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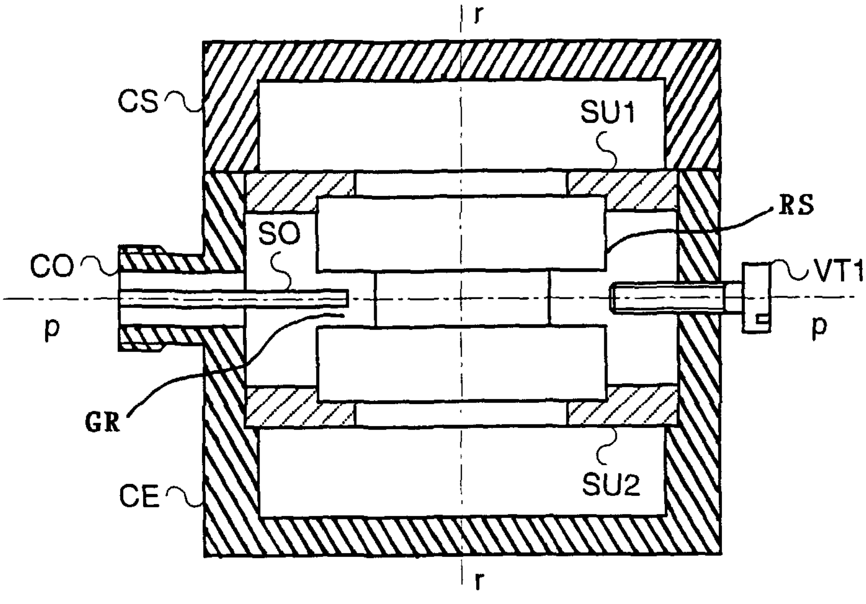
[Continued on next page]

(54) Title: DIELECTRIC LOADED CAVITY FOR HIGH FREQUENCY FILTERS



(57) Abstract: The dielectric loaded cavity for high frequency filters consists of a metal container housing a dielectric block held in position by supporting plates, that also sustains coupling and tuning elements. This invention provides broadband filters, small in size and with low losses. Its high symmetry structure considerably reduces the energising of spurious modes and furthermore facilitates the design using automatic calculation procedures, on the basis of accurate electromagnetic models.

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR)*
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"DIELECTRIC LOADED CAVITY FOR HIGH FREQUENCY FILTERS"

Description

This invention refers to devices for telecommunication systems and in particular it regards a dielectric-loaded cavity for high frequency filters.

In telecommunication systems for civilian use, with special reference to mobile telephones, there is a problem of providing microwave filters that, placed along a transmission line, allow the separation of different band or frequency channels; for example, separating transmission channels from receiving channels.

Usually these filters are implemented with a plurality of cavities in cascade and are mutually coupled through irises, screws or the like. As is known, these cavities, which may be of the waveguide type with a cylindrical or prismatic shape, or the co-axial type, with an internal metal conductor, are of a size that depends on the wavelength of the signal to be filtered, therefore the filter obtained may be quite large, especially at lower frequencies (1-4 GHz), and as a consequence the resulting overall dimensions may be excessive.

This problem becomes more critical when the telecommunications system development is such as to make a considerable quantity of these filters necessary, especially when these are fitted near aerials, often installed on the roofs of civil buildings.

One method of reducing the size of these filters, which has become common in recent years, is to insert a block of dielectric material into each cavity.

Because of the high permittivity of the material introduced into the resonator, the electromagnetic field remains mainly concentrated inside, and thus the dimensions of the cavity, calculated to obtain the resonance at a certain wavelength, are considerably reduced. In fact, the dimensions of an equivalent filter with dielectric-loaded resonators are reduced from between one third to one sixth of the original volume. The electrical characteristics of the filter are not excessively penalised, because of the availability of low loss, high temperature-stability ceramic materials.

Another method of obtaining small sized filters is to reduce the number of cavities used, exploiting two or more resonant modes in each cavity by means of the re-use technique, which permits the design of dual mode or triple mode resonators. The coupling between the modes is obtained by perturbing the cavity section in the diagonal plane in relation to the polarisation planes of the modes themselves. The effect that results is the same as that which can be obtained with two ordinary cavities, thus a filter with a desired band can be obtained with half the number of cavities.

Moreover, the re-use of the same cavity also permits more sophisticated transfer functions than transfer functions with all the infinite or polynomial transmission zeroes, characteristic of a cavity plurality simply connected in cascade.

One of the problems found in the preparation of filters that use cavities of the type mentioned, is the difficulty in obtaining couplings with a sufficiently high value, especially when the band pass required is comparatively wide, e.g. more than one percent of the central frequency.

It is a known fact that cavity couplings are obtained by the introduction of mechanical elements, such as probes or screws, the latter also permitting the tuning of the same. Obviously, if the cavity contains dielectric material inside, there are further difficulties in the arrangement of these elements. In fact, the dielectric material, on one hand makes stronger the internal electromagnetic field, limiting the peripheral field that intervenes in the couplings, on the other hand it mechanically limits the penetration of the screws and probes.

The problem becomes worse due to the fact that all these elements are to be preferably located on the plane which is perpendicular to the rotation axis of the dielectric material and divides it into two equal parts: in fact, in this way the operation is carried out where there is a high electromagnetic field, obtaining a coupling of a greater value, and the energising of spurious resonating modes is avoided, which could generate anomalous responses in the operating band.

Furthermore, when the filter is designed to function at very low frequencies, for example between 1 and 4 GHz, where the wavelength, and therefore also the size of the cavity, is greater, the cavity internal volume has to be occupied as much as possible by the dielectric material, so as to obtain the maximum reduction in the overall dimensions. As a consequence, the space to house screws and probes is further limited.

Among the dielectric loaded cavities known at present, there is that described in US Patent no. 5008640, issued in the United States on April 6th

1991, entitled "Dielectric-loaded cavity resonator", in the name of the same applicant, which solves the problem arising from the dimensions and has low losses in the pass band. However, it is not suitable for broadband filters, which require very tight couplings between resonators and therefore considerable penetration of the coupling elements in the dielectric resonator transverse symmetry plane.

Another known cavity is that described in WO 99/19933 published on April 22nd 1999, in the name of Filtronic PLC, entitled "Composite resonator". In the resonator described, the dielectric element rests on the base of the metal cavity and has a metal disk on the summit. This configuration permits a considerable reduction in the presence of spurious modes in the vicinity of the filter operating frequency, but increases the resonator losses. Furthermore, to obtain the required couplings, certain mechanical devices are necessary, such as plates and disks with a rather critical adjustment.

The dielectric-loaded cavity for high frequency filters, subject of this invention, avoids these difficulties and solves the technical problems described, permitting the realisation of broadband filters, maintaining small dimensions and low losses. Its high symmetry structure permits considerable reduction in the energising of spurious modes and moreover facilitates the design, using automatic calculation procedures thanks to the availability of accurate electromagnetic models.

This invention provides a dielectric loaded cavity for high frequency filters, as described in the characterizing part of claim 1.

The foregoing and other characteristics of this invention will be made clearer by the following description of some preferred forms of the invention, given by way of non-limiting example, and by the annexed drawings in which:

- Fig. 1 is a longitudinal section of the cavity;
- Fig. 2 is a cross section of the same cavity as in Fig. 1;
- Fig. 3 is a cross section of a second cavity form;
- Fig. 4 is a longitudinal section of a third cavity form;

- Fig. 5 is a partial section of two cavities overlaid and coupled through the bases;
- Fig. 6 is a partial section of two cavities side by side, coupled through the side surface;
- Fig. 7 is a partial section of two cavities side by side, coupled through the side surface in a different manner.

The cavity illustrated in Fig. 1 consists of a metal container in which a proper cylindrical cavity with a rotation axis r-r has been obtained, and a cylindrical block RS of dielectric material held in position by a pair of supporting plates SU1 and SU2, so as to render the whole mechanically stable without the use of adhesives. In Fig. 1, the block RS is not shown in section.

The dielectric material of block RS is of high permittivity, so as to load the cavity, reducing the operating frequency, and the block includes a groove GR on a plane p-p transversal to the rotation axis r-r, the groove extending over the entire circumference. More precisely, plane p-p coincides with an electrical symmetry plane of the cavity, but not necessarily with a geometric symmetry plane, and also contains the various coupling and tuning elements fastened to the metal container.

The dielectric cylindrical block RS is held in a coaxial position with the cavity by two supporting washer-shaped plates SU1 and SU2, each of which has an axial hole to cut down losses and a centering bottom that houses one of the bases of the grooved cylindrical block RS.

The cylindrical metal container is divided crosswise to the rotation axis r-r into two parts, CE and CS, which are mutually fixed by screws. The part indicated by CE houses the group composed of the supporting plates SU1 and SU2 and block RS.

The inner diameter of the cavity is slightly enlarged to contain this group in CE and the group is held at a suitable distance from the bottom by a step that is created by a difference of two diameters of part CE. The depth of the cavity section with the greater diameter is advantageously made equal to the height of the group of the supporting plates and the grooved cylindrical block. In this way it is sufficient to prepare part CS with a slightly smaller diameter than that of the supporting plates to hold the whole group firmly in position.

Coupling and tuning elements are fitted in part CE of the metal container, corresponding to the electric symmetry plane p-p, i.e.: a probe SO, connected to a coaxial connector CO, that couples the cavity to a generator or an external load, and a plurality of metal screws VT1, VT2, VT3, ..., to obtain both coupling between resonant modes inside the cavity, and the tuning of the same. Probe SO and screws VT1, VT2, VT3 can penetrate into the groove GR of cylindrical block RS to the depth required to obtain the desired coupling and tuning effects.

Fig. 2 illustrates the angular arrangement of the probe and the screws that permits a conventional dual-mode functioning of the cavity.

The first resonant mode, energised by probe SO, is tuned by screw VT1, angled at 180° to the probe. Screw VT2, which is at a right-angle to VT1, tunes the second resonant mode, coupled to the first by screw VT3, which is angled at 45° to VT1 and VT2.

Fig. 3 highlights another angular arrangement of the probe and the screws, to obtain a different cavity dual-mode functioning. In this case, probe SO is not symmetrical to either one of the two tuning screws VT1 and VT2, which are at 90° to each other. Probe SO generates the coupling to the generator or the external load of both resonant modes tuned by VT1 and VT2. Another screw, not shown in the figure, could be set at 45° to VT1 and VT2 to further mutually couple the two resonant modes.

Fig. 4 shows an extreme case in which the groove GR in the cylindrical block RS has the same depth as the radius; thus the original cylinder divides into two coplanar cylinders RS1 and RS2 of lesser height. In this case, it is necessary to interpose another supporting plate SU3 to keep the two cylinders RS1 and RS2 at the required distance, SU3 having radial through-holes for the coupling and tuning elements.

The supporting plates SU1, SU2 and SU3, shown in this figure and the previous ones, are made of a low permittivity, low loss plastic or ceramic dielectric material.

The groove, and in the extreme case, the separation of the dielectric cylindrical block into two cylinders, allows the coupling and tuning elements to penetrate deeply into the regions of the cavity, where the electromagnetic field is more intense. In this way higher coupling values and more extended tuning ranges can be obtained, facilitating the realisation of filters with relatively higher percentage bands, for example, over 1% of the central frequency.

The structure of the cavity described allows an easy coupling between similar cavities to obtain band-pass filters of various complexities.

Fig. 5 shows two cavities CA1 and CA2 coaxially overlaid and with a common base. The coupling takes place through an iris IR, usually rectangular in shape, prepared in the base itself.

Figures 6 and 7 illustrate two cavities, CA1 and CA2, side by side and coupled either through an opening AP in the adjacent side walls, or by a probe SA, that extends in the two cavities through the side walls.

Obviously this description is given as a non-limiting example. Variants and modifications are possible, without emerging from the protection field of the claims.

For example, both the cavity and the dielectric block may be prismatic instead of cylindrical and the groove may be in a position that is not intermediate as shown in the figure, but closer to one end of the dielectric block.

Claims

1. Dielectric loaded cavity for high frequency filters, consisting of:
   - a metal container, divided transversally into two parts (CE, CS), mutually secured,
   - a dielectric block (RS), of a high permittivity material, able to load the cavity reducing the operating frequency,
   - supporting plates (SU1, SU2, SU3) to hold the dielectric block (RS) in place inside the metal container,
   - coupling and tuning elements (SO, VT1, VT2, VT3),

   characterised in that said dielectric block (RS) includes a groove (GR) lying in a transverse plane (p-p) and extending over the entire perimeter of the block.

2. Dielectric loaded cavity as in claim 1, characterised in that said groove (GR) in the dielectric block (RS) has a depth such as to divide the original block into two coplanar blocks of lesser height (RS1, RS2).

3. Dielectric loaded cavity as in claim 2, characterised in that a further supporting plate (SU3) is interposed between the two coplanar blocks (RS1, RS2).

4. Dielectric loaded cavity as in any of the previous claims, characterised in that said supporting plates (SU1, SU2, SU3) are of a plastic or ceramic low permittivity, low loss dielectric material.

5. Dielectric loaded cavity as in any of the previous claims, characterised in that said plane (p-p), in which the groove of the dielectric block (RS) lies, intersects said coupling and tuning elements (SO, VT1, VT2, VT3), fastened to the metal container.

6. Dielectric loaded cavity as in any of the previous claims, characterised in that said dielectric block (RS) is cylindrical in shape.

7. Dielectric loaded cavity as in any of the previous claims, characterised in that said metal container, transversally divided into two parts (CE, CS), is cylindrical in shape.

8. Dielectric loaded cavity as in any of the previous claims, characterised in that a first screw (VT1) is placed at 180° to a probe (SO) to tune a first resonant mode, a second screw (VT2) is placed at a right angle to the first screw to tune a second resonant mode and a third screw (VT3) is placed at 45° to the first and the second screw to couple the first and second resonant modes.

9. Dielectric loaded cavity as in any of claims 1 to 7, characterised in that a probe (SO) is in a position that is not symmetrical in relation to either one of a first and a second tuning screw (VT1, VT2).

10. Dielectric loaded cavity as in any of the previous claims, characterised in that is is fitted with an iris (IR), in a base of the metal container, for coupling to other cavities.

11. Dielectric loaded cavity as in any of the previous claims, characterised in that it has an opening (AP), in the side part of the metal container, for coupling to other cavities.

12. Dielectric loaded cavity as in any of the previous claims, characterised in that it has a probe (SA) that is fastened to the side wall of the metal container, for coupling to other cavities.

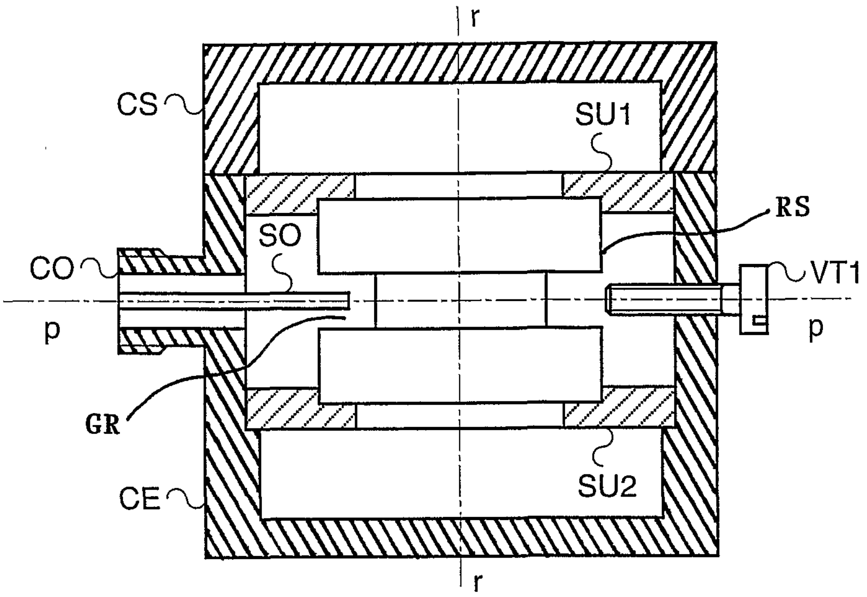

Fig. 1

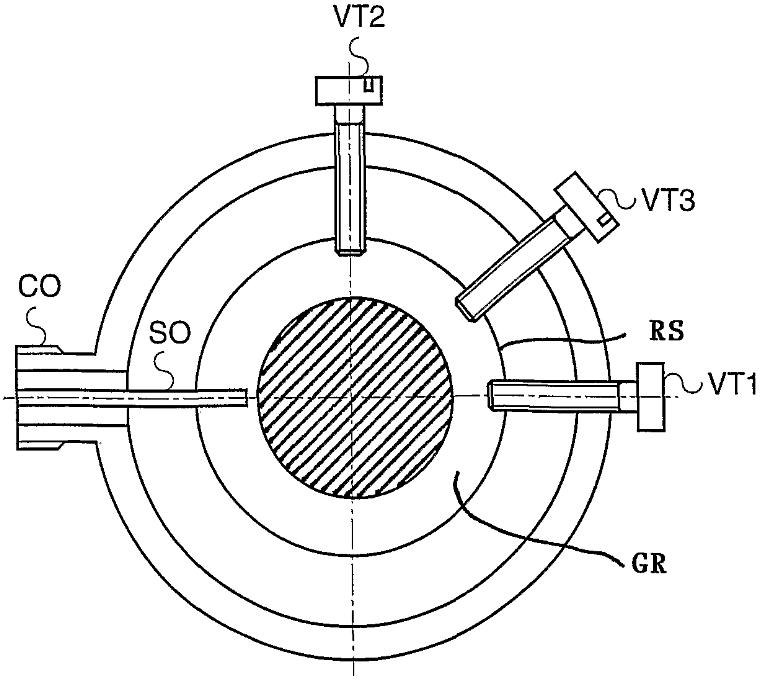

Fig. 2

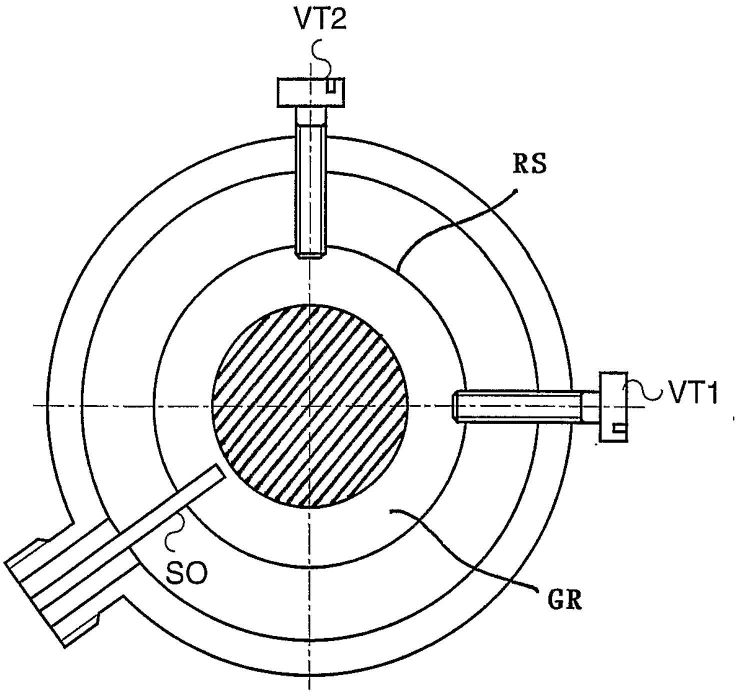

Fig. 3

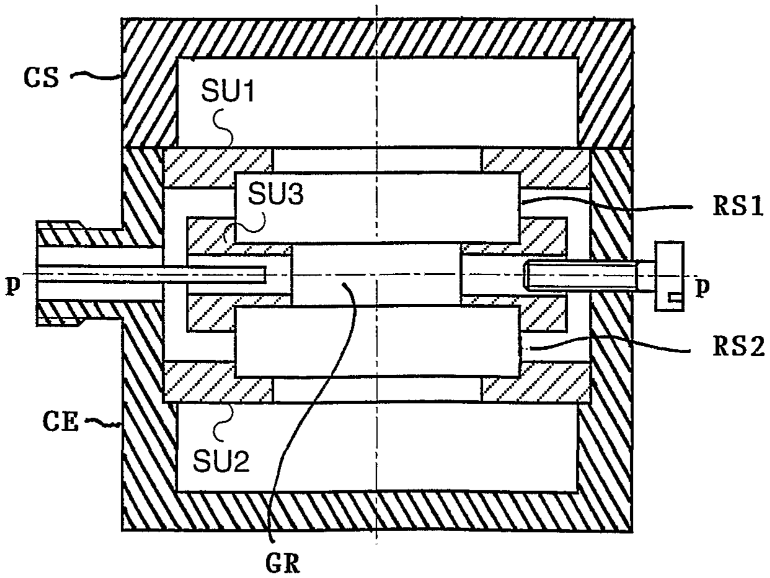

Fig. 4

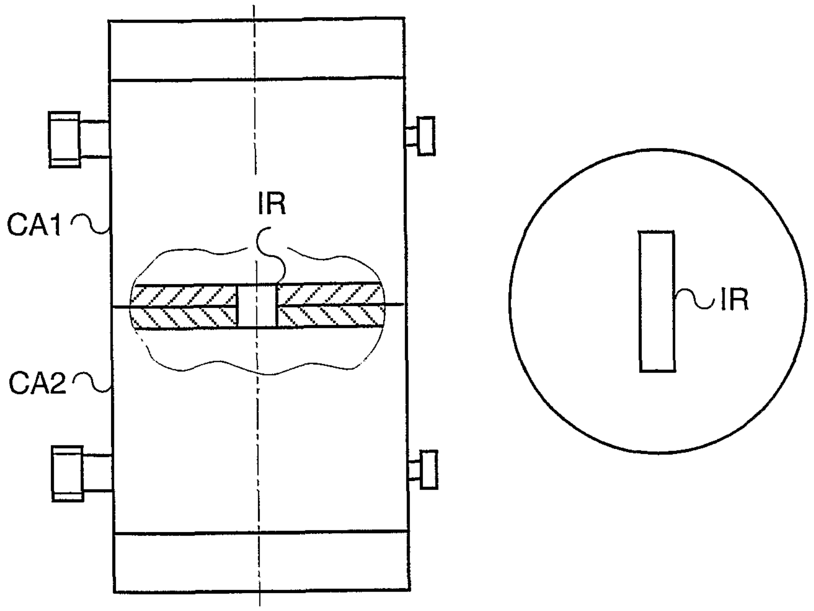

Fig. 5

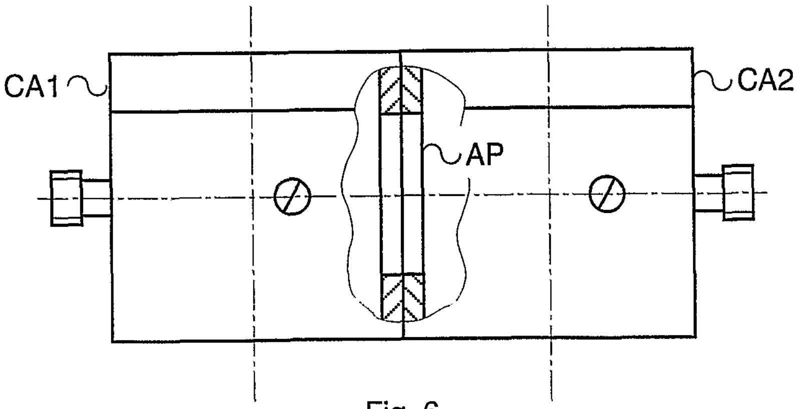

Fig. 6

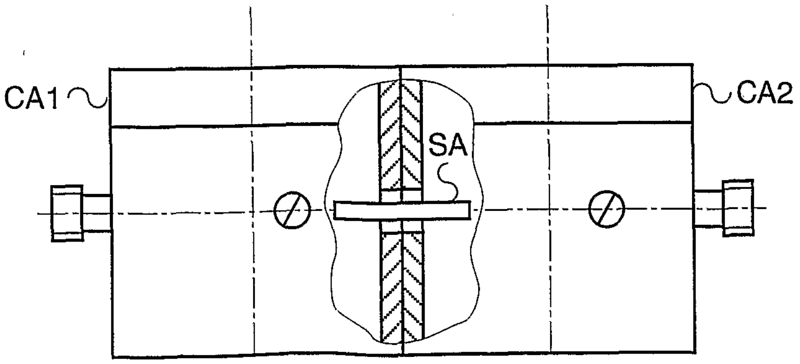

Fig. 7

INTERNATIONAL SEARCH REPORT

Int nal Application No
PCT/EP 01/08289

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01P7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SENG-WOON CHEN ET AL: "TUNABLE, TEMPERATURE-COMPENSATED DIELECTRIC RESONATORS AND FILTERS" IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, IEEE INC. NEW YORK, US, vol. 38, no. 8, 1 August 1990 (1990-08-01), pages 1046-1052, XP000140367 ISSN: 0018-9480 figure 3	1,2,4-9
Y		3,10-12

Y	US 5 059 929 A (TANAKA) 22 October 1991 (1991-10-22) figures 4-7	3

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search
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INTERNATIONAL SEARCH REPORT

Int al Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	GENDRAUD S ET AL: "DESIGN AND REALIZATION OF A FOUR POLE ELLIPTIC MICROWAVE FILTER USING LOW DIELECTRIC LOADED CAVITIES" 1997 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST. DENVER, JUNE 8 - 13, 1997, IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST, NEW YORK, NY: IEEE, US, vol. 2, 8 June 1997 (1997-06-08), pages 1091-1094, XP000767684 ISBN: 0-7803-3815-4 figure 6 ---	10
Y	EP 0 961 338 A (ACE TECHNOLOGY) 1 December 1999 (1999-12-01) column 1, line 30-45; figures 1A,B ---	11
Y	US 4 453 146 A (FIEDZIUSZKO) 5 June 1984 (1984-06-05) column 3, line 8 -column 4, line 66; figure 1 ---	12
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 148 (E-1522), 11 March 1994 (1994-03-11) & JP 05 327324 A (NGK SPARK PLUG CO LTD), 10 December 1993 (1993-12-10) abstract ---	1,5
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 332 (E-453), 12 November 1986 (1986-11-12) & JP 61 136302 A (MURATA MFG CO LTD), 24 June 1986 (1986-06-24) abstract ---	1
A	EP 0 351 840 A (CSELT) 24 January 1990 (1990-01-24) column 3, line 2-9; figure 1 -----	1

INTERNATIONAL SEARCH REPORT

Int nal Application No
PCT/EP 01/08289

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5059929 A	22-10-1991	DE 3928015 A1	08-03-1990
		GB 2222315 A ,B	28-02-1990
		JP 2002469 C	20-12-1995
		JP 2168702 A	28-06-1990
		JP 7028168 B	29-03-1995
EP 0961338 A	01-12-1999	EP 0961338 A1	01-12-1999
		JP 2000031706 A	28-01-2000
		US 6262639 B1	17-07-2001
US 4453146 A	05-06-1984	CA 1199692 A1	21-01-1986
		DE 3382428 D1	14-11-1991
		EP 0104735 A2	04-04-1984
		JP 1047043 B	12-10-1989
		JP 1560320 C	31-05-1990
		JP 59080002 A	09-05-1984
JP 05327324 A	10-12-1993	JP 2809555 B2	08-10-1998
JP 61136302 A	24-06-1986	NONE	
EP 0351840 A	24-01-1990	CA 1311022 A1	01-12-1992
		DE 68920496 D1	23-02-1995
		DE 68920496 T2	24-05-1995
		DE 351840 T1	02-05-1991
		EP 0351840 A2	24-01-1990
		JP 1958619 C	10-08-1995
		JP 2256302 A	17-10-1990
		JP 6091362 B	14-11-1994
		US 5008640 A	16-04-1991