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(54) Multimode dielectric resonator apparatus, filter, duplexer, and communication apparatus
Multimodales dielektrisches Resonatorgerät, Filter, Duplexer, und Kommunikationsgerät
Dispositif résonateur multimode à diélectrique, filtre, duplexeur, et dispositif de communication

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(56) References cited:

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a multimode dielectric resonator apparatus that operates in multiple resonant modes, to a filter and a duplexer therewith, and to a communication apparatus therewith.

2. Description of the Related Art

[0002] Conventionally, a dielectric resonator having a dielectric core arranged in a cavity uses a mode such as a TE01σ mode or a TM01σ mode. In a configuration of a multistage dielectric resonator apparatus formed using the aforementioned dielectric resonators, a plurality of the dielectric cores is therefore provided in a cavity.

[0003] In the aforementioned configuration using the single resonant mode generated in the single dielectric core, however, the overall size thereof is increased proportionally to the increase in the number of resonators. In addition, the plurality of dielectric cores must be positioned and fixed with high accuracy. This causes difficulties in the manufacture of dielectric resonator apparatuses, such as dielectric filters, having consistent characteristics.

[0004] As is disclosed in Japanese Unexamined Patent Application Publication No. 11-145704, the present applicant submitted a patent application regarding a dielectric resonator apparatus in which, while a single dielectric core is used, the multiplex number is increased. In the dielectric resonator apparatus according to the above application, an arrangement is made such that, when resonant spaces are represented by x, y, and z rectangular coordinates, TMx, TMy, and TMy modes in which electric-field vectors form loops in the plane directions perpendicular to the individual x, y, and z axes, and TEy, TEz, and TEx modes in which electric-field vectors form loops in the plane directions perpendicular to the individual x, y, and z axes are generated, and at most six modes can thereby be used.

[0005] In the multimode dielectric resonator apparatus according to the above-described patent application, to couple predetermined resonant modes to each other, either grooves or an opening are provided in a portion in which electric fields of two modes that will be coupled together are concentrated, perturbations are applied to the portion, and energy is thereby transferred between the two resonant modes. However, when the TM mode and the TE mode are coupled together in the described construction, the two modes contact perpendicular to each other, secure coupling cannot be easily obtained. The coupling grooves or openings must be deeply formed to obtain secure coupling therebetween. However, since electric-field distributions of the individual resonant modes are thereby diverged, problems are caused in that the resonant frequencies are increased, and in addition, modulation of their filter characteristics is difficult.

[0006] WO 99/12225 discloses a multimodal dielectric resonance device having dielectric cores that resonate in a plurality of modes, including one TM-mode and two TE-modes. However, this document does not contain any specific disclosure as to the frequencies of the respective TM-mode and TE-mode resonances. The cores are arranged in a symmetrical manner with regard to the conductive cavity of the device.

[0007] In view of the above, an object of the present invention is to provide a multimode dielectric resonator apparatus that allows TE modes and TM modes to be securely coupled to each other without increasing the resonant frequencies and that allows characteristic modulation to be easily implemented.

[0008] Another object of the invention is to provide a filter using the aforementioned multimode dielectric resonator apparatus.

[0009] Still another object of the invention is to provide a duplexer that uses the aforementioned multimode dielectric resonator apparatus.

[0010] Still another object of the invention is to provide a communication apparatus using the above.

[0011] According to one aspect of the present invention, a multimode dielectric resonator apparatus is configured in a dielectric resonator apparatus formed by arranging a dielectric core in a conductive cavity. The dielectric core is configured of a TM-mode dielectric core portion for primarily determining resonant frequencies of TM modes so that at least one of the TM modes resonates in an operating frequency band, and other TM modes resonate at frequencies higher than the operating frequency band; and a TE-mode dielectric core portion for primarily determining resonant frequencies of TE modes so that the individual TE modes of a multi-TE mode resonate in the operating frequency band. Either the shapes of the TM-mode dielectric core portion and the TE-mode dielectric core portion or support structures therefor are arranged asymmetrically, and predetermined TM modes and TE modes are coupled to each other so that, in areas where electric fields of the predetermined TM-modes are distributed, TE-mode electric fields having the same directional components as those of the electric fields of the TM modes are generated.

[0012] As described above, although neither grooves nor openings for coupling the TM modes and the TE modes are not provided, secure coupling can be obtained according to the arrangement in which the TM modes and the TE modes are coupled together without causing their resonant frequencies to increase. In addition, characteristic modulation can be easily implemented according to the arrangement made such that divergences that can be caused by the coupling grooves or openings in electric-field distributions in the individual modes are reduced; that is, according to the arrangement made such that the coupling structures between
the TM modes and the TE modes do not influence other resonant modes, characteristic modulation can be easily implemented.

[0013] In the multimode dielectric resonator apparatus, the TM-mode dielectric core portion is formed to have a plate-like shape, the TE-mode dielectric core portion is formed to have a shape protruding from an upper face and a lower face of the plate-like portion. Also, the TM-mode dielectric core portion and the TE-mode dielectric core portion are arranged to be asymmetric according to the difference between the upper-side protruding amount and the lower-side protruding amount. According to this construction, the asymmetry can be easily arranged therefor, TM-mode electric-field distribution areas and TE-mode electric-field distribution areas can be separated to be relatively clear, and the design procedure can therefore be simplified.

[0014] Also, dielectric members for supporting the TM-mode dielectric core portion and the TE-mode dielectric core portion in the cavity are arranged asymmetric to the dielectric core. Thereby, the support structures of the TM-mode dielectric core portion and the TE-mode dielectric core portion are arranged to have the asymmetry. According to the asymmetry thus arranged using the support members that support the dielectric core into the cavity, the dielectric core is arranged to be asymmetric, so that the manufacture thereof can be facilitated. In addition, the divergences in the electromagnetic-field distributions in other modes can be minimized.

[0015] In addition, in the multimode dielectric resonator apparatus, the TM-mode dielectric core portion and the TE-mode dielectric core portion are independently supported in the cavity, either the position of one of the dielectric core portions or the positions of the two dielectric core portions are determined, and the TM-mode dielectric core portion and the TE-mode dielectric core portion are thereby arranged to have the asymmetry. According to this construction, the relative positional relationship between the TM-mode dielectric core portion and the TE-mode dielectric core portion and the positions thereof in the cavity can be determined after the apparatus is assembled. Alternatively, the intensity of coupling between the TM modes and the TE modes can be determined in a wide range at the time of assembly of the multimode dielectric resonator apparatus; and the coupling adjustment thereof can be implemented. In addition, by coupling TM modes and TE modes according to other forms of asymmetry, indirect coupling can be easily implemented among a plurality of multimode resonators sequentially coupled to each other.

[0016] Furthermore, the TE-mode dielectric core portion is provided in a position deviating from the center of the plate-like portion, which is the TM-mode dielectric core portion, in the face direction of the plate-like portion, thereby imparting the asymmetry thereto. According to this construction, TE modes in which electric-field vectors form an electric-field loop along the face of the plate-like portion, which is the TM-mode dielectric core portion, are coupled to TM modes in which electric-field vectors extend perpendicular to the direction in which the TE-mode dielectric core portion is deviated.

[0017] Also, in the multimode dielectric resonator apparatus, the dielectric core is provided in a position deviating from the center of the cavity in the face direction of the plate-like portion, which is the TM-mode dielectric core portion, thereby imparting the asymmetry thereto. According to this construction, the asymmetry of electric-field vectors in TM modes in the TM-mode dielectric core portion are deformed, and perturbations are generated between the TM modes and TE modes forming a loop in the face direction of the plate-like portion, thereby allowing the modes to be coupled together. Also, the position of the TE-mode dielectric core portion in the face direction of the plate-like TM-mode dielectric core portion can be arranged to be in a symmetric shape. Therefore, the manufacture can be facilitated, and in addition, the divergences in electromagnetic fields of other resonant modes can be minimized.

[0018] According to another aspect of the present invention, a filter comprises the multimode dielectric resonator apparatus having the above-described construction, and input/output means coupled to predetermined resonant modes in the multimode dielectric resonator apparatus. According to this construction, the filter can be formed as a small and low-loss-type filter according to the multiple stages of resonators while it uses the single dielectric core and the single cavity.

[0019] According to still another aspect of the invention, a filter comprises the above-described multimode dielectric resonator apparatus, either coaxial resonators or semicoaxial resonators that are coupled to predetermined modes, and input/output means coupled to the aforementioned resonators. According to the above-described construction, external coupling is made for either the semicoaxial resonators or the coaxial resonators, and secure coupling is thereby obtained according to coupling loops to increase the band range. In addition, a spurious mode according to the aforementioned multimode dielectric resonator is minimized according to either the semicoaxial resonators or the coaxial resonators, and the entire spurious-mode characteristics are thereby decreased. Furthermore, the semicoaxial resonators nor the coaxial resonators need to be securely coupled to the multimode dielectric resonator. Therefore, the input/output means in the multimode dielectric resonator portion can be miniaturized, direct passage of signals between the input and the output can be reduced, and in addition, deterioration in characteristics due to the direct passage can thereby be prevented.

[0020] According to still another aspect of the invention, a duplexer comprises two sets of the aforementioned filter. According to this construction, the duplexer can be small as a whole and can be a low-loss type. The duplexer thus formed can be used as an antenna-sharing unit.
BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing a basic configuration of a multimode dielectric resonator apparatus according to a first embodiment; FIG. 2A is an upper view of the multimode dielectric resonator apparatus in FIG. 1, and FIG. 2B is a cross-sectional view thereof; FIGS. 3A to 3E show electric-field distributions in individual modes; FIGS. 4A and 4B show states of coupling between a TMx mode and a TEy mode; FIG. 5 is a graph showing the relationship between the amount of deviation of a spherical portion forming a TE-mode dielectric core portion with respect to a plate-like portion and the coupling relationship between TM modes and TE modes; FIGS. 6A and 6B show the relationship between a TM-mode dielectric core portion and a TE-mode dielectric core portion; FIGS. 7A and 7B show an example shape of the TE-mode dielectric core portion; FIGS. 8A and 8B show another example shape of the TE-mode dielectric core portion; FIGS. 9A and 9B show still another example shape of the TE-mode dielectric core portion; FIGS. 10A and 10B show still another example shape of the TE-mode dielectric core portion; FIGS. 11A and 11B show still another example shape of the TE-mode dielectric core portion; FIGS. 12A and 12B show still another example shape of the TE-mode dielectric core portion; FIG. 14 shows an example support structure for a dielectric core in a cavity; FIGS. 15A and 15B show an example filter using a quintuple mode resonator configured of the individual modes sequentially coupled to each other; FIGS. 16A to 16D show states of coupling between TEx modes and TEz modes; FIGS. 17A to 17D show example filters using other quintuple mode resonators; FIGS. 18A and 18B show states of coupling between a TEz mode and a TEx mode; FIGS. 19A to 19D show example filters using other quintuple mode resonators; FIGS. 20A and 20B show states of coupling between a TEz mode and a TEx mode; FIGS. 21A and 21B show other example support structures for a dielectric core in a cavity; FIGS. 22A and 22B show views showing example configurations of filters individually using semicoaxial resonators and the quintuple mode resonator; FIG. 23 shows an example configuration of a duplexer; and FIG. 24 is a block diagram showing a configuration of a communication apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 to 6B, a description will be given of a configuration of a multimode dielectric resonator apparatus according to a first embodiment of the present invention.

In FIG. 1, support members for supporting the dielectric core 10 in the cavity 2 and input/output means that perform input and/or output of signals with the outside have been omitted to clearly show the arrangement of the structure of the dielectric core 10 in the cavity.

The dielectric core 10 is formed of a plate-like TM-mode dielectric core portion 11 and a TE-mode dielectric core portion 12 spherically protruding from the TM-mode dielectric core portion 11. The dielectric core 10 is formed such that conductive films are formed on peripheral surfaces of a ceramic four-sided housing-like member. On upper and lower opening faces of the cavity 2 in the figure, either dielectric plates or metal plates on which conductive films are formed, and a substantially parallelepiped shield space is thereby formed. In FIG. 1, support members for supporting the dielectric core 10 in the cavity 2 and input/output means that perform input and/or output of signals with the outside have been omitted to clearly show the arrangement of the structure of the dielectric core 10 in the cavity.

Referring to FIGS. 1 to 6B, a description will be given of a configuration of a multimode dielectric resonator apparatus according to a first embodiment of the present invention.

In FIG. 1, support members for supporting the dielectric core 10 in the cavity 2 and input/output means that perform input and/or output of signals with the outside have been omitted to clearly show the arrangement of the structure of the dielectric core 10 in the cavity.
shows a TEx mode. In the TEz mode, electric-field vectors form a loop in the plane direction perpendicular to the y-axis; and in addition, electric-field vectors form a loop in the plane direction perpendicular to the x-axis. 

A TMz mode in which electric-field vectors extend along the z-axis is also generated. However, since a dimension in the thickness direction of the plate-like TM-mode dielectric core portion 11 is smaller than dimensions in other directions, the resonant frequency of the TMz mode is increased higher than resonant frequencies of the other modes, i.e., the operating frequency band.

FIGS. 4A and 4B show states of coupling the above-described TMy mode and TEy mode. Arrows indicated in the figure with curved lines represent electric-field vectors. When the mode shown in Fig. 4A is assumed to be an even mode, and the mode shown in Fig. 4B is assumed to be an odd mode, since the protruding amount of the spherical TE-mode dielectric core portion 12 with respect to the plate-like TM-mode dielectric core portion 11 is asymmetric, perturbations are applied to electric-field intensity distributions in the TMx mode and the TEy mode. Accordingly, energy is transferred between the TMx mode and the TEy mode, and the two modes are coupled together.

Examples in FIGS. 4A and 4B show views regarding a cross section of the xy plane extending through the center of the dielectric core 10. However, the electric-field vectors in the TMx mode and the TEx mode form similar patterns also on a cross section of the xy plane extending through the center of the dielectric core 10. This allows the TMx mode and the TEx mode to be similarly coupled together.

FIG. 5 shows the relationship in the amount of deviation of the spherical portion, which is the TE-mode dielectric core portion 12, with respect to the plate-like portion, which is the TM-mode dielectric core portion 11, to the z-axis direction and the coefficient of coupling between the aforementioned TM and TE modes. In proportion to increase in the aforementioned deviation amount, the coupling coefficient regarding the two modes increases. Using this relationship, the aforementioned deviation amount is determined so as to meet a predetermined coupling coefficient.

Since electromagnetic fields in the described individual modes of the TM mode and the TE mode coexist in a central portion of the dielectric core 10, the central portion is the TM-mode dielectric core portion 11, and concurrently, the TE-mode dielectric core portion 12. To separate these two portions perfunctorily and completely, as shown in FIG. 6A, they can be separated into a plate-like TM-mode dielectric core portion 11 and two hemispherical TE-mode dielectric core portions 12a and 12b. Alternatively, as shown in FIG. 6B, they can be separated into a plate-like TM-mode dielectric core portion 11 having an opening in the central portion and a spherical TE-mode dielectric core portion 12 to be inserted therein. However, even in the case shown in FIG. 6A, TM-mode electric-field vectors extend to the TM-mode dielectric core portion 11, and even in the case shown in FIG. 6B, TE-mode electric-field vectors extend to the TE-mode dielectric core portion 12. It is to be noted that the individual TM-mode dielectric core portion 11 and the TE-mode dielectric core portion 12 according to the present invention are shared in the TM modes and the TE modes in the central portion of the dielectric core.

Hereinbelow, referring to FIGS. 7A to 12B, a description will be given of configurations of multimode dielectric resonator apparatuses using other dielectric cores having different shapes. In the individual figures, the figures having the reference symbol "A" attached thereto are upper views, and figures having the reference symbol "B" attached thereto are cross-sectional views thereof.

In an example shown in FIGS. 7A and 7B, a TE-mode dielectric core portion 12 is provided to have the shape as a stepped pyramid. That is, a four-sided pyramid-like base is formed in the upper-lower direction with steps from the TM-mode dielectric core portion 11. In an example shown in FIGS. 8A and 8B, a TM-mode dielectric core portion 12 having the shape of a four-sided pyramid formed to protrude on the upper and lower sides of the TM-mode dielectric core portion 11. In an example shown in FIGS. 9A and 9B, a TM-mode dielectric core portion 12 having the shape of a circular column formed to protrude on the upper and lower sides of the TM-mode dielectric core portion 11. In an example shown in FIGS. 10A and 10B, a TM-mode dielectric core portion 12 having the shape of a hexagonal column formed to protrude on the upper and lower sides of the TM-mode dielectric core portion 11. In an example shown in FIGS. 11A and 11B, a TE-mode dielectric core portion 12 having the shape of a hexagonal column is formed to protrude on the upper and lower sides of the TM-mode dielectric core portion 11. In an example shown in FIGS. 12A and 12B, a TM-mode dielectric core portion 12 having the shape of an octagonal column is formed to protrude on the upper and lower sides of the TM-mode dielectric core portion 11. Alternatively, a polyhedral protruded portion having the shape as a polyhedral column, a polyhedral pyramid, or a polyhedral trapezoid, may be provided as a TE-mode dielectric core portion.

With any one of these shapes, the plate-like TM-mode dielectric core portion 11 and the cavity 2 mainly function as a resonator in the TMx mode and the TMy mode; and the TE-mode dielectric core portion 12 mainly functions as a resonator in the TEx mode, TEy mode, and TEz modes. Also, the protruding amounts of the upper and lower portions of the TE-mode dielectric core portion 12 with respect to the TM-mode dielectric core portion 11 are arranged to be asymmetric. Thereby, coupling between the TMx mode and the TEy mode can be obtained concurrently with coupling between the TMy mode and the TEx mode.
views of types similar to that shown in FIG. 2B, and shows two example dielectric cores differing in the shape from each other. In the examples described above, the protruding amounts of the upper and lower portions of the TE-mode dielectric core portion 12 with respect to the TM-mode dielectric core portion 11 are determined, and predetermined dielectric cores 10 are formed. Alternatively, however, as shown in FIGS. 13A and 13B, the TE-mode dielectric core portion 12 may be a shape formed such that the TE-mode dielectric core portion 12 which is originally symmetric with respect to the TM-mode dielectric core portion 11 is partly removed, and the symmetry is thereby provided.

[0036] Hereinbelow, referring to FIGS. 15A and 15B, a description will be given of an example of FIG. 14 is a cross-sectional view of a type similar to that shown in FIGS. 2A and 2B. The example is such that support members 3' are fitted to a TM-mode dielectric core portion 11, and other support members 3 are used to support the portions between the cavity 2 and the support members 3'. According to this construction, the symmetry of the dielectric members existing on the upper and lower portions of the TM-mode dielectric core portion 11 is deformed, and electric fields of the individual resonant modes move to a side where many dielectric members exist. This allows the asymmetry to be arranged. Thereby, coupling is generated between the TMx mode and the TEy mode and between the TMy mode and the TMz mode. For this reason, the coupling amounts are determined according to the relative permittivities and the arrangement positions of the support members 3 and 3'.

[0037] Hereinbelow, referring to FIGS. 15A and 15B, a description will be given of an example filter in which the above-described five resonant modes are sequentially coupled to each other.

[0038] Similarly to the type shown in FIGS. 2A and 2B, FIG. 15A is an upper view, and FIG. 15B is a cross-sectional view thereof. In these figures, reference symbols 5a and 5b each denote a coaxial connector, and probes 4a and 4b each jutting out in a cavity 2 are fitted with central conductors thereof. Reference symbols 14a and 14a' denote grooves for coupling the TEy mode and the TEx mode together, and in addition, reference symbols 14b and 14b' denote grooves for coupling the TEz mode and the TMz mode together.

[0039] FIGS. 16A to 16D show operation of the above-described coupling grooves 14 and 14'. FIG. 16A shows dielectric-field vectors in the TEx mode and the TEz mode, and FIG. 16B shows dielectric-field vectors in the two modes in an xy-plane cross section. In this case, when an added mode of the TEx mode and the TEz mode (TEx + z mode) is considered, the mode forms a loop on a plane perpendicular to the x + z axis direction, as shown in FIG. 16C. Also, as shown in FIG. 16D, a vector in a differential mode between the TEx mode and the TEz mode (TEx - z mode) becomes a mode that forms a loop on a plane perpendicular to the x - z axis direction.

[0040] Since the coupling grooves 14b and 14b' exist in a position where the electric-field vector in the TEx - z mode passes through, they function in the direction of weakening the electric field in the TEx - z mode, and the TEx mode and the TEz mode are coupled together according to the perturbations. Similarly, in FIGS. 15A and 15B, the coupling grooves 14 and 14' provide perturbations to a TEy + z mode and a TEy - z mode, and thereby allow the TEy mode and the TEz mode to be coupled together.

[0041] Thus, since TMx-mode → TEy-mode coupling and TEx-mode → TMy-mode coupling are caused according to the vertical asymmetry of a TM-mode dielectric core and a TE-mode dielectric core, TEx-mode → TEz-mode coupling is caused according to the coupling groove 14a, TEx-mode → TEz-mode coupling is caused according to the coupling groove 14b, the configuration functions as a quintuple-mode resonator in which five resonators are coupled to each other in the order of TMx → TEy → TEz → TEx → TMy.

[0042] In FIGS. 15A and 15B, the probe 4a couples by electric fields to the TMx mode, which is a first-stage resonator; and the probe 4b couples by electric fields to a TMy mode, which is a last-stage resonator. Therefore, the portion between the coaxial connectors 5a and 5b forms a filter presenting characteristics of a band-pass filter using five stages of resonators.

[0043] Hereinbelow, referring to FIGS. 17A to 20B, a description will be given of example filters in which so-called indirect coupling is provided.

[0044] FIGS. 17A to 17D are upper views of filters individually in a state where an upper cover of a cavity is removed. In the example shown in FIG. 17A, the center of a TM-mode dielectric core portion 11 is provided in the center of a TM-mode dielectric core portion 12, and the center of the TM-mode dielectric core portion 12 is shifted from the center of the TM-mode dielectric core portion 11 in the y-axis direction.

[0045] FIGS. 18A and 18B individually show a state where a TMy mode and a TEx mode in the state shown in FIG. 17A. Thus, by imparting the TM-mode dielectric core portion 11 and the TE-mode dielectric core portion 12 to be asymmetric to each other, perturbations are generated in the electric-field distributions of the TEx mode and the TEz mode, and the two modes are thereby coupled together. Since the two modes are first and third stages of resonators, they are indirectly coupled together. Similarly, as shown in FIG. 17B, by shifting the TM-mode dielectric core portion 12 in the x-axis direction, perturbations are generated in the electric-field distributions of the TMy mode and the TEz mode, and the two modes are thereby coupled together. Since these two modes are third and fifth stages of resonators, they are indirectly coupled together.

[0046] Also, as shown in FIG. 17C, by shifting the TE-mode dielectric core portion 12 to the individual x-axis direction and y-axis direction, the TMx mode and the TEz mode are indirectly coupled together, and concurrently, the TMy mode and the TEz mode are indirectly
coupled together. That is, the first stage and the third stage are indirectly coupled together, and in addition, the third stage and the fifth stage are indirectly coupled together.

In the example shown in FIG. 17D, a probe 4a connected to a central conductor of a coaxial connector 5a is arranged in an x + y axis direction and is provided in a corner portion of a TM-mode dielectric core portion 11. A probe 4b connected to a central conductor of a coaxial connector 5b is arranged in an x - y axis direction and is provided in another corner portion of the TM-mode dielectric core portion 11. Therefore, the probe 4a couples to a TMx + y mode, and the probe 4b couples to a TMx - y mode. Thus, quintuple resonant modes according to the TM-mode dielectric core portion 11 are coupled to each other in the order of TMx + y mode and the TEz mode, and these two modes are thereby coupled together. Similarly, perturbations are generated in the individual electric-field distributions of the TMx + y mode and the TEz mode, and these two modes are thereby coupled together.

Therefore, a first stage and a third stage are indirectly coupled together, and the third stage and a fifth stage are indirectly coupled together.

FIGS. 19A to 19D show examples in each of which predetermined TM modes and predetermined TE modes are coupled so as to cause indirect coupling therewithin. In the example shown therein, the entity of a dielectric core 10 is arranged in a position shifted from the center of a cavity 2 to the y-axis direction.

FIGS. 20A and 20B individually show a state where a TMx mode and a TEz mode in the state shown in FIG. 19A. Thus, depending on the position of the dielectric core in the cavity 2, the electric-field vectors in the TMx mode are attracted toward the wall-face side of the cavity 2. Therefore, perturbations are generated into the TMx mode and the TMz mode, the TMx mode and the TEz mode are coupled together; that is, and the first stage and the third stage are indirectly coupled together. Similarly, as shown in FIG. 19B, by shifting a dielectric core 10 in the x-axis direction, the TMy mode and the TEz mode are coupled together; that is, a third stage and a fifth stage are indirectly coupled together. Also, as shown in FIG. 19C, by shifting a dielectric core 10 individually in the x-axis direction and the y-axis direction, the TMx mode and the TEz mode are coupled together, and the TEz mode and the TMx mode are coupled together; that is, a third stage and a fifth stage are indirectly coupled together, and the third stage and a fifth stage are indirectly coupled together.

In addition, in the example shown in FIG. 19D, a probe 4a couples to a TMx + y mode, and a probe 4b couples to a TMx - y mode; thus, quintuple resonant modes are coupled to each other in the order of TMx + y → TEz → TEx + y → TMx - y. In this example, a dielectric core 10 is shifted from the center of a dielectric core 10 to the y-axis direction. Therefore, perturbations are generated in the individual electric-field distributions of the TMx + y mode and the TEz mode, and these two modes are thereby coupled together.

Similarly, perturbations are generated in the individual electric-field distributions of the TMx - y mode and the TEz mode, and these two modes are thereby coupled together. That is, a first stage and a third stage are indirectly coupled together, and the third stage and a fifth stage are indirectly coupled together.

In the above-described manners, indirect coupling is caused in either one portion or two portions, and either one attenuation pole or two attenuation poles are generated depending on the indirect coupling. For example, an attenuation pole is generated either in the low-band side of a passband according to five stages of resonators or in the high-band side thereof; alternatively, the attenuation pole is generated in each of the two sides, thereby sharpening characteristics in the transition from the passband to the attenuation pole in the bandpass characteristics.

Hereinbelow, referring to FIGS. 21A and 21B, a description will be given of a multimode dielectric resonator apparatus that uses a dielectric core having a construction that differs from those described above.

FIG. 21A shows a cross sectional face at an intermediate height of the multimode dielectric resonator apparatus, and FIG. 21B shows a cross-sectional face extending through the center. Specifically, FIG. 21A is a cross-sectional view along the line A-A, and FIG. 21B is a cross-sectional view along the line B-B.

In FIGS. 21A and 21B, reference numeral 11 denotes a TM-mode dielectric core portion having a dielectric-plate-like shape in which a central circular portion is cut out, and reference numeral 12 denotes a spherical TE-mode dielectric core portion to be inserted in the aforementioned opening. The TM-mode dielectric core portion 11 is supported in a cavity 2 such that four corners thereof are supported by support members 3a to 3d. The TE-mode dielectric core portion 12 is supported such that upper and lower portions thereof are supported by support members 3e and 3f to cover portions 6 that cover upper and lower opening faces of the cavity 2. All the support members 3a to 3f are formed of a low-permittivity material. Before the dielectric core portions 11 and 12 are immobilized, the individual support members 3a to 3f are provided so as to be movable with respect to the cavity 2 and cover portions 6. Therefore, the TM-mode dielectric core portion 11 is movable by a specific amount in the xy-plane direction. Also, according to immobilization the support members 3a to 3d at predetermined positions of wall faces of the cavity 2, the position of the TM-mode dielectric core portion 11 in the cavity 2 can be determined. Similarly, before the support members 3e and 3f are immobilized to the cover portions 6, the TE-mode dielectric core portion 12 is...
movable in the z-axis direction. Also, according to immobilization of support members 3e and 3f to the cover portions 6 in a state where the TE-mode dielectric core portion 12 is arranged at a predetermined position, the relative position of the TE-mode dielectric core portion 12 with respect to the TM-mode dielectric core portion 11 is determined.

According to the arrangement thus made to allow the relative position of the TE-mode dielectric core portion 12 in the z-axis direction with respect to the TM-mode dielectric core portion 11 to be shifted, the intensity of coupling between a TMx mode and a TEy mode and coupling between a TMy mode and a TEx mode can be set in an arbitrary wide range, and modulation thereof can be implemented. In addition, according to the arrangement made to allow the position of the TM-mode dielectric core portion 11 on the xy plane with respect to the TE-mode dielectric core portion 12 and the cavity 2 to be shifted, either coupling between a TEz mode and the TMx mode or the TMy mode to be arbitrarily set, and modulation thereof can be implemented.

Hereinbelow, referring to FIGS. 22A and 22B, a description will be given of an example configuration of a filter formed by adding other resonators in the multimode dielectric resonator apparatus. In FIGS. 22A and 22B, reference numeral 20 denotes a quintuple mode resonator. This resonator is formed such that the dielectric core of the quintuple mode resonator shown in FIGS. 15A and 15B is configured of a plate-like TM-mode dielectric core portion and a stepped-pyramid-like TE-mode dielectric core portion, and the input/output directions are rotated by 45 degrees in the xy plane. Therefore, quintuple resonant modes according to the TM-mode dielectric core portion 11 are coupled to each other in the order of TMx + y → TEz → TEy → TEz → TEy + y → TMx - y. Also, reference numerals 21 and 22 individually denote semicoaxial resonators 21 and 22. The individual semicoaxial resonators 21 and 22 have a central conductor 8 in a cavity, and the resonant frequency is determined according to electrostatic capacitance generated between a lower end portion of a magnetic field coupling screw 9 and an upper end portion of the central conductor 8, the length of the central conductor 8, and the like. A coupling loop 7a is provided between a central conductor of a coaxial connector 5a and an inner face of the cavity, and external coupling is made through the coupling loop 7a. Similarly, a coupling loop 7d is provided between a central conductor of a coaxial connector 5b and an inner face of the cavity, and external coupling is made through the coupling loop 7b. Coupling loops 7b and 7c are connected to the probes 4a and 4b, respectively; and the coupling loops 7b and 7c are coupled in magnetic field to the semicoaxial resonators 21 and 22, respectively.

The above-described configuration, which has the first and last stages of resonators and five dielectric resonators therebetween, operates as a filter that has a total of seven stacked of resonators and that has band-pass characteristics. As described above, since the first and last stages of resonators are the semicoaxial resonators, and secure coupling can be obtained by the coupling loops, broadband characteristics can be easily obtained. In addition, since the spurious mode due to the quintuple mode resonator 20 is minimized by the semicoaxial resonators 21 and 22, all of entire spurious characteristics can be decreased. Furthermore, since direct coupling to the outside is not necessary, the probes 4a and 4b in the quintuple mode resonator 20 can be miniaturized, direct passage of signals between the input and the output is reduced, and deterioration in characteristics because of the direct passage is therefore not caused.

In the example shown in FIGS. 22A and 22B, although the semicoaxial resonators are used, semicoaxial resonators can be similarly used for the first stage and the last stage. Even in this case, effects similar to the above can be provided.

Hereinbelow, referring to FIG. 23, a description will be given of an example configuration of a duplexer. In FIG. 23, reference symbols 20TX and 20RX individually denote quintuple mode resonators that are similar to those shown in FIG. 22; and reference symbols 21TX, 22TX, 21RX, and 22RX individually denote semicoaxial resonators that are similar to those shown in FIG. 22. By the two semicoaxial resonators 21TX and 22TX and the quintuple mode resonator 20TX, a transmission filter portion is configured; and similarly, by the two semicoaxial resonators 21RX and 22RX and the quintuple mode resonator 20RX, a reception filter portion is configured.

Coupling loops 7e connected to a central conductor of a coaxial connector 5a are individually coupled in magnetic field to the semicoaxial resonators 22TX and 21RX, and transmission signals and reception signals are thereby separated. Thus, the duplexer as an antenna-sharing apparatus is configured.

FIG. 24 is a block diagram showing a configuration of a communication apparatus in which the above-described duplexer is used. In this way, by connecting a transmission circuit and a reception circuit to an input port of the transmission filter and an output port of the reception filter, respectively, and by connecting an antenna to the input and output ports of the duplexer, a high frequency section of the communication apparatus is configured.

In addition to this example, the above-described quintuple mode resonator may be provided as an independent bandpass filter.

In the individual embodiments, both the TMx mode and TMy mode are generated in the square plate-like portion of the dielectric core. However, the arrangement may be such that, by making it to be in a rectangular plate-like state, for example, only the TMx mode is resonated in an operating frequency band, the resonant frequencies of the TMy mode and the TMz mode are increased to be higher than the operating frequency
band, and only the single TM mode is used. Also, although the three modes of the TE mode are used in the embodiments, the arrangement may be such that only two TE modes thereof are used.

In one embodiment of the invention, the TM-mode dielectric core portion and the TE-mode dielectric core portion are independently supported in the cavity. It should be noted that this embodiment is not shown in the figures. In accordance with this embodiment, either the position of one of the dielectric core portions or the positions of the two dielectric core portions are determined thereby.

Claims

1. A multimode dielectric resonator apparatus configured in a dielectric resonator apparatus formed by arranging a dielectric core (10) in a conductive cavity (2), characterised the dielectric core (10) comprising:

   a TM-mode dielectric core portion (11) determining resonant frequencies of TM modes so that at least one of the TM modes resonates in an operating frequency band, and other TM modes resonate at frequencies higher than the operating frequency band; and

   a TE-mode dielectric core portion (12) generating a multiple TE-mode determining resonant frequencies of TE modes so that the individual TE modes of the multi-TE mode resonate in the operating frequency band, wherein

   either the TM-mode dielectric core portion (11) is formed to have a plate-like shape, the TE-mode dielectric core portion (12) is formed to have a shape protruding from an upper face and a lower face of the plate-like portion, and the asymmetry is arranged therefor according to the difference between the upper-side protruding amount and the lower-side protruding amount or support members (3) supporting the TM-mode dielectric core portion (11) and the TE-mode dielectric core portion (12) in the cavity are arranged asymmetrically to the TM-mode dielectric core, and

   predetermined TM modes and TE modes are coupled to each other so that, in areas where electric fields of the predetermined TM-modes are distributed, TE-mode electric fields having the same directional components as those of the electric fields of the TM modes are generated.

2. A multimode dielectric resonator apparatus as stated in claim 1, wherein the TM-mode dielectric core portion (11) and the TE-mode dielectric core portion (12) are independently supported in the cavity (2), and either the position (11,12) of one of the dielectric core portions (11, 12) or the positions of the two dielectric core portions are thereby determined.

3. A multimode dielectric resonator apparatus as stated in any of claims 1-2, wherein the TM-mode dielectric core portion (11) is formed to have a plate-like shape, the TE-mode dielectric core portion (12) is formed to have a shape protruding from an upper face and a lower face of the plate-like portion, and the TE-mode dielectric core portion (12) is provided in a position deviating from the center of the plate-like portion, which is the TM-mode dielectric core portion (11), in the face direction of the plate-like portion, thereby imparting the asymmetry thereto.

4. A multimode dielectric resonator apparatus as stated in any of claims 1-2, wherein the TM-mode dielectric core portion (11) is formed to have a plate-like shape, the TE-mode dielectric core portion (12) is formed to have a shape protruding from an upper face and a lower face of the plate-like portion, and the dielectric core (10) is provided in a position deviating from the center of the cavity (2) in the face direction of the plate-like portion, which is the TM-mode dielectric core portion (11), thereby imparting the asymmetry thereto.

5. A filter comprising:

   the multimode dielectric resonator apparatus as stated in one of claims 1 to 4 and

   input/output means (5a, 5b) coupled to predetermined resonant modes in the multimode dielectric resonator apparatus.

6. A filter comprising:

   the multimode dielectric resonator apparatus as stated in one of claims 1 to 4, either coaxial resonators or semicoaxial resonators (4a, 4b) that are coupled to predetermined modes, and

   input/output means (3a, 5b) coupled to the resonators.

7. A duplexer configured of two sets of the filter as stated in one of claims 5 and 6.

8. A communication apparatus comprising either the filter as stated in one of claims 5 and 6 or the du-
Patentansprüche

1. Eine mehrmodige dielektrische Resonatorvorrichtung, die in einer dielektrischen Resonatorvorrichtung konfiguriert ist, die durch ein Anordnen eines dielektrischen Kerns (10) in einem leitfähigen Hohlraum (2) gebildet ist, dadurch gekennzeichnet, daß der dielektrische Kern (10) folgende Merkmale aufweist:

- einen dielektrischen TM-Mode-Kernabschnitt (11), der Resonanzfrequenzen von TM-Moden bestimmt, so daß zumindest eine der TM-Moden in einem Betriebsfrequenzband in Resonanz ist und andere TM-Moden bei höheren Frequenzen als dem Betriebsfrequenzband in Resonanz sind;

2. Eine mehrmodige dielektrische Resonatorvorrichtung gemäß Anspruch 1, bei der der dielektrische TM-Mode-Kernabschnitt (11) und der dielektrische TE-Mode-Kernabschnitt (12) unabhängig in dem Hohlraum (2) getragen sind und entweder die Position (11, 12) eines der dielektrischen Kernabschnitte (11, 12) oder die Positionen der zwei dielektrischen Kernabschnitte dadurch bestimmt sind.


4. Eine mehrmodige dielektrische Resonatorvorrichtung gemäß einem der Ansprüche 1-2, bei der dielektrische TM-Mode-Kernabschnitt (11) gebildet ist, um eine plattenähnliche Form aufzuweisen, der dielektrische TE-Mode-Kernabschnitt (12) gebildet ist, um eine Form aufzuweisen, die von einer oberen Fläche und einer unteren Fläche des plattenähnlichen Abschnitts vorspringt, und der dielektrische Kern (10) an einer Position vorgesehen ist, die von der Mitte des Hohlraums (2) in die Flächenrichtung des plattenähnlichen Abschnitts abweicht, wodurch die Asymmetrie an dieselbe übertragen wird.

5. Ein Filter, das folgende Merkmale aufweist:

- die mehrmodige dielektrische Resonatorvorrichtung gemäß einem der Ansprüche 1 bis 4
- eine Eingang/Ausgang-Einrichtung (5a, 5b), die mit vorbestimmten Resonanzmoden in der mehrmodigen dielektrischen Resonatorvorrichtung gekoppelt ist.

6. Ein Filter, das folgende Merkmale aufweist:

- die mehrmodige dielektrische Resonatorvorrichtung gemäß einem der Ansprüche 1 bis 4
- entweder Koaxialresonatoren oder Semikoaxialresonatoren (4a, 4b), die mit vorbestimmten Moden gekoppelt sind, und
- eine Eingang/Ausgang-Einrichtung (3a, 5b), die mit den Resonatoren gekoppelt ist.

7. Ein Duplexer, der aus zwei Sätzen des Filters ge-
mäß einem der Ansprüche 5 und 6 konfiguriert ist.

8. Eine Kommunikationsvorrichtung, die entweder das Filter gemäß einem der Ansprüche 5 und 6 oder den Duplexer gemäß Anspruch 7 aufweist.

Revendications

1. Dispositif formant résonateur diélectrique multimode configuré sous la forme d’un dispositif formant résonateur diélectrique constitué par la disposition d’un noyau diélectrique (10) dans une cavité conductrice (2), caractérisé en ce que le noyau diélectrique (10) comprend :

une partie de noyau diélectrique à modes TM (11) pour déterminer des fréquences de résonance à modes TM de sorte qu’au moins l’un des modes TM résonne dans une bande de fréquences de fonctionnement et d’autres modes TM résonnent à des fréquences supérieures à la bande de fréquences de fonctionnement; et une partie de noyau diélectrique à modes TE (12) produisant un mode TE multiple déterminant des fréquences de résonance à modes TE de telle sorte que les modes TE individuels du mode TE multiple résonnent dans la bande de fréquences de fonctionnement,

2. Dispositif formant résonateur diélectrique multimode selon la revendication 1, dans lequel la partie de noyau diélectrique à modes TM (11) est formée de manière à posséder une forme de plaque, la partie de noyau diélectrique à modes TE (12) est formée de manière à posséder une forme qui fait saillie à partir d’une face supérieure et d’une face inférieure de la partie en forme de plaque, et la dissymétrie est agencée à cet effet conformément à la différence entre le degré de disposition en saillie sur le côté supérieur, et le degré de disposition en saillie sur le côté inférieur ou des éléments de support (3) supportant la partie de noyau diélectrique à modes TM (11) et la partie de noyau diélectrique à modes TE (12) dans la cavité sont disposés de manière dissymétrique par rapport au noyau diélectrique à modes TM, et des modes TM et des modes TE prédéterminés sont couplés entre eux de telle sorte que, dans des zones où des champs diélectriques des modes TE prédéterminés sont distribués, des champs électriques des modes TE possédant les mêmes composantes directionnelles que celles des champs électriques des modes TM sont produits.

3. Dispositif formant résonateur diélectrique multimode selon l’une quelconque des revendications 1 et 2, dans lequel la partie de noyau diélectrique à modes TM (11) est formée de manière à posséder une forme de plaque, la partie de noyau diélectrique à modes TE (12) est formée de manière à posséder une forme qui est en saillie par rapport à une face supérieure et à une face inférieure de la partie en forme de plaque, et la partie de noyau diélectrique à modes TE (12) est située dans une position qui s’écarte du centre de la partie en forme de plaque, qui est la partie de noyau diélectrique à modes TM (11), en direction de la face de la partie en forme de plaque, ce qui confère la dissymétrie à ladite partie.

4. Dispositif formant résonateur diélectrique multimode selon l’une quelconque des revendications 1 et 2, dans lequel la partie de noyau diélectrique à modes TM (11) est formée de manière à posséder une forme qui fait saillie à partir d’une face supérieure et d’une face inférieure de la partie en forme de plaque, et le noyau diélectrique (10) est situé dans une position qui s’écarte du centre de la cavité (2) en direction de la face de la partie en forme de plaque, qui est la partie de noyau diélectrique à modes TM (11), ce qui confère une dissymétrie à cette partie.

5. Filtrant comprenant :

le dispositif formant résonateur diélectrique multimode selon l’une des revendications 1 à 4, et des moyens d’entrée/sortie (5a,5b) couplés à des moyens de résonants prédéterminés dans le dispositif formant résonateur diélectrique multimode.

6. Filtrant comprenant :

le dispositif formant résonateur diélectrique multimode selon l’une des revendications 1 à 4, l’un ou l’autre des résonateurs coaxiaux ou des résonateurs semi-coaxiaux (4a,4b), qui sont couplés à des modes prédéterminés, des moyens d’entrée/sortie (3a,5b) couplés aux résonateurs.


8. Dispositif de communication comprenant soit le fil-
tre indiqué dans l'une des revendications 5 et 6, soit le duplexeur tel qu'indiqué dans la revendication 7.
Fig. 4A

Fig. 4B

Fig. 5

\[ k(\%) \]

DEVIATION AMOUNT
Fig. 16A

Fig. 16B

Fig. 16C

Fig. 16D
Fig. 24

ANTENNA

DUPLEXER

TRANSMISSION-SIGNAL INPUT PORT (Tx)

TRANSMISSION CIRCUIT

TRANSMISSION FILTER

RECEPTION-SIGNAL OUTPUT PORT

(ANT)

ANTENNA PORT

RECEPTION FILTER

RECEPTION CIRCUIT