(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 785 592 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.07.1997 Bulletin 1997/30

(51) Int Cl.6: H01P 1/205, H01P 7/04, H01P 1/212

(21) Application number: 97300227.2

(22) Date of filing: 15.01.1997

(84) Designated Contracting States:
DE DK FR GB SE

(30) Priority: 19.01.1996 FI 960277

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(54) A dielectric resonator structure providing harmonic attenuation

(57) The harmonic multiples of the operating frequency of a dielectric filter are attenuated by a non-conducting pattern, which is formed on one (19) or more side faces of a housing block (12) which are otherwise coated with a conducting material. The pattern may consist of linear areas (20,22), the optimum width of which is approximately 1 mm.

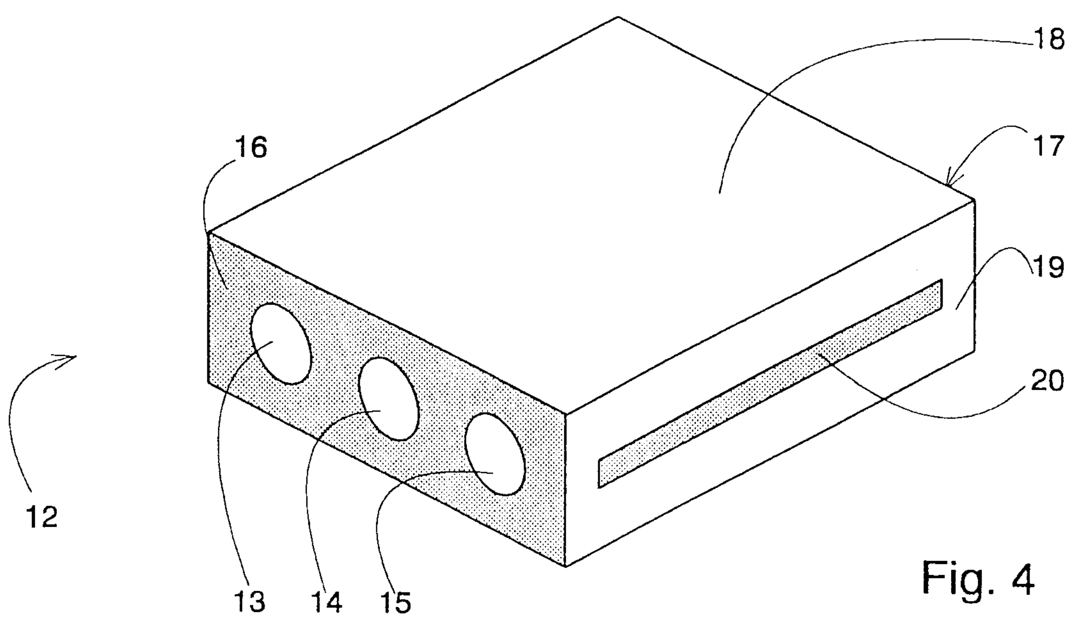

Fig. 4

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Description

This invention relates in general to the structure and characteristics of dielectric radio-frequency filters and in particular to the way in which the harmful effect of harmonic multiples of the operating frequency may be attenuated by filter structure.

A dielectric coaxial resonator is generally used in, among other things, radio-frequency filters. The coaxial resonator structure has typically a short-circuited end and an open end and is in length as long as a quarter-wave multiple of the operating frequency. The filter structure may comprise several resonators. Frequently, the filter structure comprises a single dielectric member, in which holes penetrating the member and surfaced with a conducting material form inner conductors coaxially and act appropriately as closed coaxial resonators. The dielectric member is coated where desired with a conducting material, which forms the external conductor of the resonators. The coating of the block is in communication with the coating of the resonator apertures in a manner known to men skilled in the art. The resonators are coupled one to another by means of electromagnetic fields through the dielectric medium. Connection is made to the filter structure itself by means of electrodes attached thereto.

With a multi-resonator made from a single member, unwanted resonances also occur. For example, in a mobile telephone, attenuation of the second and third harmonics of the fundamental frequency is required. The coaxial resonator also resonates at these frequencies in the direction of the principal axis or parallel with the inner conductor, in which case oscillation occurs at a multiple of the fundamental frequency.

In a filter structure effected from a single member resonation may occur also in directions other than those of the principal axes of the resonators, or transverse resonances may occur. Dielectric resonator structures effected from a single member may also, as is well-known, be penetrated by unwanted frequencies as a result of the above-mentioned spurious resonances. The natural way of attenuating these unwanted frequencies lies in the use of a separate narrowband absorbent filter or a low-pass-type adapting element. Such a separate structure may be constructed in front of the filter proper or as an immediate extension thereto and may be designed for the harmonic frequency which one wishes to attenuate. The use of such separate harmonic filters involves certain difficulties. The filter must be manufactured in a separate process away from the filter proper and must be attached to it at a final assembly stage, and this introduces large numbers of additional work stages and potential sources of error into the manufacture of the filter. A separate harmonic filter encased in the same housing increases the size of the filter and furthermore, if the separate filter is an independent component, the space requirement on the circuit board to which the filter is attached also grows. An additional drawback of the separate filter is the difficulty in providing it with adequately powerful RF filtration.

Finnish Patent No. 90158 describes a method for effecting attenuation of harmonic frequencies. In this method, a filter for filtering frequencies above the operating frequency of the filter in accordance with Figure 1 is situated in at least one resonator circuit aperture of the ceramic filter. The filter is so designed that it is formed from a metal rod 1 which goes through resonator aperture 2. To the rod are attached discoid insulation plates 3, 4, 5, which at their periphery are supported on the coating of the aperture. Parts of the rod lying in between the insulation plates form the filter's longitudinal inductances and the insulation plates together with the conducting surfaces lying against them form transverse capacitances. In this way a low-pass filter is formed, with which one may attenuate harmful harmonic frequencies. One drawback of this structure is the number of additional components which it requires. Also, the manufacturing precision required for harmonic filters contained in small ceramic filters also increases the production costs.

U.S. Patent No. 4,506,241 describes a design solution according to Figure 2, with which harmonic frequencies may be attenuated. In this solution there is a resonator 6, at one end of which is a thicker portion, and at the other end a thinner portion, made from a dielectric material, a step 7 being formed between the portions. Thus, a so-called step structure is created, the basis for which is that the impedance ratio of the thinner and thicker portions is less than one, it being possible with this structure to attenuate harmonic frequencies. The drawback of this solution is also its processibility. If the step structure is made inside the resonator aperture as shown in Figure 2, the problem lies in its precision and coatability. If on the other hand it is created on the outer conductor, the problem lies particularly in its being produced in a filter which is manufactured from a one-piece ceramic member, since all forms deviating from the level plane on the outer surface of the ceramic member are from the manufacturing standpoint more difficult than straight planes.

In U.S. Patent No. 4,455,503, harmonic attenuation is achieved with a groove made in the surface of strip line resonator, which in depth equals 30-70 % of the total thickness of the piezoelectric substrate. It is in this way possible to attenuate harmonic frequencies in the directions of both breadth and thickness. The patent involves a slightly different application from that in the present invention, since the operation of the piezoelectric resonator is based upon mechanical oscillation and not upon the resonances of electromagnetic fields. The structure and use according to the said U.S. patent are not in themselves suited to a ceramic filter in which coaxial resonators have been formed from coated apertures. A deep groove would affect other properties of a filter, such as for example the connection between the resonators, but not harmonic attenuation. For example, U.

S. Patent No. 4,431,977, as shown in Figure 3, proposes the creation of a groove 8 in a ceramic block 9 between resonators 10, 11, in which case connection between these may be affected. The groove is not however as deep as in the solution according to the previously mentioned U.S. patent No. 4,455,503, since this patent involves a coaxial resonator structure, in which there are resonator apertures.

An aim of this invention is to provide a dielectric filter structure with structural characteristics which attempt to attenuate electromagnetic resonance at harmonic frequencies of the operating frequency.

An aim of embodiments of the invention is also to provide a relatively simple filter structure for attenuating harmonic frequencies which is economical to manufacture and does not entail unreasonable precision requirements. A further aim of embodiments of the invention is that the structure for attenuation of harmonic frequencies according to it should be applicable to filters which are of different sizes and designed for different frequencies.

With this in mind, the present invention forms on at least one side face of the housing block of the dielectric filter an area which is not coated with an electrically conductive material.

The filter structure according to this invention is defined in the appended claims, and in one embodiment comprises a dielectric housing block essentially in the form of a rectangular prism, in which there is at least one resonator aperture in the direction of a particular principal axis, this resonator aperture having a specified electromagnetic operating frequency, and where those faces of the housing block which are perpendicular to the principal axis are the top and bottom faces and the other faces of the housing block are the side faces, is characterized by the fact that at least one of the side faces, which is in essential respects coated with an electrically conductive material, comprises a non-conducting area for the attenuation of harmonic multiples of the operating frequency which occur in the housing block.

This invention is based upon a concept whereby the side faces of the block which acts as the filter housing, and in particular their conducting properties, have considerable significance as regards resonation of the harmonic frequencies. By forming on the side faces, which are otherwise coated with a conducting material, separate non-conducting patterns, it is possible to attenuate the harmonic frequencies. By the side faces is meant in particular those surfaces of the di-electric housing block which are parallel with the principal axes of the resonator apertures. In a housing block in the form of a rectangular prism there are altogether four side faces. The two faces of the housing block which are at right angles to the principal axes of the resonator apertures are termed the top and bottom faces.

This invention does not restrict the quantity and form of the pattern which is to be created on the side faces. In the research which led up to this invention it was observed that effective attenuation is achieved by a linear pattern for example, which may comprise one or more linear elements which the width of one line is 1 mm approximately. In the case of two or more lines, these may be parallel or may intersect or touch one another. The lines may be straight or they may be curved or contain bends. The patterning may be created on one or more side faces of the housing block. It may extend to the edge of the surface in question or it may be situated fully in the central portion of the face. In addition to or in place of lines, the patterning may comprise areas in the form of a triangle, a square, a circle, an ellipse or some other geometrical figure or of irregular form. The correct form, size and positioning of the figure may be sought by experiment taking into account the special characteristics required of the filter under development at any time.

In a preferable embodiment of the invention the uncoated line or lines that serve as harmonic attenuators are not wider than the diameter of the resonator holes. If the line or lines lie parallel to the resonator holes, its/their length is preferably in the range of 40 - 95% of the resonator length. This applies also to the case of a line or other uncoated area that is not parallel to the resonator holes; in this case the projection of that area in the direction parallel to the resonator holes should be in the mentioned range. Further, in its preferred embodiment the uncoated area crosses the fictitious plane that is perpendicular to the direction of the resonator holes and divides the resonator holes into two parts of equal length. In other words, if we divide the dielectric block into two along the mentioned plane, some parts of the harmonic frequency attenuator according to the invention are found in both halves.

The non-conducting patterning according to this invention may be produced on the surface of the block which acts as the housing for the dielectric filter by using, in that manufacturing phase which corresponds to coating of the entire block, a mask which leaves behind an item corresponding to the pattern without coating with the conducting material. Alternatively, the patterning may be created on the block, which is already coated, by removing electrically conductive material from the side face or -faces. Both of these manufacturing variants only require manufacturing technology known to a man skilled in the art, and do not require an unreasonably high level of precision, so that manufacturing of the filter structure according to the invention is economical. The invention is also readily applicable to filters of different sizes and ones designed for different frequencies, since the size and form of the patterning may be adapted to other dimensioning of the filter block which is being produced.

The invention will be described in greater detail below with reference to favourable embodiments presented as examples and with reference to the attached drawings, where

Figure 1 represents one dielectric filter structure according to the prior art,

Figure 2 represents a second dielectric filter structure according to the prior art,

Figure 3 represents a third dielectric filter structure according to the prior art,

Figure 3 represents a third dielectric filter structure according to the prior art,

Figure 4 represents one favourable embodiment of this invention,

Figure 5 represents a second favourable embodiment of this invention,

Figure 6 represents a third favourable embodiment of this invention,

Figures 7-9 represent test results of harmonic attenuation with a filter according to Figure 6 and with a similar structure without the patterning according to the invention.

In the above description of the prior art there are references to Figures 1-3, and so in the following description of this invention and of favourable embodiments thereof, reference will primarily be made to Figures 4-9. In the drawings, the same reference numbers are used for corresponding parts.

Figure 4 shows a dielectric filter, the housing of which consists of a block 12 in the form of a rectangular prism, manufactured from a ceramic material in a manner known for this purpose. In it are formed three resonator apertures 13, 14 and 15, which in this embodiment extend through the entire block 12 from its top face 16 to its bottom face 17. The apertures could also extend only part of the way through block 12, in which case they would only open onto the top or the bottom face. The block 12 has four sides faces, of which faces 18 and 19 are visible in the drawing. Of these faces, 18 is parallel with that plane of symmetry of block 12 which includes the principal axes of resonator apertures 13-15, and face 19 is perpendicular to the said plane of symmetry. Due to the dimensioning of the block, face 19 is noticeably smaller than face 18, and so 19 is also called the end face.

The side and bottom faces of the block 12 and the internal surface of the resonator apertures are coated by a method known for this purpose with a conducting material, which is shown in white in the drawing. The uncoated top face 16 of the block is shown shaded. On it, conducting patterns (not shown in the drawing) may be applied by a known method, and these may for example be strip line conductors for affecting electromagnetic connection between the resonators or soldering spots for the attachment of surface-mounted components. According to the invention face 19 has a non-conducting pattern 20, which in this case is a single straight line. Its width is approximately 1 mm and its length is slightly less than the length of face 19 from the top face to the bottom face.

Figure 5 shows a second favourable embodiment of this invention. In it the dielectric filter is in basic structure similar to that in Finnish Patent Application No. 933056, "A Dielectric Filter". The surfaces of housing block 12 have been coated with an electrically conductive material excepting the top face 16 and that side face which in Figure 5 lies against printed circuit board 21. On the last-mentioned face are formed conducting patterns (not shown in the drawing), which are for interconnection of resonators 13, 14 and 15 as necessary. On side face 19 of the block there is, according to the invention, a non-conducting pattern 22, which in this case comprises two lines, which lie essentially at right angles to each other, forming a symmetrical cross figure at their point of intersection.

Figure 6 shows a dielectric duplex filter, in which harmonic attenuation in accordance with the above invention is employed. It comprises a printed circuit board 21, a ceramic housing block 12 and a non-conducting linear pattern 22 formed on one face 19 of the block just as in the embodiment in Figure 5. In the housing block 12 are formed in total 5 resonator apertures 23-28 and on the printed circuit board 21 are formed a transmitter port TX, an antenna port ANT and a receiver port RX. In order to realize the functional aim of the invention, three duplex filters were produced of basic design according to the embodiment shown in Figure 6; in the first of these, a harmonic attenuation pattern 22 was formed in the same way as in Figure 6, in the second a similar pattern was formed on face 18 instead of on face 19, and in the third there was no harmonic attenuation pattern whatsoever. The filters were designed for a nominal frequency of 1.9 GHz, so that they were suitable for the PCN (Personal Communication Network) for example. Figures 7-9 show test results, in which the frequency characteristics of these filters are compared.

In the test in Figure 7 the harmonic frequencies between the RX port and TX port of the first and third trial filters are compared. Curve 29 relates to the first filter, in which there is thus patterning on face 19 in accordance with the invention, and curve 30 represents the third filter, in which there is no harmonic attenuation. It is observed that the attenuation characteristics of the filter according to the invention at the point marked $\frac{\Delta}{3}$ are clearly better. In the test in Figure 8, curve 31 relates to the second filter, in which the attenuation pattern according to the invention is on face 18, and curve 32 corresponds to the curve 30 in Figure 7. The improved harmonic frequency attenuation characteristics are noticeable as in Figure 7. In the test in Figure 9, the trial filters are the same as in Figure 8, but curves 33 (patterning according to the invention) and 34 (no patterning) represent only the RX branch of the filters. The improved attenuation at the points marked $\frac{\Delta}{3}$ and $\frac{\Delta}{4}$ is clearly evident.

As has been stated above in connection with the general description of this invention, the non-conducting pattern on the surface of the dielectric housing for the purpose of attenuating harmonic frequencies may vary widely in form, size and positioning within the framework of the patent claims set out below. In addition, the number of resonators, for example, in a filter where a solution according to the invention may be applied for the purpose of attenuation of harmonic frequencies is not specified, but there may be one or more thereof.

Claims

1. A filter structure, consisting essentially of a housing block in the form of a rectangular prism (12), in which there is at least one resonator aperture (13-15; 23-28) in the direction of a particular principal axis, the resonator aperture having a specified electromagnetic operating frequency, in which case those faces (16,17) of the said housing block which are at right angles to the said principal axis are the top and bottom faces and other faces (18,19) of the said housing block are side faces, and the bottom face (17) and at least one side face (19) and the internal surface of the at least one resonator aperture (13-15; 23-28) are in essential respects coated with a conducting material, and characterized in that the at least one side face (19), which is in essential respects coated with a conducting material, comprises a non-conducting area (20,22) for attenuation of harmonic multiples of the operating frequency which occur in the housing block.

2. A filter structure in according with Claim 1, characterized in that said non-conducting area comprises at least one linear area (20).

3. A filter structure in accordance with Claim 2, characterized in that said linear area (20) is approximately as wide in a direction at right angles to its longitudinal direction as the diameter of the resonator apertures.

4. A filter structure in accordance with Claim 2, characterized in that said linear area (20) is essentially parallel with the principal axis of the at least one resonator aperture.

5. A filter structure in accordance with Claim 4, characterized in that the length of said linear area is between 40 and 95 per cent of the length of the at least one resonator aperture.

6. A filter structure in accordance with Claim 2, characterized in that said linear area is essentially at an angle to the principal axis of the at least one resonator aperture.

7. A filter structure in accordance with Claim 6, characterized in that the length of the projection of said linear area in the direction of the at least one resonator aperture is between 40 and 95 per cent of the length of the at least one resonator aperture.

8. A filter structure in accordance with Claim 1, characterized in that said non-conducting area (22) comprises at least two linear part-areas.

9. A filter structure in accordance with Claim 8, characterized in that said at least two linear part-areas (22) intersect each other.

10. A filter structure in accordance with Claim 8, characterized in that said at least two linear part-areas (22) are parallel.

11. A filter structure in accordance with Claim 1, characterized in that said non-conducting area (20,22) extends across the fictitious plane that is perpendicular to the pricipal axis of the at least one resonator aperture and divides the at least one resonator aperture into two parts of equal length.

12. A filter structure in accordance with Claim 1, characterized in that at least two side faces of the housing block (12), which are essentially coated with a conducting material, comprise a non-conducting area for attenuation of harmonic multiples of the operating frequency which occur in the housing block.

13. A filter structure comprising a dieletric block between opposed first and second faces of which a resonator aperture extends, the aperture opening onto either one or both of the first and second faces, the first face being uncoated and a plurality of other faces of the block and the surface defining the aperture being coated with conductive material, characterised in that a said coated face of the block connecting the first and second faces includes a non-conducting region to attenuate harmonics of the filter's operating frequency.

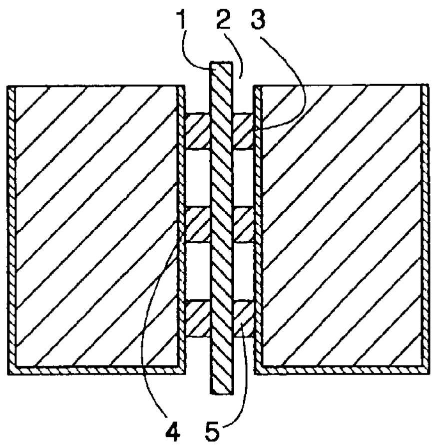


Fig. 1

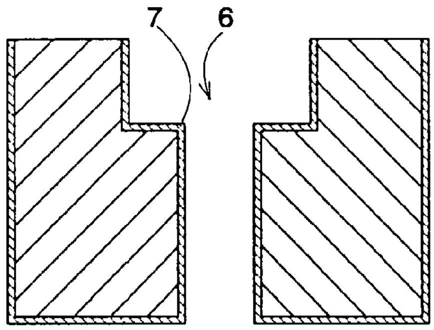


Fig. 2

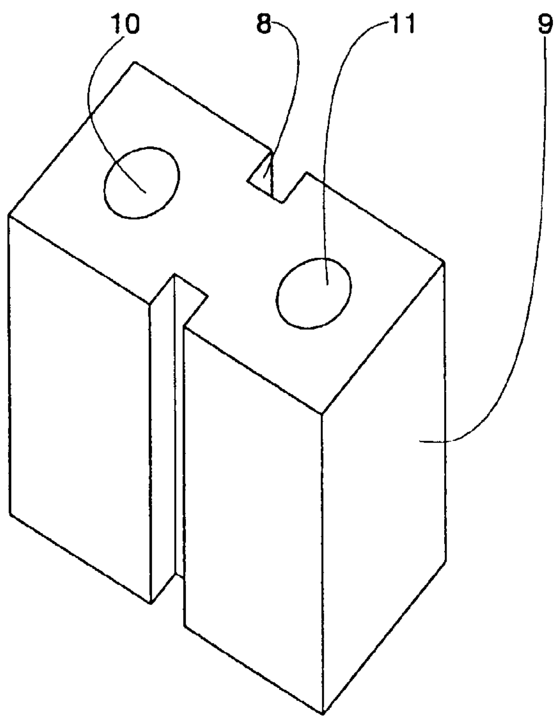


Fig. 3

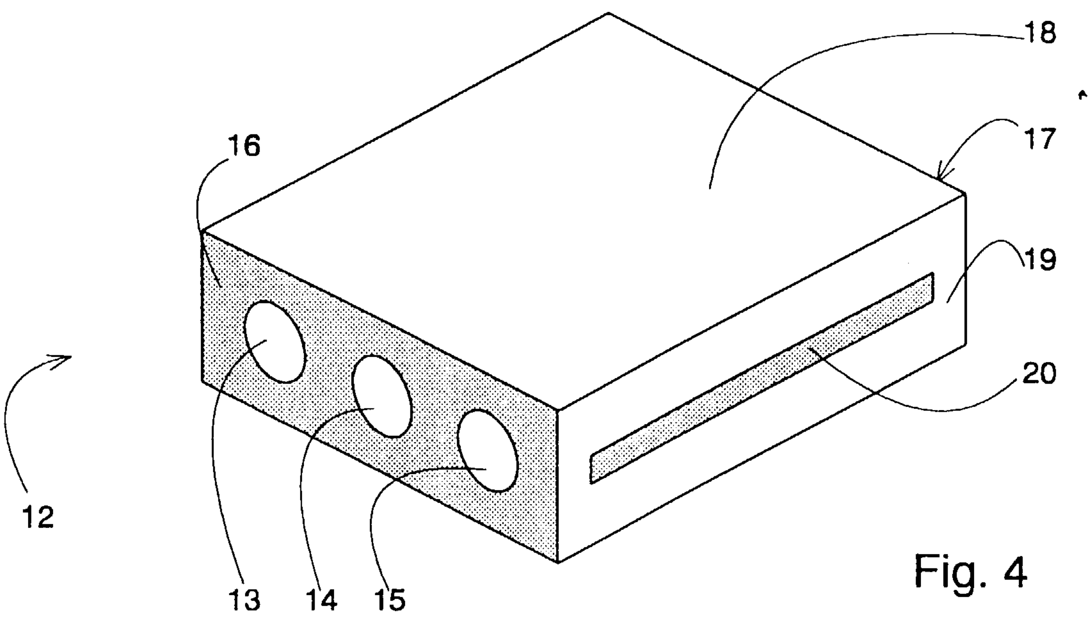


Fig. 4

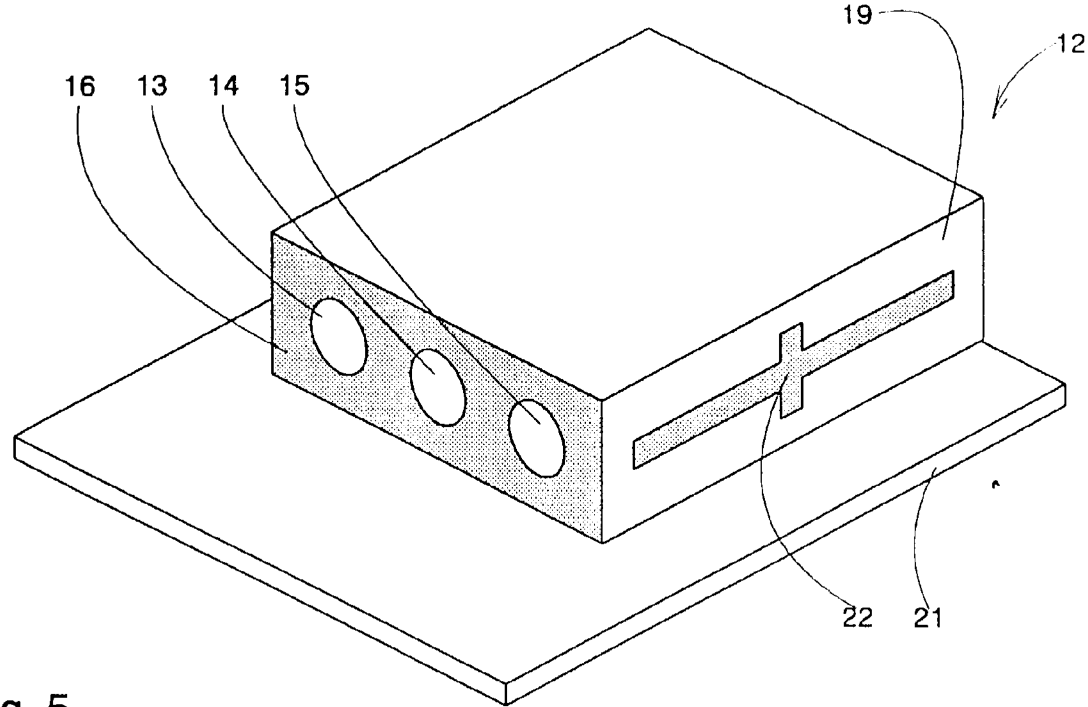


Fig. 5

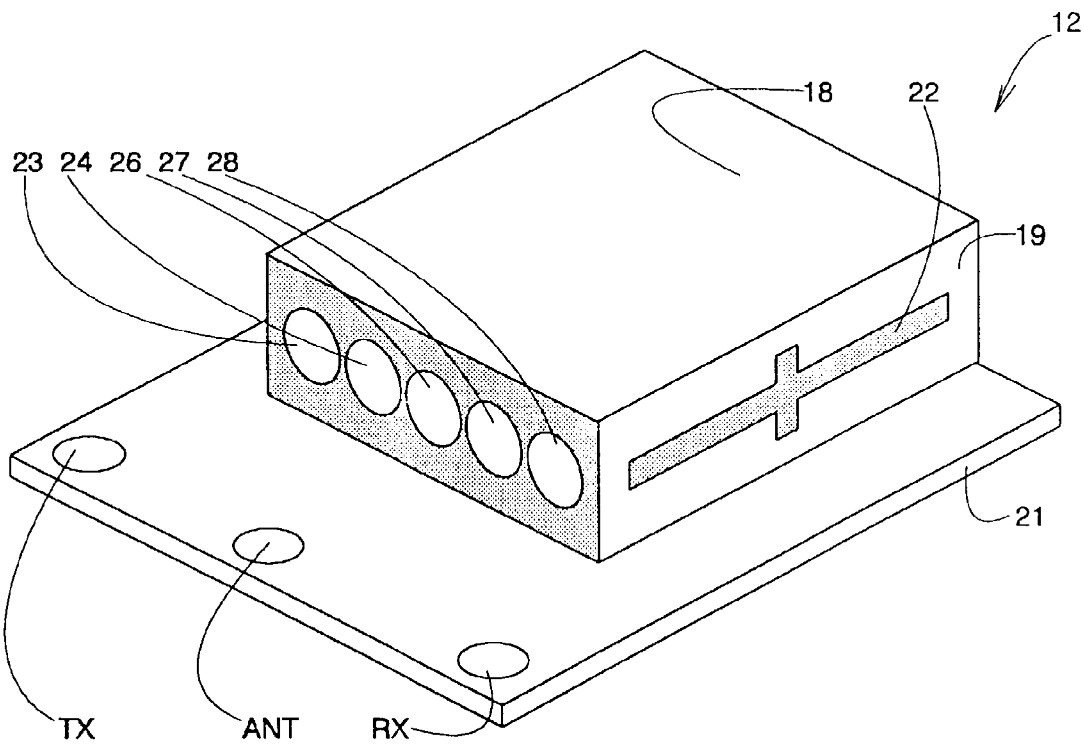
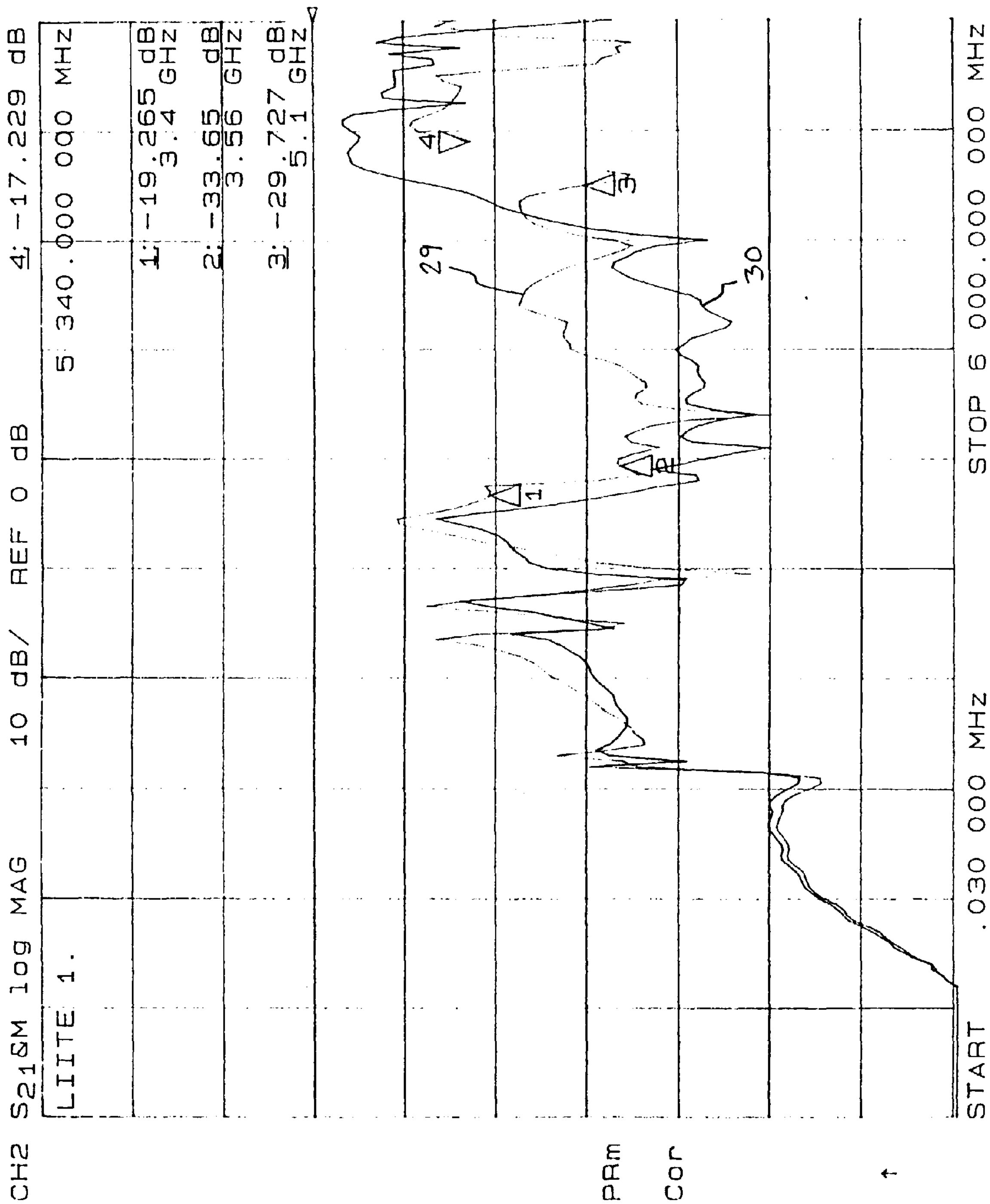


Fig. 6

Fig. 7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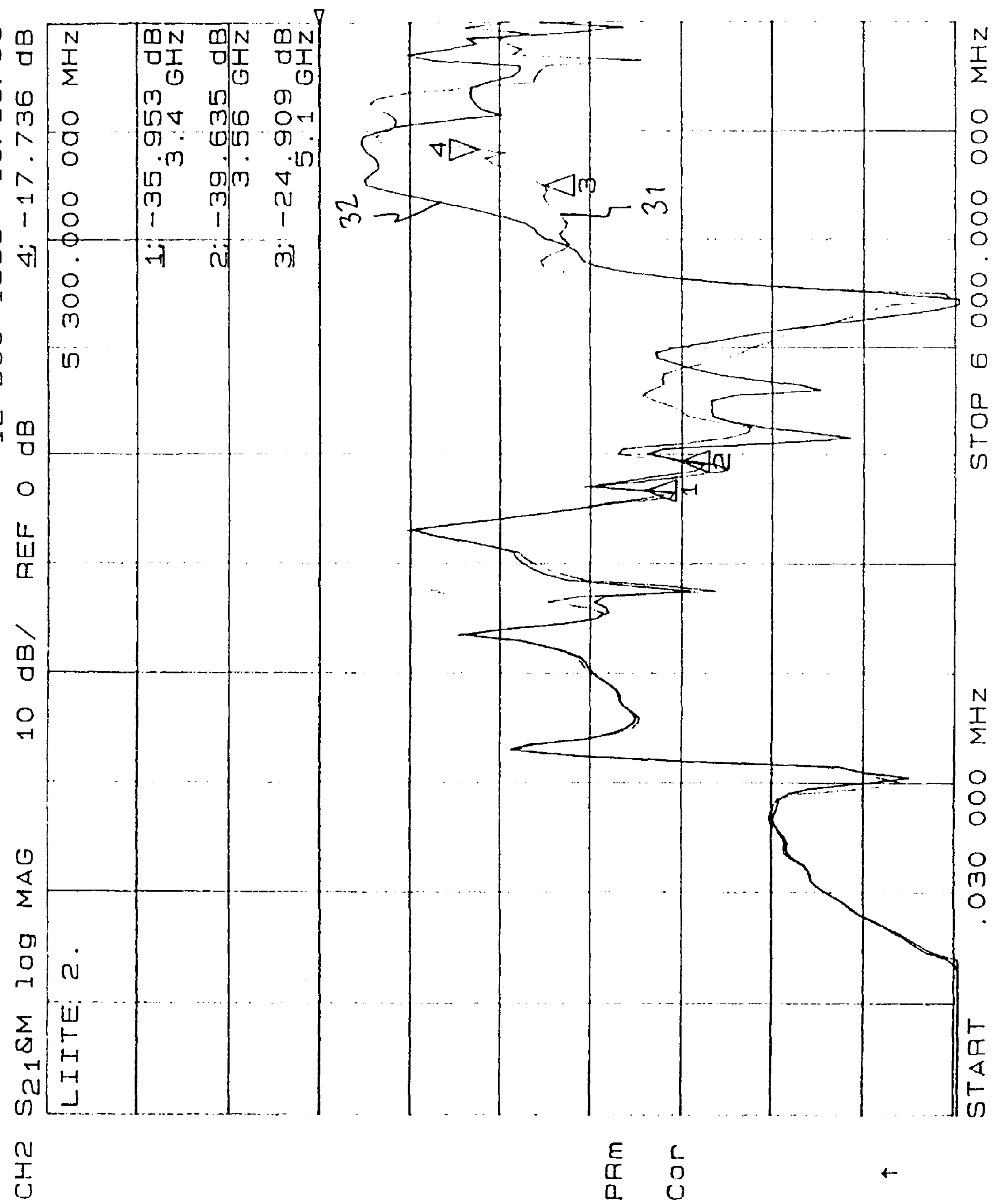
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Fig. 8

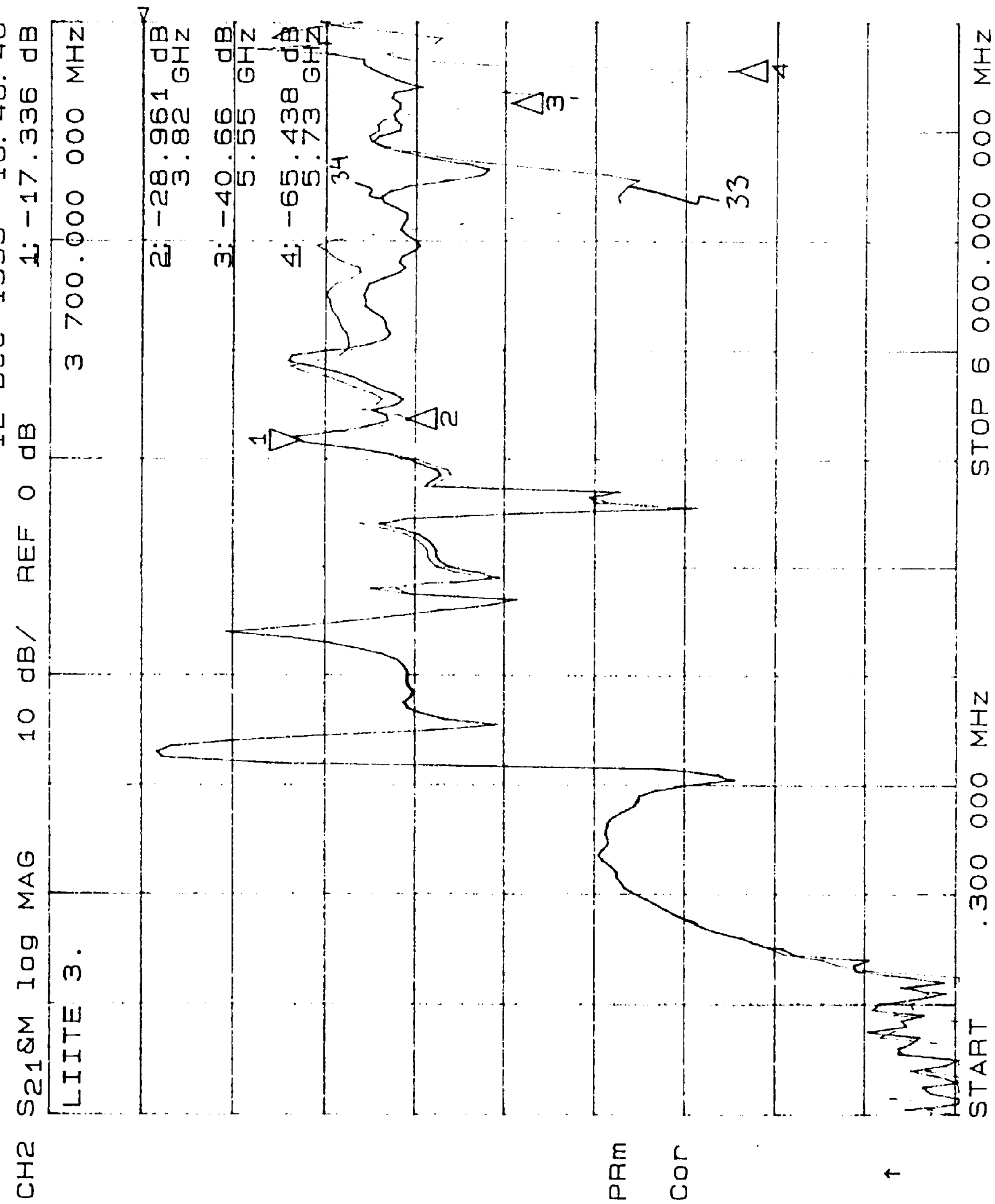
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Fig. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 0227

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	1987 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM-DIGEST, 9 - 11 June 1987, LAS VEGAS (US), pages 383-386, XP002030374 Y. ISOTA ET AL.: "A grooved monoblock comb-line filter suppressing the third harmonics " * page 383, right-hand column, line 1 - page 384, left-hand column, line 5; figure 1 * ---	1	H01P1/205 H01P7/04 H01P1/212
A	EP 0 524 011 A (MATSUSHITA ELECTRIC IND. CO. LTD.) * column 9, line 21 - line 40 * * column 11, line 52 - column 12, line 19; figures 7,12 * ---	1	
A	US 5 436 602 A (MCVEETY ET AL.) * column 2, line 21 - line 65; figure 1 * ---	1,2,5,13	
A	PATENT ABSTRACTS OF JAPAN vol. 8, no. 239 (E-276) [1676] , 2 November 1984 & JP 59 119901 A (FUJITSU K.K.), 11 July 1984, * abstract * ---	1,2,5,8, 10,13	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01P
A	EP 0 645 836 A (NGK SPARK PLUG CO LTD) * column 1, line 8 - line 47 * * column 3, line 23 - line 52; figures 2,5 * ---	1,13	
P,X	EP 0 743 696 A (MURATA MANUFACTURING CO. LTD.) * the whole document * -----	1,12,13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 April 1997	Den Otter, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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