PATENT SPECIFICATION

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(54) MICROWAVE BAND-PASS FILTER PROVIDED WITH DIELECTRIC RESONATOR

(71) We, MURATA MANUFACTURING CO., LTD., a Japanese Body Corporate, of 16 Nishijin-cho, Kaiden, Nagaokakyo-shi, Kyoto-fu, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to a microwave filter and particularly, but not exclusively, concerns an improved type of microwave band-pass filter provided with at least one dielectric resonator and at least one adjusting screw for adjusting the resonance characteristics of the filter in the region higher than the resonance frequency thereof, thus improving the sensitivity of the microwave band-pass filter.

It is well known that a microwave band-pass filter utilizes one or more resonators made of dielectric material for improving the quality factor Q of a dominant mode to be filtered. However, conventionally, in a filter employing the dielectric resonator, a sensitivity of the filtering effect, referred to as sensitivity characteristics hereinbelow, does not result in a symmetrical feature, that is, the wave shape of the sensitivity characteristics above the resonance frequency f_0 is different from that of the sensitivity characteristics below the resonance frequency f_0, as shown in Fig. 1 in which the abscissa and the ordinate represent frequency and attenuation, respectively. In most of the cases, the sensitivity characteristics in a region A which is below the resonance frequency f_0 shows a comparatively rapid set up of a dominant mode, while, on the other hand, the sensitivity characteristics in a region B which is above the resonance frequency shows a slow fadeout of the dominant mode.

It has been found that such difference in the filtering effect between the regions A and B is caused by the variation of coupling coefficient between the neighbouring resonators, or otherwise by the overlap of undesirable mode appearing close to the resonance frequency f_0 in the region B onto the dominant mode.

In order to eliminate such difference, one method is to construct the resonators with different material or in a different size from each other for matching the coupling coefficient. However, this method is comparatively difficult, since it takes much skill and time before obtaining a well balanced filter without any variation of coupling coefficient between the neighbouring resonators.

Another method is to provide an auxiliary dielectric resonator adjacent the dielectric resonator for producing antiresonance in the region B for improving the wave shape of the sensitivity in the region B. However, this method is not only difficult to accomplish, but also involves high manufacturing cost.

The present invention is based on a fact that the positioning of a suitable member in a region where the intensity of an electric field produced by a resonance mode at frequency f_1 is high, causes the resonance frequency to shift from f_1 to $f_1-\Delta f$. The reduction in resonance frequency Δf is determined by the degree of intrusion of the member into the electric field; i.e. Δf increases as the intrusion increases.

It has been found that the intensity of electric field due to the dominant mode of resonance is low around the side surface of the dielectric resonator, while the intensity of the electric field due to the spurious mode of resonance is high in this region.

Accordingly, the present invention provides a microwave filter comprising;

an electrically shielded casing;

input and output means for the propagation of microwaves along a path defined within the casing between the input and output means;

at least one dielectric resonator disposed within said casing between said input and output means and electrically insulated from said casing and spaced from the internal surface of said casing, said resonator having opposite end surfaces adjacent which, in use, the electric field due to the dominant mode of resonant vibration is high and a side surface adjacent which, in use, the electric field due to a spurious mode of resonant vibration is concentrated; said resonator having an axis through said end surfaces directed transverse to the direction of said path;

at least one member provided adjacent and at the side of said dielectric resonator where the intensity of the electric field produced, in use, by said spurious mode is high, reducing the frequency of said spurious mode to cause the spurious mode characteristic to overlap the dominant mode characteristic for improving the overall sensitivity characteristic of the filter.

The member may be an adjusting screw adjustably threaded through the wall of the casing to facilitate adjustment of the intrusion of the member into the region of high electric field intensity of the spurious mode.

By providing the adjusting screw closely adjacent the dielectric resonator, the resonance frequency of a spurious mode can be shifted from f_1 to $f_1-\Delta f$, which frequency $f_1-\Delta f$ slightly smaller than the frequency f_0 of the dominant mode. Thus, the wave shape of the spurious mode is made to overlap with that of the dominant mode, especially in the region A. The shifted spurious mode causes the sensitivity characteristics of the dominant mode to drop more rapidly in the region B. The wave shape in the region B thus becomes steeper, and substantially symmetrical with the wave shape in the region A. Furthermore, the quality factor Q of the filter is improved.

Some preferred embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Fig. 1 is a drawing referred to the foregoing description and particularly showing the sensitivity characteristic of the conventional band-pass filter employing the dielectric resonator;

Fig. 2 is a perspective view of a band-pass filter of the present invention partly broken to show the arrangement of adjusting screws in relation to the dielectric resonators employed therein;

Fig. 3(a) is a sectional side view taken along the line III(a)—III(a) of Fig. 2;

Fig. 3(b) is a sectional front view taken along the line III(b)—III(b) of Fig. 3(a);

Figs. 4(a) to 4(e) are graphs showing the manner in which the wave form of the spurious mode overlaps with the same of the dominant mode and the way in which the wave form of the dominant mode changes with respect to the shift of the same of the spurious mode.

Fig. 5 is a fragmentary top plan view of the microwave band-pass filter shown in Fig. 2, particularly showing a horizontal range within which the adjusting screw can be provided; and

Fig. 6 is a sectional side view of the microwave band-pass filter shown in Fig. 2, particularly showing a vertical range within which the adjusting screw can be provided.

Before the description of the preferred embodiments proceeds, it should be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

Referring first to Fig. 2, a microwave band-pass filter according to the present invention comprises a casing 10 of substantially box-like configuration made of any known metallic material such as brass, which casing 10 includes top and bottom coverings 10a and 10b, a pair of opposed side walls 10c and 10d and a pair of end walls 10e and 10f. Although the walls 10a to 10f are shown as integrally formed together by machining a rigid metal block, the walls may be formed by metallic sheets of plates with the neighboring walls being rigidly connected to each other, by the use of, for example, a plurality of set of screws.

Within the casing 10, one or more resonators, which are shown in three in number and indicated by 11a, 11b and 11c, are mounted on the bottom covering 10b through respective supporting spacers 12a, 12b and 12c and arranged in spaced and side-by-side relation with each other in a row. The supporting spacers 12a to 12c are made of any known electrically insulating material of relatively low dielectric constant.

One of the opposed side walls 10c is provided at respective portions adjacent to the opposed ends thereof with couplers 15a and 15b for respective connection with coaxial cables for microwave input and output transmission lines (not shown). These couplers 15a and 15b have axial terminals which are electrically insulated from the metal casing 10 and which are respectively connected with rods or probes 16a and 16b made of either electrically conductive material or dielectric material. The probes 16a and 16b in the instance as shown in Fig. 2 extend in parallel relation to any of the end walls 10e and 10f and respectively between the end wall 10e and the end resonator 11a and between the end wall 10f and the end resonator 11c. One of the opposed ends of each of the probes 16a and 16b, which is remote from the corresponding coupler 15a or 15b, is supported by the side wall 10d by means of a mounting piece 17a or 17b made of electrical insulating material such as polytetrafluoroethylene. The size of the casing 10, particularly of the inner side thereof is arranged in a certain size to have a predetermined cutoff frequency.

With particular reference to Figs. 3 and 4, there are shown details of the microwave band-pass filter of the present invention. The description hereinbelow is particularly directed to the first resonator 11a provided at most left-hand side as viewed in Fig. 2, however, it is to be noted that other resonators 11b and 11c are formed in the same manner and have the same structure as the resonator 11a. The dielectric resonator 11a is made of a cylindrical block of any known dielectric material. The size of the cylindrical block is such that the diameter D thereof is a few centimeters, for example, in one type 1.45 cm, the thickness T thereof is about half the size of the diameter D and is determined by the resonance frequency. Such resonator as described above is fixedly bonded onto the cylindrical supporting spacer 12a which is in turn fixedly bonded onto the bottom covering 10b. The height of the supporting spacer 12a is such that the center of the resonator 11a bonded onto the spacer 12a matches with the center of a depth A of the casing 10. The inner dimensions of the casing 10 are such that the depth A is arranged within a range of 2T to 3T, while the width E, corresponding with the extending direction of the probes 16a and 16b, is arranged within a range of 2D to 3D. The distance measured along the longitudinal direction of the casing 10 is determined by the number of the resonators to be placed in the casing 10.

Still referring to Fig. 3, the three resonators 11a, 11b and 11c are spaced apart from each other in a distance M which is normally arranged within a range of D/2 to D, while the distance between the resonator 11a and the probe 16a and the distance between the resonator 11c and the probe 16b are both arranged to be M/2. Each of the probes 16a and 16b is spaced apart from the end walls 10e and 10f, respectively, at a distance arranged within a range of B to 3B in which B is a diameter of the probe. It is to be noted that the axis of the probes 16a and 16b are in alignment with the center of the resonators.

Referring back to Fig. 2, the casing 10 is further provided with screws 13a, 13b and 13c, made of metal which are, respectively, threaded through screw holes 14a, 14b and 14c provided in the front side wall 10c. The screw holes 14a, 14b and 14c are arranged at places approximately half the height of the side wall 10c and are spaced apart from each other in a predetermined distance, so that the tip end of each of the screws locates closely adjacent the side surface of the resonator. Preferably, each of the screw extends with the tip end thereof aligned with a center of the respective resonator. A clearance G formed between the tip end of each of the screws and the surface of the respective resonators can be adjusted upon turning the screws. Normally, the clearance G is adjusted not less than 0.3 mm.

It should be noted that the screws 13a, 13b and 13c described as being made of metal can alternatively be made of dielectric material. In other words, the screws can be any type of material provided that they can influence the electric field or magnetic field generated in the casing.

The function of the foregoing screws 13a, 13b and 13c is described hereinbelow in connection with graphs shown in Figs. 4(a) to 4(e).

When the microwave band-pass filter is constructed with the use of dielectric resonators 11a, 11b and 11c, the dominant mode of resonance is $H_{01\delta}$ while the resonance frequency is determined to be f_0[GHz], for example, 7GHz. It is to be noted that the dominant mode as well as the resonance frequency may be changed, with respect to the change of size of the casing 10 and each of the resonators. In the case where the microwave band-pass filter is not provided with the adjusting screws, the wave form of the dominant mode $H_{01\delta}$ gradually droops down in a frequency region between 7 and 8GHz. At the same time, there is produced a spurious mode $E_{11\delta}$ at frequency of f_1[GHz] which is, for example, approximately in a frequency region of 9GHz. Upon providing the screws 13a, 13b and 13c into respective screw holes, the screws of conductive material influence the electric field produced by the spurious mode, so that the spurious mode $E_{11\delta}$ is gradually shifted towards a smaller frequency region where the dominant mode $H_{01\delta}$ exists, in relation to the amount of insertion of the screws into the casing 10. When each of the screws is threaded in about a half the distance between the side wall 10c and the surface of the resonator, the wave form of the spurious mode $E_{11\delta}$ overlaps with the wave form of the dominant mode $H_{01\delta}$ and deforms the wave form of the dominant mode $H_{01\delta}$, thus the wave form of the dominant mode $H_{01\delta}$ resulting in a shape as shown in Fig. 4(c). As is seen in Fig. 4(c), the wave form of the dominant mode $H_{01\delta}$ droops more rapidly than those wave forms shown in Figs. 4(a) and 4(b).

When the screws are further threaded into the respective screw holes, the spurious mode $E_{11\delta}$ further moves towards a smaller region, for example to a region below 7GHz, whereupon the curve of the dominant mode $H_{01\delta}$ shows further rapid drop down in the region higher than 7GHz.

When the screws are threaded in, to have the distance G as small as 0.3mm, then, the spurious mode $E_{11\delta}$ is shifted to a region close to 6GHz, whereupon the curve of the dominant mode $H_{01\delta}$ substantially drops down linearly in the region higher than 7GHz.

Accordingly, by providing the screw closely adjacent the side face of the resonators where there is produced high intensity of electric field by the spurious mode, the wave shape of the dominant mode in the higher region thereof rapidly drops down, so that it is possible to construct the microwave band-pass filter which operates with accuracy through a simple construction as described above with comparatively low manufacturing cost.

Although the resonance frequency of the dominant mode may be shifted slightly towards above a predetermined frequency, in response to the insertion of the screws 13a, 13b and 13c, such shift in the resonance frequency can be simply corrected by any known correcting means such as correcting screws (not shown) provided on top of each of the resonators.

It is to be noted that the screws may be replaced with bars or rods made of conductive or dielectric material such as metal or synthetic resin. In this case the bars or rods are preferably arranged with means for adjusting the degree of insertion of the bars or rods into the respective openings provided therefor in the casing.

It is also to be noted that the screws may be displaced from the above described position in relation to the resonator and yet obtaining the same effect as described above. The degree of displacement is described hereinbelow in connection with Figs. 5 and 6.

Any one of the screws may be displaced, as shown in Fig. 5, along the longitudinal direction of the casing 10 within a range of D which is equal to the diameter of the resonator, while, on the other hand, any one of the screws may be displaced, as shown in Fig. 6, along the height of the casing 10 within a range of 2T.

It is further to be noted that the adjusting screw described as provided to have the tip end thereof located closely adjacent the dielectric resonator may be provided to have the tip end thereof in contact with the dielectric resonator.

It is still further to be noted that the number of the adjusting screw is not limited to one, but it is possible to provide more than one adjusting screws for each of the dielectric resonators.

Although the present invention has been fully described by way of example in connection with preferred embodiment thereof, it should be noted that various changes and modifications are apparent to those skilled in the art. By way of example, the microwave band-pass filter of the present invention is not restricted only to the one referred to above, but other types of microwave band-pass filters such as microstrip filters and waveguide filters which employ the dielectric resonators are construed as included in the present invention. In employing the dielectric resonators in other types of microwave band-pass filters such as waveguide, the input and output for the microwave path therethrough may be formed by merely openings at opposite ends of the path instead of input and output terminal means such as probes described above. In addition, even in the embodiment shown in Fig. 1, the adjusting screws may be modified to take any other forms such as plate form or cylindrical form, while the adjusting screws may either be insulated from the casing 10 or electrically connected to the casing 10.

WHAT WE CLAIM IS:—

1. A microwave filter comprising:

an electrically shielded casing;

input and output means for the propagation of microwaves along a path defined within the casing between the input and output means;

at least one dielectric resonator disposed within said casing between said input and output means and electrically insulated from said casing and spaced from the internal surface of said casing, said resonator having opposite end surfaces adjacent which, in us' the electric field due to the dominant mode of resonant vibration is high and a side surface adjacent which, in use, the electric field due to a spurious mode of resonant vibration is concentrated; said resonator having an axis through said end surfaces directed transverse to the direction of said path;

at least one member provided adjacent and at the side of said dielectric resonator where the intensity of the electric field produced, in use, by said spurious mode is high, for reducing the frequency of said spurious mode to cause the spurious mode characteristic to overlap the dominant mode characteristic for improving the overall sensitivity characteristic of the filter.

2. A microwave filter as claimed in Claim 1, wherein said input and output means are input and output terminal members extending from the outside of said casing into the interior of said casing, the portions of said terminal members disposed within said interior of said casing being mutually spaced.

3. A microwave filter as claimed in Claim 1, wherein said member is an adjusting screw member adjustably threaded through the wall of said casing and having one end

within the casing situated adjacent the resonator.

4. A microwave filter as claimed in Claim 3, wherein said adjusting screw member is made of conductive material.

5. A microwave filter as claimed in Claim 3, wherein said adjusting screw member is made of dielectric material.

6. A microwave filter as claimed in Claim 3, wherein said adjusting screw member extends with said one end centrally aligned with said dielectric resonator.

7. A microwave filter as claimed in Claim 6, wherein said one end of said adjusting screw member is spaced a predetermined distance from said dielectric resonator for forming a clearance between said dielectric resonator and said one end of said screw member.

8. A microwave filter as claimed in Claim 7, wherein said clearance is not less than 0.3 mm.

9. A microwave filter substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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FIG. 1

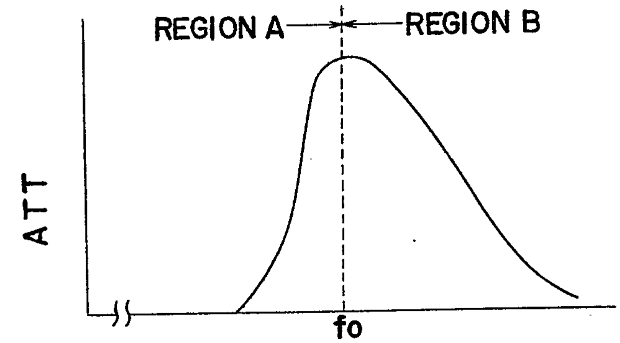

FIG. 2

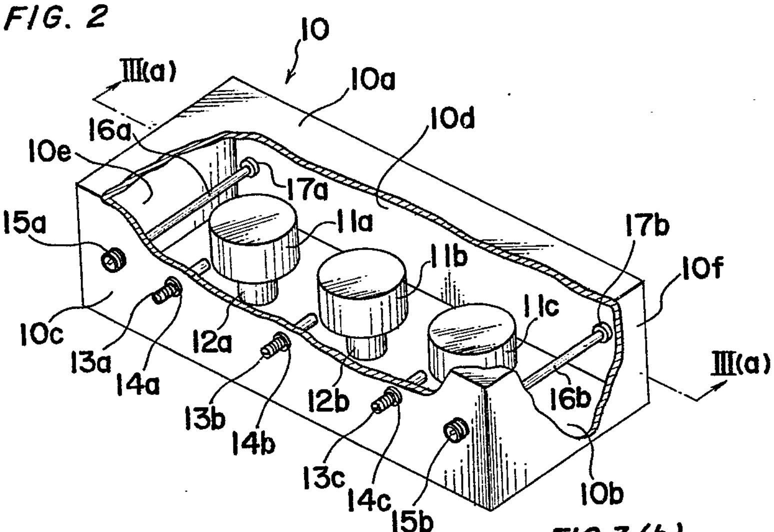

FIG. 3 (a)

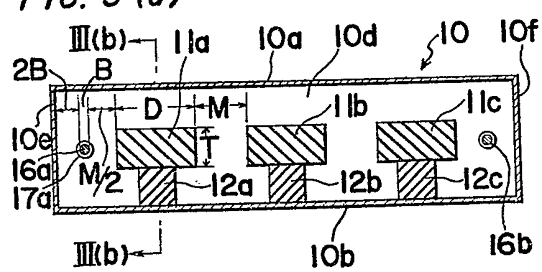

FIG. 3 (b)

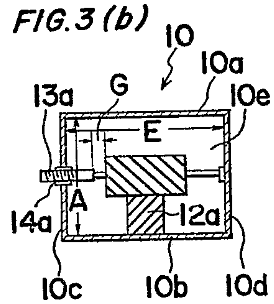

FIG. 4 (a)

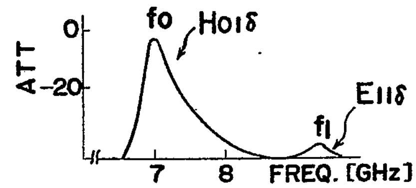

FIG. 4 (b)

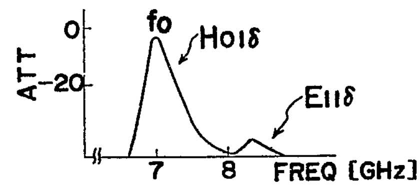

FIG. 4 (c)

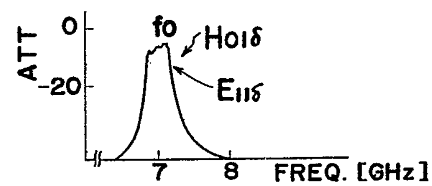

FIG. 4 (d)

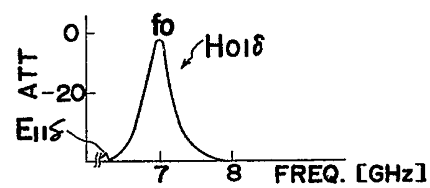

FIG. 4 (e)

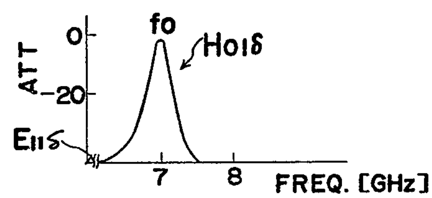

FIG. 5

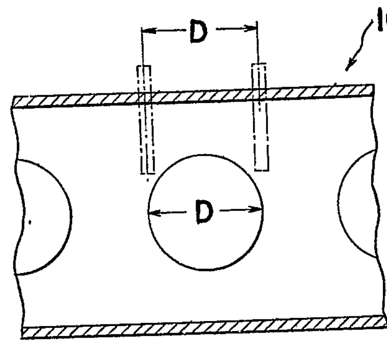

FIG. 6