JP H0690104 A	29-03-1994
		US 5867076 A	02-02-1999
US 3448412 A	03-06-1969	NONE	
EP 2533356 A1	12-12-2012	EP 2533356 A1	12-12-2012
		FI 20115557 A	09-12-2012
		US 2012313735 A1	13-12-2012
US 2014347148 A1	27-11-2014	NONE	
JP 2002076709 A	15-03-2002	NONE	

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **J.S. HONG ; M.J. LANCASTER.** Microstrip Filters for RF/Microwave Applications. John Wiley & Sons, 2001 **[0004]**