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Resonator und dielektrischer Filter

Résonateur et filtre diélectrique

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(56) References cited:
WO-A-03/026060 US-A- 5 404 118
US-A- 5 777 533 US-B1- 6 417 745

- **PATENT ABSTRACTS OF JAPAN vol. 1998, no. 06, 30 April 1998 (1998-04-30) & JP 10 051203 A (NGK SPARK PLUG CO LTD), 20 February 1998 (1998-02-20)**

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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The present invention relates to a resonator in accordance with the precharacterizing part of claim 1 and to a dielectric filter comprising said resonator. A resonator and a dielectric filter of that kind are known from US-A-5,777,533.

2. Description of the Related Art

[0002] As a communication system using a high-frequency radio wave in a microwave-band or a millimeter-wave band as a carrier, for example, a telephone system such as a cellular phone or a wireless local area network (LAN) has become widely used, it has become possible to transmit and receive a variety of types of data easily and not through a repeater etc., at a variety of places both indoors and outdoors.

[0003] An instrument used in such a communication system is provided with a filter element such as a low-pass filter (LPF), a high-pass filter (HPF), or band-pass filter (BPF). The filter element is designed so that it can be used in a distributed parameter circuit, not in a lumped parameter circuit, in order to process a signal in the high-frequency band. For example, a filter having a tri-plate structure is formed using a pair of parallel electric conductor patterns.

[0004] Further, to carry the instrument easily, an attempt has been made to miniaturize it by means of high-density packaging, multi-layering of its substrates, etc. For example, in configuring of pattern wiring line layers, dielectric insulating layers, etc. into a multi-layered structure, such layers in which filters, capacitors, inductors, registers, etc. are formed and pattern layers in which signal wiring lines, power supply lines, etc. are formed are configured into a multi-layer structure to provide a high-frequency module device in practice.

[0005] However, in the case of, for example, a comb-line type filter by which one pair of conductor patterns each having a length that is one fourth a wavelength of a signal to be transmitted therethrough is coupled to each other electromagnetically, if the signal to be transmitted has a low frequency, the conductor patterns must be elongated, to make it impossible to miniaturize the filter.

[0006] Furthermore, if an instrument is miniaturized by configuring into a multi-layer structure such layers as filter layers designed as those of a distributed parameter circuit and pattern wiring line layers, behaviors of the filter are influenced by signal wiring line patterns etc, thus making it impossible to obtain desired filter characteristics in some cases. For example, if a signal wiring line pattern is arranged between a grounding conductor layer and conductor patterns, a condition of electromagnetic coupling between one pair of parallel conductor patterns changes, thereby making it impossible to obtain desired filter characteristics in some cases.

[0007] The resonator and dielectric filter described in US-A-5,777,533 cited above includes an intermediate ground layer, and the capacitor layers of the resonant electrodes are formed opposite to the inductive pattern layers between the basic ground layer and the intermediate ground layer, wherein the size in thickness direction of the known resonator and the dielectric filter is increased. Further, this construction of the known resonator and the dielectric filter may require more and longer wires through the dielectric layers to the basic ground layer.

SUMMARY OF THE INVENTION

[0008] It is an object of the present invention to provide a resonator and a dielectric filter which can be reduced in size and costs and have desired characteristics with a high accuracy and a suppressed loss.

[0009] The present invention provides a resonator according to claim 1.

[0010] The resonator of the present invention may be included in a dielectric filter for transmitting a signal input to the signal input terminal within a desired frequency band and outputting as an output signal at the signal output terminal.

[0011] In the present invention, one pair of resonant electrodes is formed in a loop shape or a spiral shape in a substrate stacking direction symmetrically to each other with respect to, for example, a gap between the resonant electrodes. Further, a first capacitor having such a stack construction that its one end is connected to the grounding conductor layer and the other end of it is connected to the signal input terminal or the resonant electrode whose open-end side is used as the signal input terminal is formed using, for example, tantalum oxide. A second capacitor having such a stack construction that its one end is connected to the grounding conductor layer and the other end of it is connected to the signal output terminal or the resonant electrode whose open-end side is used as the signal output terminal is formed using, for example, tantalum oxide. A third capacitor having such a stack construction that its one end is connected to the signal input terminal or the resonant electrode whose open-end side is used as the signal input terminal and the other end of it is connected to the signal output terminal or the resonant electrode whose the open-end side is used as the signal output terminal is formed using, for example, tantalum oxide.

[0012] According to the present invention, one pair of resonant electrodes is formed in a loop shape or a spiral shape in a substrate stacking direction symmetrically to each other. This allows a longitudinal space in substrate to be reduced, thereby miniaturizing the resonator and the dielectric filter. The first capacitor having one end connected to the grounding conductor layer and the other end connected to the signal input terminal or the resonant electrode whose open-end side is used as the signal input terminal, and the second capacitor having one end connected to the grounding conductor layer and the other end connected to the signal output terminal or the resonant electrode whose open-end side is used as the signal output terminal, are provided so that the resonant electrode may be further reduced, thereby reducing the instrument in size. Further, the third capacitor having one end connected to the signal input terminal or the resonant electrode whose open-end side is used as the signal input terminal and the other end connected to the signal output terminal or the resonant electrode whose open-end side is used as the signal output terminal is provided. This allows a trapped frequency to be adjusted, by adjusting static capacitance of the third capacitor. Additionally, using tantalum oxide as dielectric material causes an area occupied by the capacitor on the substrate to be reduced, thereby reducing the instrument in size. Since the layer of conductive material arranged between the grounding conductor layer and the resonant-pattern conductor layer includes a slot so that it may contain a region facing the resonant electrodes, the resonator or the dielectric filter having a desired characteristic may be obtained without receiving any influence from other conductor layers or wiring line patterns.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1 is a plan view showing a configuration of a dielectric filter according to the invention;
FIG. 2 is an outlined cross-sectional view (taken along line A-A' in FIG. 1) of the dielectric filter;
FIG. 3 is an outlined cross-sectional view (taken along line B-B' in FIG. 1) of the dielectric filter;
FIG. 4 is an exploded perspective view of the dielectric filter;
FIG. 5 is an equivalent circuit diagram of the dielectric filter;
FIG. 6 is a plan view showing another configuration of the dielectric filter;
FIG. 7 is a plan view showing still another configuration of the dielectric filter;
FIG. 8 is an outlined fragmentary cross-sectional view of a portion of a tantalum oxide capacitor;
FIG. 9 is a plan view showing an implementation embodiment of the dielectric filter;
FIG. 10 is a diagram showing transmission characteristics of the embodiment; and
FIG. 11 is a diagram showing reflection characteristics of the embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The following will describe embodiments of the present invention with reference to drawings. FIG. 1 is a plan view of a configuration of a dielectric filter 10. FIG. 2 is a cross-sectional view of the dielectric filter 10 taken along line A-A' in FIG. 1. FIG. 3 is a cross-sectional view of the dielectric filter 10 taken along line B-B' in FIG. 1. FIG. 4 is an exploded perspective view of the dielectric filter 10. FIGS. 1-4 show the dielectric filter 10 in a condition where one pair of resonant electrodes is formed symmetrically to each other in a spiral shape in a substrate stacking direction.

[0015] On a rear side of a stack substrate 11 in which multiple layers of dielectric material (hereinafter referred to as "dielectric layer") and conductive material (hereinafter referred to as "conductor layer") are stacked, a first conductor layer 12 is formed as a grounding conductor layer. On, for example, the right layer side of the stack substrate 11 opposite the first conductor layer 12 via the dielectric layer, such a fourth conductor layer 19 is formed opposite the first conductor layer 12 as to comprise a conductor pattern having a resonant electrode 191a, a capacitor electrode 192a, and a signal input terminal 193a, a conductor pattern having a resonant electrode 191b, a capacitor electrode 192b, and a signal output terminal 193b, and a conductor pattern to provide grounding electrodes 194 and 195.

[0016] The resonant electrodes 191a and 191b each have a U-shape and are formed roughly parallel to each other with a predetermined distance in-between. One end of the resonant electrode 191a is connected to a resonant electrode 171a described later and the other end of it is open. On the side of the open end of this resonant electrode 191a, the signal input terminal 193a is provided roughly perpendicular to the resonant electrode 191a. Further, one end of the resonant electrode 191b is connected to a resonant electrode 171b described later and the other end of it is open. On the side of the open end of the resonant electrode 191b, the signal output terminal 193b is provided roughly perpendicular to the resonant electrode 191b.

[0017] On a side opposite the resonant electrode 191b with respect to the resonant electrode 191a, the capacitor electrode 192a is formed in such a manner as to protrude from the resonant electrode 191a. Further, on a side opposite the resonant electrode 191a with respect to the resonant electrode 191b, the capacitor electrode 192b is formed in such a manner as to protrude from the resonant electrode 191b. Furthermore, a third conductor layer 17 is provided opposite the fourth conductor layer 19 via a fourth dielectric layer 18 in-between in parallel condition. This third conductor layer 17 comprises a conductor pattern in which resonant electrodes 171a and 171b and capacitor electrodes 172a and 172b are connected to a grounding electrode 174, a conductor pattern which provides a capacitor electrode 173, and a conductor pattern which provides a grounding electrode 175. That is, in the dielectric filter 10 shown in FIGS. 1-4, the third conductor layer 17 and the fourth conductor layer 19 constitute a resonant pattern conductor layer.

[0018] The resonant electrodes 171a and 171b each have an L-shape and are formed roughly parallel to each other with a predetermined distance in-between. One end of the resonant electrode 171a is connected to the above-mentioned resonant electrode 191a and the other end of it is connected to the grounding electrode 174. On the other hand, one end of the resonant electrode 171b is connected to the above-mentioned resonant electrode 191b and the other end of it is connected to the grounding electrode 174. By thus connecting the resonant electrodes 171a and 171b and the resonant electrodes 191a and 191b, it is possible to form resonant electrodes in a spiral shape in the substrate stacking direction. It is to be noted that the shapes of the resonant electrodes 171a and 171b and those of the resonant electrodes 191a and 191b are not limited to those shown in FIGS. 1-4 as far as a spiral shape can be formed in the substrate stacking direction by connecting the resonant electrodes 171a and 171b and the resonant electrodes 191a and 191b. For example, the resonant electrodes 171a and 171b may be U-shaped and the resonant electrodes 191a and 191b may be L-shaped.

[0019] The capacitor electrode 172a is formed in such a manner as to be opposite the capacitor electrode 192a. This capacitor electrode 192a, the fourth dielectric layer 18, and the capacitor electrode 172a constitute a capacitor C1. Further, the capacitor electrode 172b is formed in such a manner as to be opposite the capacitor electrode 192b. This capacitor electrode 192b, the fourth dielectric layer 18, and the capacitor electrode 172b constitute a capacitor C2. Furthermore, the grounding electrode 174 has a shape similar to the grounding electrode 194 so that a region that faces the resonant electrodes 171a, 171b, 191a, and 191b may be a slot.

[0020] The resonant electrode 191a is connected to the capacitor electrode 173 through a conductor-layer connecting portion (hereinafter referred to as "via" simply) 20 such as a via hole or a through hole. The capacitor electrode 173 is formed so as to be parallel to and opposite a pattern face of the resonant electrode 191b via the fourth dielectric layer 18 made of a dielectric material in-between, thus being combined with the capacitor electrode 173 and the resonant electrode 191b to constitute a capacitor C3. Further, through a via 21, the first conductor layer 12, the grounding electrodes 174, 175, 194, and 195, and a second conductor layer 14 are made conductive to each other.

[0021] A first dielectric layer 13 provides a base for the stack substrate 11 and has the first conductor layer 12 formed on one side of the first dielectric layer 13 and a second conductor layer 14 formed on the other side. In the second conductor layer 14, a slot is formed in such a manner as to contain a region that faces the resonant electrodes 191a and 191b, in which slot a second dielectric layer 15 is provided.

[0022] By thus providing the slot, there exists no other conductor layer between the first conductor layer 12 and the resonant electrodes 171a, 171b, 191a, and 191b, so that the mutual electromagnetic coupling between the resonant electrodes 171a and 171b and the mutual electromagnetic coupling between the resonant electrodes 191a and 191b is not changed by the other conductor layers.

[0023] FIG. 5 shows an equivalent circuit diagram of the dielectric filter 10. In this dielectric filter 10, a parallel circuit composed of inductance La-1 and stray capacitance Ca-1 of the resonant electrode 171a and a parallel circuit composed of inductance La-2 and stray capacitance Ca-2 of the resonant electrode 191a are connected in series and, to this series-connected circuit, the capacitor C1 is connected in parallel. Further, a parallel circuit composed of inductance Lb-1 and stray capacitance Cb-1 of the resonant electrode 171b and a parallel circuit composed of inductance Lb-2 and stray capacitance Cb-2 of the resonant electrode 191b are connected in series and, to this series-connected circuit, the capacitor C2 is connected in parallel. A circuit to which the capacitor C1 is connected in parallel and that to which the capacitor C2 is connected in parallel are shown as being capacitive-coupled to each other via the capacitor C3. Further, the resonant electrodes 171a and 171b are electromagnetically coupled to each other and the resonant electrodes 191a and 191b and the resonant electrodes 191a and 191b are electromagnetically coupled to each other. It is to be noted that M1 and M2 each indicate mutual inductance.

[0024] Therefore, by adjusting a length of a portion along which the resonant electrodes 171a and 171b are adjacently opposed to each other, a length of a portion along which the resonant electrodes 191a and 191b are adjacently opposed to each other, and capacitances of the capacitors C1, C2, and C3, a high-frequency signal RFin, when input from the signal input terminal 193a, can be filtered to obtain at the signal output terminal 193b a signal RF out transmitted through a desired frequency band.

[0025] According to this dielectric filter, if static capacitance of the capacitors C1 and C2 is increased, a resonant frequency of a resonator constituted of the resonant electrodes 191a and 191b can be shifted to a lower-frequency side. That is, a pass-band of the dielectric filter can be shifted to a lower-frequency side. If the capacitance of the capacitors C1 and C2 is decreased, on the other hand, the resonant frequency can be shifted to a higher-frequency side. That is, the pass-band of the dielectric filter can be shifted to the higher-frequency side.

[0026] Furthermore, the capacitor C3 has a function as a trap, so that if capacitance of the capacitor C3 is increased, a frequency to be trapped (notch point) can be shifted to a lower-frequency side, and if the capacitance of the capacitor C3 is decreased, the notch point can be shifted to a higher-frequency side. Furthermore, since the resonant electrodes are formed in a spiral shape in the substrate stacking direction, a portion along which the resonant electrodes are adjacently opposed to each other is elongated without elongating the resonant electrode longitudinally, thus decreasing the resonant frequency.

[0027] The following will describe a procedure for generating a dielectric filter with reference to the exploded perspective view shown in FIG. 4. A dielectric filter uses a so-called printed wiring assembly as a base substrate. For example, a printed wiring assembly in which a dielectric substrate has a conductor layer formed on both sides is used as a base substrate.

[0028] One of the conductor layers on the base substrate is referred to as the first conductor layer 12 and the other conductor layer is referred to as the second conductor layer 14. These first conductor layer 12 and second conductor layer 14 are electrically connected to each other via the via 21 made of, for example, copper. The via 21 is formed by making at a portion of the dielectric substrate an opening that passes through this dielectric substrate by drilling, laser beam machining, plasma etching, etc. By performing via plating, for example, electrolytic plating by use of a copper sulfate solution on this opening, the via can be formed.

[0029] The dielectric substrate corresponds to the first dielectric layer 13 and preferably is made of a material that has a small dielectric loss (low-tan δ), that is, a material excellent in high-frequency response. Such materials include, for example, an organic material such as poly-phenyl ethylene (PPE), bismuleid triazine (BT-resin), polytetrafluoroethylene, polyimide, liquid-crystal polymer (LCP), polynorbornene (PNB), or ceramic, and a mixed material between ceramic and an organic material. Further, preferably the first dielectric layer 13 is made of, besides the these materials, a material having heat resistance and chemical resistance; a dielectric substrate made of such a material may include an inexpensive epoxy-made substrate FR-5 etc. By using such an inexpensive organic material as the first dielectric layer 13, costs are reduced as compared to a case where a relatively expensive silicon substrate or glass substrate is used conventionally.

[0030] In the second conductor layer 14, a slot is formed in such a manner as to contain a region that faces the resonant electrodes 191a and 191b. A conductor on the slot portion is removed by, for example, etching.

[0031] On the second conductor layer 14 in which the slot is formed, an insulator film made of an insulating material having a high dielectric constant, for example, epoxy-based resin is formed. It is to be noted that the insulator film may be formed on both sides of the base substrate. In this case, the first conductor layer 12 can be protected by the insulator film formed on the first conductor layer 12. After the insulator film is formed, such a portion of the insulator film as to be on the second conductor layer 14 is polished off until the second conductor layer 14 is exposed. It is thus possible to form the second dielectric layer 15 and eliminate a step between the second conductor layer 14 and the second dielectric layer 15, thereby forming a flat surface used as a built-up surface.

[0032] On the built-up surface, a third dielectric layer 16 is stacked, on which third dielectric layer 16 a capacitor or a resonant electrode is formed using a thin film formation technology or a thick film formation technology. Preferably this third dielectric layer 16 is made of a material having a low dielectric loss (low tan δ), that is, an organic material excellent in high-frequency response or an organic material having heat resistance or chemical resistance. Such an organic material may include, for example, benzocyc butene (PCB), polyimide, poly norbornen (PNB), liquid crystal polymer (LCP), epoxy resin, acrylic resin, etc. The third dielectric layer 16 can be stacked by forming such an organic material accurately on the built-up surface by using a method excellent in application uniformity and film-thickness control such as, for example, spin coating, curtain coating, roll coating, or dip coating.

[0033] Next, on the third dielectric layer 16, a conductor film made of, for example, nickel or copper is formed throughout the surface and, then, using a photolithographic technology, a conductor pattern for the third conductor layer 17 is formed. That is, by using as a mask a photo-resist patterned into a predetermined shape, this conductor film is etched to form a conductor pattern in which the resonant electrodes 171a and 171b and the capacitor electrodes 172a and 172b are connected to the grounding electrode 174, a conductor pattern which provides the capacitor electrode 173, and a conductor pattern which provides the grounding electrode 175. For example, a conductor film constituted of a copper film having a thickness of about several micrometers is formed by electrolytic plating by use of, for example, a copper sulfate solution and etched to form the resonant electrodes 171a and 171b, the capacitor electrodes 172a, 172b, and 173, and the grounding electrodes 174 and 175. Further, a via 21 is formed in the third dielectric layer 16 to connect the second conductor layer 14 and the grounding electrodes 174 and 175 to each other.

[0034] On the third dielectric layer 16 on which the resonant electrodes 171a and 171b, the capacitor electrodes 172a, 172b, and 173, and the grounding electrodes 174 and 175 are formed, the fourth dielectric layer 18 made of the above-mentioned organic material is formed, on which a conductor film made of, for example, nickel or copper or the like is formed throughout the surface. Then, the photolithographic technology is used as described above to form the resonant electrodes 191a and 191b, the capacitor electrodes 192a and 192b, the signal input terminal 193a, the signal output terminal 193b, and the grounding electrodes 194 and 195. Further, the vias 21 and 22 are formed in the fourth dielectric layer 18, through the via 21 of which the grounding electrode 174 for the third conductor layer 17 and the grounding electrode 194 for the fourth conductor layer 19 are connected to each other and the grounding electrode 175 for the third conductor layer 17 and the grounding electrode 195 for the fourth conductor layer 19 are connected to each other. Further, through the via 22, the resonant electrodes 171a and 191a are connected to each other and the resonant electrodes 171b and 191b are connected to each other.

[0035] By thus using the thin-film patterning technology, it is possible to reduce a width of the wiring lines of the resonant electrodes and spacing between the wiring lines than conventional ones. For example, by reducing the thickness of the electrodes or the dielectric layers to about 10-30 μm, it is possible to reduce the width of the resonant electrode wiring lines to 5-20 μm and the spacing between the resonant electrodes to 5-20 μm. Accordingly, self-inductance or mutual inductance M of the resonator can be increased to make the resonant electrode wiring line short. That is, the dielectric filter can be miniaturized. Further, a capacitor is added between the resonant electrode and the grounding electrode, so that by adjusting static capacitance of this capacitor, the pass-band can be controlled to a desired frequency band. Furthermore, a trap can be provided by adjusting a capacitor arranged between the resonant electrodes, thereby adjusting a band of frequencies to be blocked for the dielectric filter.

[0036] Further, since the stack substrate is constituted of a thin film, the dielectric filter can also be thinned. For example, a base substrate having a thickness of about 200-800 μm is used to form a built-up surface on it. On this built-up surface, a conductor layer and a dielectric layer can be stacked to thereby form a stack substrate with a thickness of about 10-30 μm on which resonant electrodes and capacitors are formed, thereby constituting a thinned dielectric filter.

[0037] Further, by forming the resonant electrodes in a spiral shape in the substrate stacking direction, the portion along which they are adjacently opposed to each other can be elongated, so that it is possible to provide a dielectric filter having a low pass-band frequency without increasing a longitudinal size of the resonant electrodes in the dielectric filter.

[0038] Further, although in the above embodiment, two conductor layers have been used to form spiral-shaped resonant electrodes, further more conductor layers can be used to increase the number of turns, thereby further lowering the pass-band frequency. Further, in a case where one conductor layer is used to form resonant electrodes, the resonant electrodes 191a and 191b can be formed in a loop shape as shown in FIG. 6, thereby elongating a portion of the wiring lines (range OA shown in FIG. 6) along which they are opposed to each other. That is, a resonant frequency can be lowered than a case where the resonant electrodes are formed linearly.

[0039] It is to be noted that there is a correlation between a length of a resonant electrode wiring line and static capacitance of a capacitor, so that if the resonant electrode wiring line is reduced, a capacitor having larger static capacitance is required. Therefore, by using a capacitor having large static capacitance with respect to its occupation area on the substrate, the dielectric filter can be miniaturized further.

[0040] The following will describe a case where a capacitor is used which has larger static capacitance with respect to the occupation area than the capacitor utilizing the fourth dielectric layer 18. FIG. 7 shows further another configuration of the dielectric filter, in which as the capacitor a tantalum oxide capacitor using, for example, tantalum oxide (Ta_2O_5) as its dielectric is employed. FIG. 8 is an outlined partially cross-sectional view (taken along line C-C' of FIG. 7) of a portion of the tantalum oxide capacitor.

[0041] In the tantalum oxide capacitor, a tantalum nitride (TaN) film 17u is formed on the capacitor electrodes 172a, 172b, and 173, each of which provides one capacitor. The tantalum nitride film 17u can be formed by chemical vapor deposition (CVD), sputtering, evaporation, etc. A surface layer of this tantalum nitride film 17u is anodized to provide a tantalum oxide film (Ta_2O_5) film 17t, which has a high dielectric constant and a low loss. Furthermore, on the tantalum oxide film, a wiring line film 17s which provides the other electrode of the tantalum oxide capacitor is formed and connected to the capacitor electrodes 192a and 192b and the resonant electrode 191b. The wiring line film can be connected to the capacitor electrodes 192a and 192b and the resonant electrode 191b by providing a via 23 to connect the wiring line film to the capacitor electrodes 192a and 192b and the resonant electrode 191b when, for example, forming the above-mentioned fourth dielectric layer 18 after the wiring line film is formed and forming the vias 20 and 21 in this fourth dielectric layer 18.

[0042] If the tantalum oxide capacitor is used in such a manner, as compared to a case where the capacitor is formed utilizing the fourth dielectric layer 18, an occupation area required to obtain the same static capacitance can be reduced, thus miniaturizing the dielectric filter. Furthermore, the capacitor, when used in a high-frequency region, self-resonates due to residual inductance caused by the electrode pattern etc., thus stopping functioning as a capacitor. Therefore, by setting a self-resonating frequency higher than the pass-band, a blocking level at frequencies higher than the pass-band can be increased.

[0043] Further, although in the dielectric filters shown in FIGS. 1, 6, and 7 respectively, the capacitor electrodes 192a and 192b have been connected somewhere along the resonant electrodes 191a and 191b respectively, the capacitor electrode 192a may be connected to the signal input terminal 193a, which is the open-end side of the resonant electrode 191a, and the capacitor electrode 192b may be connected to the signal output terminal 193b, which is the open-end side of the resonant electrode 191b. In this case, an electromagnetic field owing to this connection of the capacitor electrode has no influence on the parallel portion of the electrode, thereby facilitating design of the dielectric filter. Further, there is no influence of an electromagnetic field due to connection of the capacitor electrode to the parallel portion of the electrode, thereby utilizing the resonant electrodes effectively.

[0044] Furthermore, although in the above embodiment, the first conductor layer 12 which is one surface side of the resonant electrodes 171a, 171b, 191a and 191b has been used as the grounding conductor layer, as in the case of a strip-line, another grounding conductor layer may be provided also on the other side of the electrodes 171a, 171b, 191a and 191b via a dielectric layer, thereby containing an electromagnetic field in the stack substrate in construction.

[0045] The resonant electrodes have thus been formed in a loop shape or in a spiral shape in the substrate stacking direction so as to be symmetrical to each other, so that a wiring line portion along which the resonant electrodes are opposed to each other is elongated. Therefore, the dielectric filter can be miniaturized even if a pass-band frequency is low. Further, by forming the slot in such a manner as to contain a region that faces the resonant electrodes, it is possible to avoid any other signal wiring line pattern etc. from being arranged in the grounding electrode and the resonant electrodes, thereby obtaining a small-sized dielectric filter having desired filter characteristics. Further, since the slot portion is made of an insulating material having a high dielectric constant to constitute the second dielectric layer 15, the length of the wiring lines of the resonant electrodes can be reduced owing to a wavelength reduction effect.

[0046] Furthermore, by using the thin-film patterning technology, a wiring line of the resonant electrodes and an interval between the resonant electrodes can be reduced to strengthen electromagnetic coupling, thereby suppressing losses, improving accuracy thereof, and thinning the filter. Further, the capacitors are incorporated, so that as compared to a case where externally mounted capacitors are used, it is possible to suppress parasitic capacitance etc. and reduce the number of externally mounted components, thereby reducing the size and costs.

[0047] FIG. 9 shows another embodiment of the dielectric filter. If it is supposed that a wiring line length RL of the resonant electrodes is 600 μm, a wiring line length K1 is 150 μm, a wiring length K2 is 200 μm, a wiring line width W of the resonant electrodes is 50 μm, a space between the resonant electrodes is 130 μm, spacing items S1 and S2 between the resonant electrodes and an edge of the slot region are 200 μm, static capacitance of the capacitors C1 and C2 are 4. 6pF, and static capacitance of the capacitor C3 is 3.7pF, transmission characteristics of the dielectric filter will be such as indicated by a solid line in FIG. 10 and its reflection characteristics will be such as indicated by a solid line in FIG. 11. It is to be noted that broken lines shown in FIGS. 10 and 11 indicate the characteristics in a case where the resonant electrodes are formed linearly to be connected to the grounding electrode and the spacing S2 between the resonant electrodes and the edge of the slot region is supposed to be 200 μm.

[0048] As shown in FIG. 9, by forming the resonant electrodes in a spiral shape in the substrate stacking direction and elongating the portion along which they are opposed to each other, a pass-band frequency can be reduced. That is, without increasing the size of the dielectric filter, the pass-band frequency can be reduced from 2.5GHz to about 1.5GHz as shown in FIG. 10. The loss can also be reduced. Further, as shown in FIG. 11, reflection can also be suppressed.

[0049] As described above, a resonator and a dielectric filter related to the present invention are useful in transmitting a signal having a desired frequency of high-frequency signals in a microwave-band, a millimeter-wave band, etc. and well applied to a cellular phone or a portable instrument using a high-frequency signal in a wireless LAN, GPS, etc.

[0050] While the foregoing specification has described preferred embodiment(s) of the present invention, one skilled in the art may make many modifications to the preferred embodiment without departing from the invention as defined in the appended claims.

Claims

1. A resonator (10) comprising a stack substrate (11) obtained by stacking multiple layers (13, 15, 16, 18) of dielectric material and multiple layers (12, 14. 17. 19) of conductive material, said stack substrate (11) including:

    a grounding conductor layer (12) formed on a rear side of said stack substrate (11) and spaced apart from the other layers (14,17,19) of conductive material by at least a first one (13) of the layers (13, 15, 16, 18) of dielectric material;

    a plurality of resonant-pattern conductor layers (17, 19) spaced to the grounding conductor layer (12) via said at least first layer (13) of the layers (13. 15, 16. 18), of dielectric material and being respectively spaced from one another by a respective second one (18) of the layers (13, 15, 16, 18) of dielectric material and parts of the resonant-pattern conductor layers (17, 19) being respectively electrically connected in the substrate stacking direction via each of said second layers (18) of dielectric, material so as to form one pair of at least electromagnetically coupled resonant electrodes (191a, 171 a and 191b, 171b), each resonant electrode (191a, 171a and 191b, 171b) having one end as a short-circuiting end connected to the grounding conductor layer (12) and the other end as an open end, to use the open-end side of one of the resonant electrodes (191a, 171a) as a signal input terminal (193a) and the open-end side of the other resonant electrode (191b, 171b) as a signal output terminal (193b),

    wherein the one pair of resonant electrodes (191a, 171a and 191b, 171b) is formed symmet-

rically to each other in any one of a loop shape and a spiral shape and extending in said substrate stacking direction, and
wherein the resonator further comprises an intermediate grounding conductor layer (14) being arranged between the grounding conductor layer (12) and the resonant-pattern conductor layers (17, 19) and including a slot without conductive material, that slot being filled with a third one (15) of the layers (13, 15, 16, 18) of dielectric material and wherein the connection of said one short-circuiting end of said pair of resonant electrodes (191a, 171a and 191b. 171b) to the grounding electrode (12) Is effected through a ground connection to said intermediate grounding conductor layer (14);
characterized in the slot in the intermediate grounding conductor layer (14) comprises a region, said region corresponding in space within the intermediate grounding conductor layer (14) to the space occupied by the resonant electrodes (191a, 171 a and 191b, 171 b) respectively within the resonant-pattern conductor layers (17, 19), whereby the intermediate grounding conductor layer (14) is the only layer comprising conductive material existing between the grounding conductor layer (12) and the resonant electrodes (191a, 171a and 191b, 171b).

2. The resonator according to claim 1, further comprising:

a first capacitor (192a, 172a; C_1) having a stack construction wherein one end thereof is connected to the grounding conductor layer (12) and the other end thereof is connected to any one of the signal input terminal (193a) and the resonant electrode (191a, 171a) whose open-side is used as the signal input terminal (193a); and
a second capacitor (192b, 172b; C_2) having a stack construction wherein one end thereof is connected to the grounding conductor layer (12) and the other end thereof is connected to any one of the signal output terminal (193b) and the resonant electrode (191b, 171b) whose open-end side is used as the signal output terminal (193b).

3. The resonator according to claim 2, wherein the first and second capacitors (192a ,172a; C_1 and 192b. 172b; C_2) use tantalum oxide as dielectric material.

4. A dielectric filter comprising the resonators as claimed in one of the claims 1 to 3 for transmitting a signal input to the signal input terminal (193a) within a desired frequency band and outputting as an output signal at the signal output terminal (193b).

5. The dielectric filter according to claim 4, further comprising a third capacitor (173, 191a, 191b; C_3) having a stack construction wherein one end thereof is connected to any one of the signal input terminal (193a) and the resonant electrode (191a) whose open-end side is used as the signal input terminal (193a) and the other end thereof is connected to any one of the signal output terminal (193b) and the resonant electrode (191b) whose open-end side is used as the signal output terminal (193b),
wherein a frequency band to be blocked within the signal input to the signal input terminal (193a) is determined by the static capacitance of the third capacitor (173, 191a, 19b; C_3).

Patentansprüche

1. Resonator (10), der einen durch Stapeln von mehreren Lagen (13, 15, 16, 18) aus dielektrischem Material und mehreren Lagen (12, 14, 17, 19) aus leitendem Material erhaltenen Substratstapel (11) aufweist, der enthält:

eine Erdleiterlage (12), die auf einer Rückseite des Substratstapels (11) gebildet und durch mindestens eine erste (13) der Lagen aus dielektrischem Material im Abstand von den anderen Lagen (14, 17, 19) aus leitendem Material vorgesehen ist;
mehrere Resonanzmuster-Leiterlagen (17, 19), die durch die mindestens eine erste Lage (13) der Lagen (13, 15, 16, 18) aus dielektrischem Material im Abstand von der Erdleiterlage (12) und im Abstand von einander durch eine jeweilige zweite (18) der Lagen (13, 15, 16, 18) aus dielektrischem Material vorgesehen sind, wobei Teile der Resonanzmuster-Leiterlagen (17, 19) elektrisch jeweils in der Substratstapelrichtung durch eine jede der zweiten Lagen (18) aus dielektrischem Material verbunden sind und auf diese Weise ein Paar aus zumindest elektromagnetisch gekoppelten Resonanzelektroden (191a, 171a, und 191b, 171b) bilden, wobei von jeder Resonanzelektrode (191a, 171a, und 191b, 171b) ein Ende als ein kurzschließendes Ende mit der Erdleiterlage (12) verbunden und das andere Ende als offenes Ende vorgesehen ist, um die Seite mit dem offenen Ende einer der Resonanzelektroden (191a, 171a) als einen Signaleingabeanschluss (193a) und die Seite mit dem offenen Ende der anderen Resonanzelektrode (191b, 171b) als einen Signalausgabeanschluss (193b) zu verwenden,
wobei das eine Paar Resonanzelektroden (191a, 171a, und 191b, 171b) in Schleifenform oder Spiralform symmetrisch zueinander gebildet ist und sich in der Substratstapelrichtung er-

streckt, und
wobei der Resonator weiterhin eine Zwischenerdleiterlage (14) aufweist, die zwischen der Erdleiterlage (12) und den Resonanzmuster-Leiterlagen (17,19) angeordnet ist und einen Schlitz ohne leitendes Material enthält, der mit einer dritten Lage (15) der Lagen (13, 15, 16, 18) aus dielektrischem Material gefüllt ist, und wobei die Verbindung des einen kurzschließenden Endes des Paars Resonanzelektroden (191a, 171a, und 191b, 171b) mit der Erdelektrode (12) durch eine Erdverbindung mit der Zwischenerdleiterlage (14) bewirkt ist;
dadurch gekennzeichnet, dass der Schlitz in der Zwischenerdleiterlage (14) einen Bereich enthält, der innerhalb der Zwischenerdleiterlage (14) räumlich dem durch die Resonanzelektroden (191a, 171a, und 191b, 171b) jeweils innerhalb der Resonanzmuster-Leiterlagen (17, 19) belegten Raum entspricht, wodurch die Zwischenerdleiterlage (14) die einzige leitendes Material aufweisende Lage ist, die zwischen der Erdleiterlage (12) und den Resonanzelektroden (191a, 171a, und 191b, 171b) vorhanden ist.

2. Resonator nach Anspruch 1, der weiterhin aufweist:

Einen ersten Kondensator (192a, 172a; C_1) mit einem Stapelaufbau, dessen eines Ende mit der Erdleiterlage (12) und dessen anderes Ende mit dem Signaleingabeanschluss (193a) oder derjenigen Resonanzelektrode (191a, 171a) verbunden ist, deren Seite mit dem offenen Ende als der Signaleingabeanschluss (193a) verwendet wird; und
einen zweiten Kondensator (192b, 172b, C_2) mit einem Stapelaufbau, dessen eines Ende mit der Erdleiterlage (12) und dessen anderes Ende mit dem Signalausgabeanschluss (193b) oder derjenigen Resonanzelektrode (191b, 171b) verbunden ist, deren Seite mit dem offenen Ende als der Signalausgabeanschluss (193b) verwendet wird.

3. Resonator nach Anspruch 2, wobei der erste und der zweite Kondensator (192a, 172a; C_1 und 192b, 172b; C_2) Tantaloxid als dielektrisches Material verwenden.

4. Dielektrisches Filter, das den Resonator nach einem der Ansprüche 1 bis 3 für die Übertragung eines dem Signaleingabeanschluss (193a) eingegebenen Signals innerhalb eines vorbestimmten Frequenzbandes und Ausgabe als ein Ausgangssignal an dem Signalausgabeanschluss (193b) aufweist.

5. Dielektrisches Filter nach Anspruch 4, das weiterhin einen dritten Kondensator (173, 191a, 191b, C_3) mit einem Stapelaufbau aufweist, dessen eines Ende mit dem Signaleingabeanschluss (193a) oder derjenigen Resonanzelektrode (191a) verbunden ist, deren Seite mit dem offenen Ende als der Signaleingabeanschluss (193a) verwendet wird, und dessen anderes Ende mit dem Signalausgabeanschluss (193b) oder derjenigen Resonanzelektrode (191b) verbunden ist, deren Seite mit dem offenen Ende als der Signalausgabeanschluss (193b) verwendet wird, wobei ein in dem dem Signaleingabeanschluss (193a) eingegebenen Signal zu blockierendes Frequenzband durch die statische Kapazität des dritten Kondensators (173, 191a, 191b, C_3) bestimmt ist.

Revendications

1. Résonateur (10) comportant un substrat d'empilement (11) obtenu en empilant des couches multiples (13, 15, 16, 18) d'un matériau diélectrique et des couches multiples (12, 14, 17, 19) d'un matériau conducteur, ledit substrat d'empilement (11) comportant :

une couche conductrice de mise à la terre (12) formée sur un côté postérieur dudit substrat d'empilement (11) et éloigné des autres couches (14, 17, 19) du matériau conducteur par au moins une première (13) des couches (13, 15, 16, 18) de matériau diélectrique ;
une pluralité de couches conductrices à motif résonnant (17, 19) espacées de la couche conductrice de mise à la terre (12) par l'intermédiaire de ladite au moins première couche (13) des couches (13, 15, 16, 18) de matériau diélectrique et étant respectivement espacées l'une de l'autre par une seconde couche respective (18) parmi les couches (13, 15, 16, 18) de matériau diélectrique et des parties des couches conductrices à motif résonnant (17, 19) étant respectivement reliées électriquement dans la direction d'empilement du substrat par l'intermédiaire de chacune desdites secondes couches (18) de matériau diélectrique de manière à former une paire d'électrodes résonnantes au moins couplées électromagnétiquement (191a, 171a et 191b, 171b), chaque électrode résonnante (191a, 171a et 191b, 171b) possédant une extrémité en tant qu'extrémité de court-circuit reliée à la couche conductrice de mise à la terre (12) et l'autre extrémité en tant qu'extrémité ouverte, afin d'utiliser le côté d'extrémité ouverte de l'une des électrodes résonnantes (191a, 171a) en tant que borne d'entrée de signal (193a) et le côté d'extrémité ouverte de l'autre électrode résonnante (191b, 171b) en tant que borne de sortie de signal (193b),
dans lequel la première paire d'électrodes ré-

sonnantes (191a, 171a et 191b, 171b) est formée symétriquement l'une par rapport à l'autre selon l'une quelconque d'une forme en boucle ou d'une forme en spirale et s'étendant dans ladite direction d'empilement du substrat, et dans lequel le résonateur comporte en outre une couche conductrice de mise à la terre intermédiaire (14) disposée entre la couche conductrice de mise à la terre (12) et les couches conductrices à motif résonnant (17, 19) et comprenant une fente sans matériau conducteur, cette fente étant remplie d'une troisième couche (15) parmi les couches (13, 15, 16, 18) de matériau diélectrique et dans lequel la connexion de ladite de première extrémité de court-circuit de ladite paire d'électrodes résonnantes (191a, 171a et 191b, 171b) à l'électrode de mise à la terre (12) est effectuée par l'intermédiaire d'une connexion de mise à la terre à ladite couche conductrice de mise à la terre intermédiaire (14) ; **caractérisé en ce que** la fente dans la couche conductrice de mise à la terre intermédiaire (14) comporte une région, ladite région correspondant dans l'espace dans la couche conductrice de mise à la terre intermédiaire (14) à l'espace occupé par les électrodes résonnantes (191a, 171a et 191b, 171b) respectivement dans les couches conductrices à motif résonnant (17, 19), moyennant quoi la couche conductrice de mise à la terre intermédiaire (14) est la seule couche comportant un matériau conducteur existant entre la couche conductrice de mise à la terre (12) et les électrodes résonnantes (191a, 171a et 191b, 171b).

2. Résonateur selon la revendication 1, comportant en outre :

un premier condensateur (192a, 172a ; C_1) possédant une structure en empilement dans lequel une extrémité de celui-ci est reliée à la couche conductrice de mise à la terre (12) et son autre extrémité est reliée à l'une quelconque de la borne d'entrée de signal (193a) ou de l'électrode résonnante (191a, 171a) dont le côté ouvert est utilisé en tant que borne d'entrée de signal (193a) ; et un second condensateur (192b, 172b ; C_2) possédant une structure en empilement dans lequel sa première extrémité est reliée à la couche conductrice de mise à la terre (12) et son autre extrémité est reliée à l'une quelconque de la borne de sortie de signal (193b) ou de l'électrode résonnante (191b, 171b) dont l'extrémité ouverte est utilisée en tant que borne de sortie de signal (193b).

3. Résonateur selon la revendication 2, dans lequel les premiers et seconds condensateurs (192a, 172a ; C_1 et 192b, 172b ; C_2) utilisent de l'oxyde de tantale en tant que matériau diélectrique.

4. Filtre diélectrique comportant les résonateurs selon l'une des revendications 1 à 3 pour transmettre un signal entré à la borne d'entrée de signal (193a) dans une bande de fréquence désirée et le délivrer en tant que signal de sortie à la borne de sortie de signal (193b).

5. Filtre diélectrique selon la revendication 4, comportant en outre un troisième condensateur (173, 191a, 191b ; C_3) possédant une structure en empilement dans lequel sa première extrémité est reliée à l'une quelconque de la borne d'entrée de signal (193a) ou de l'électrode résonnante (191a) dont le côté d'extrémité ouverte est utilisé en tant que borne d'entrée de signal (193a) et son autre extrémité est reliée à l'une quelconque de la borne de sortie de signal (193b) ou de l'électrode résonnante (191b) dont le côté d'extrémité ouverte est utilisé en tant que borne de sortie de signal (193b),
dans lequel une bande de fréquence à bloquer dans le signal entré à la borne d'entrée de signal (193a) est déterminée par la capacité statique du troisième condensateur (173, 191a, 191b ; C_3).

F I G. 1

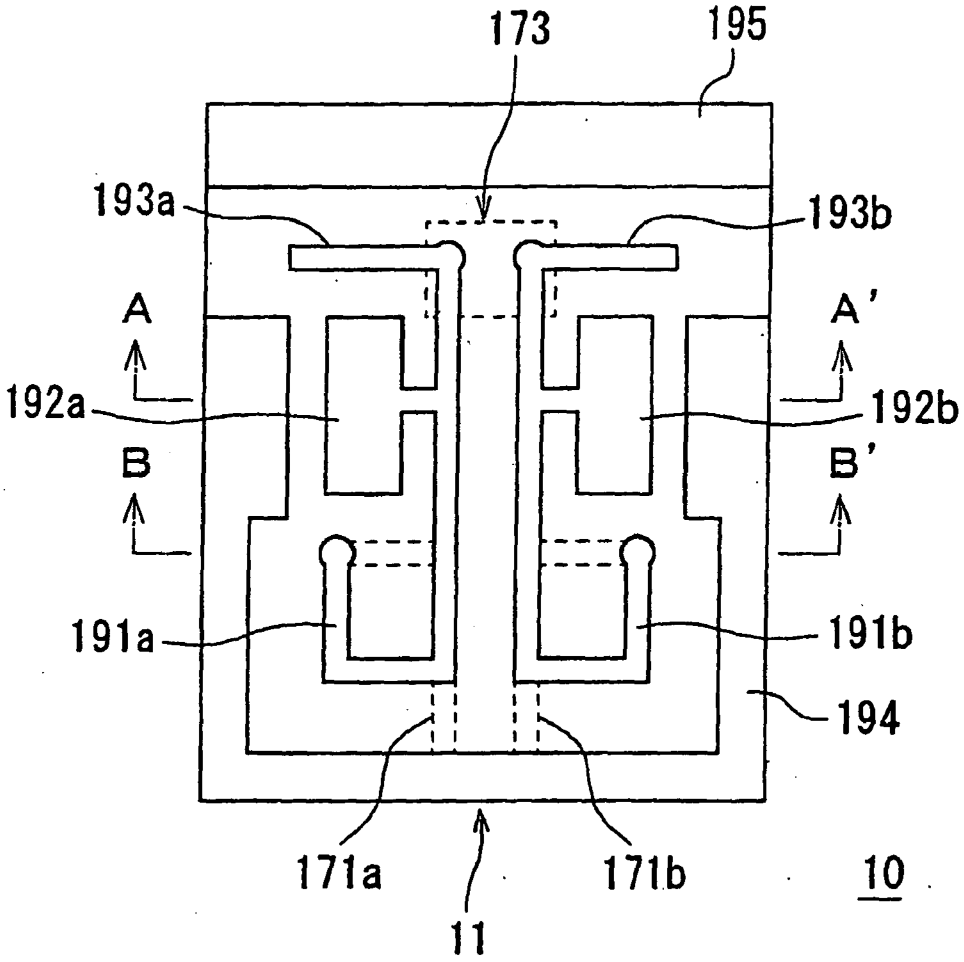


FIG. 2

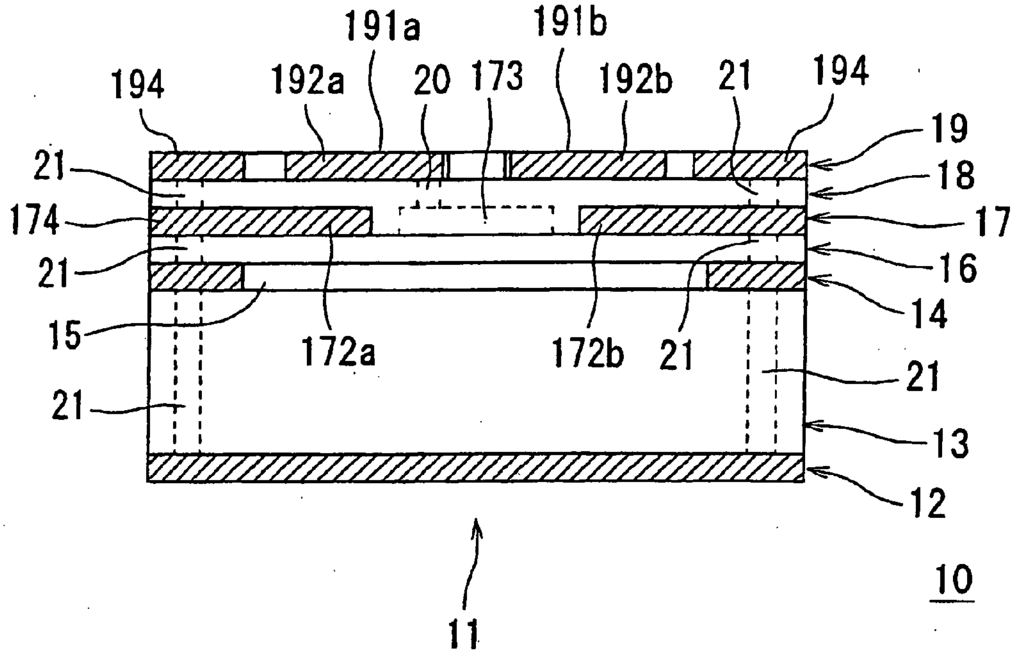

191a
191b
194
192a
20
173
192b
21
194
19
21
18
174
17
21
16
14
15
172a
172b
21
21
21
13
12
11
10

FIG. 3

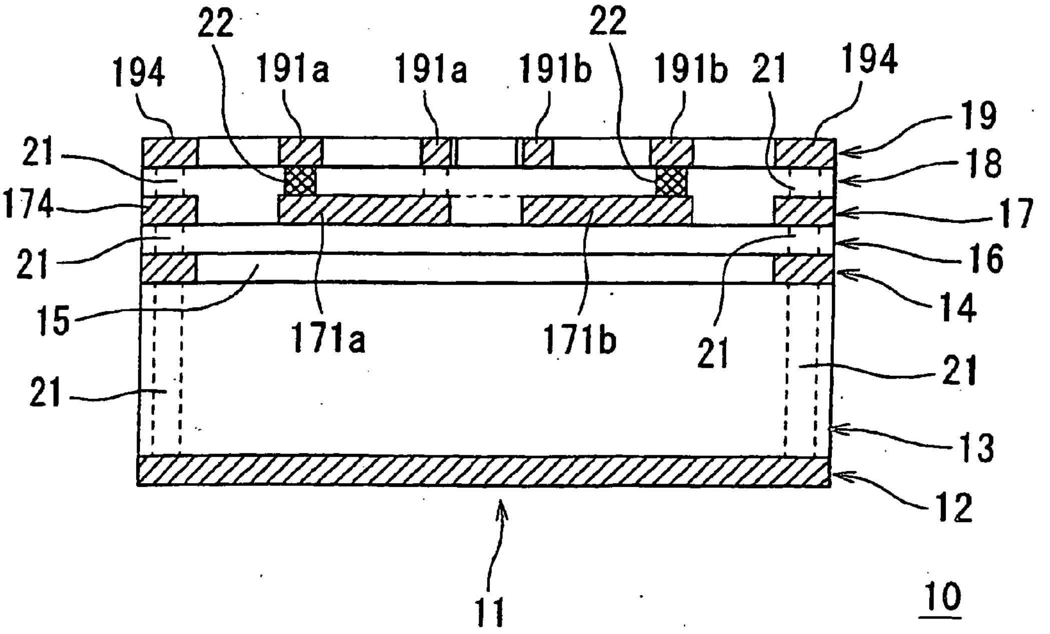

22
22
194
191a
191a
191b
191b
21
194
19
21
18
174
17
21
16
14
15
171a
171b
21
21
21
13
12
11
10

FIG. 4

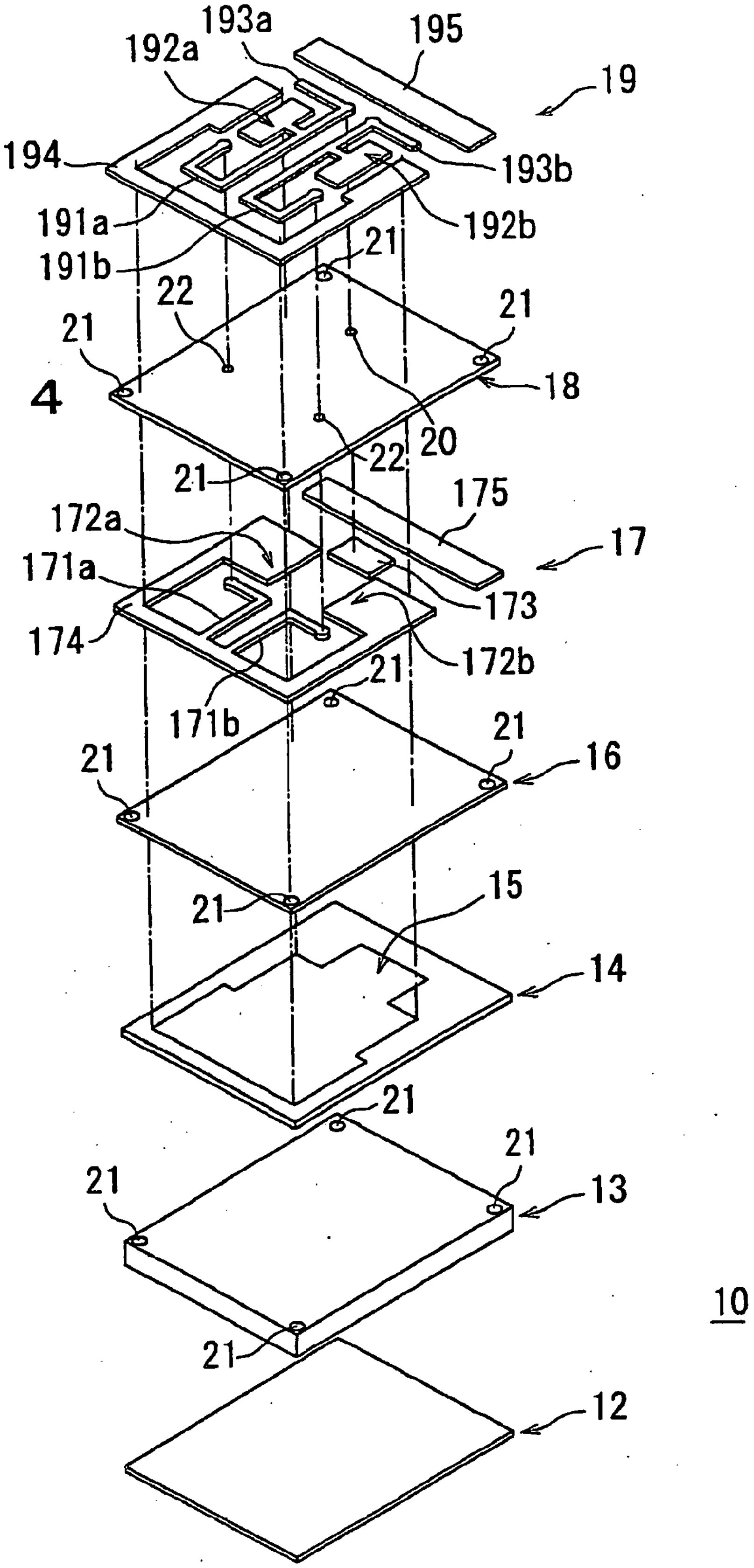

193a
195
192a
19
194
193b
191a
192b
191b
21
22
21
21
18
20
22
21
175
172a
17
171a
173
174
172b
21
171b
21
16
21
21
15
14
21
21
13
21
21
10
12

FIG. 5

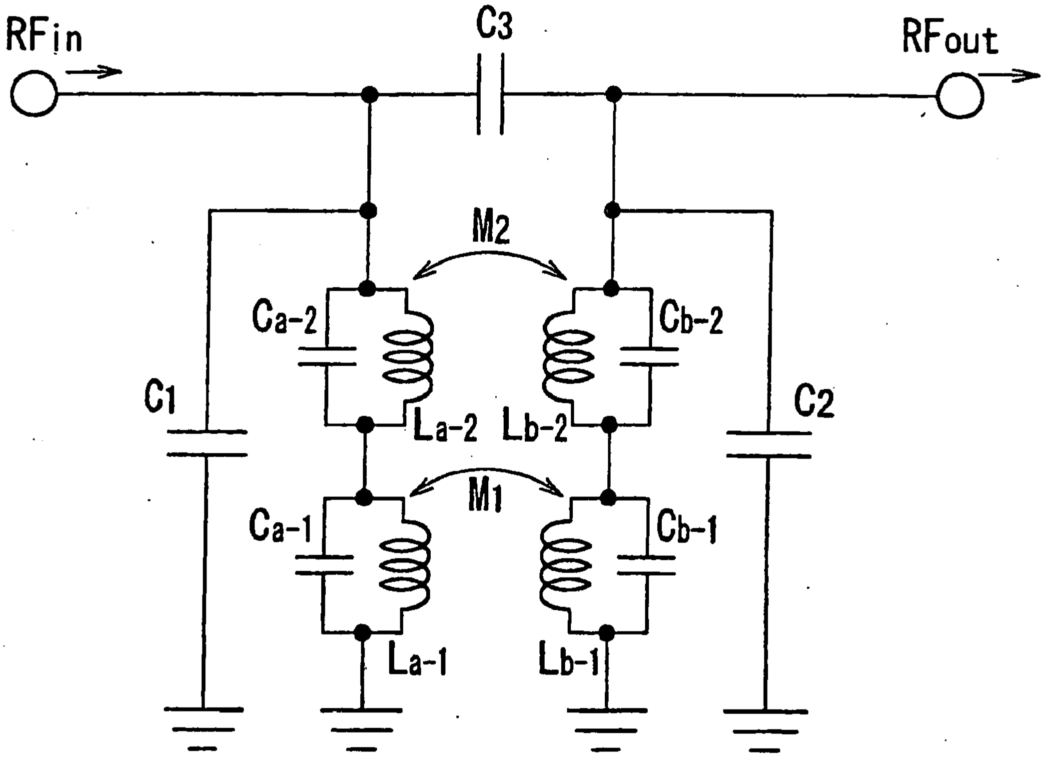
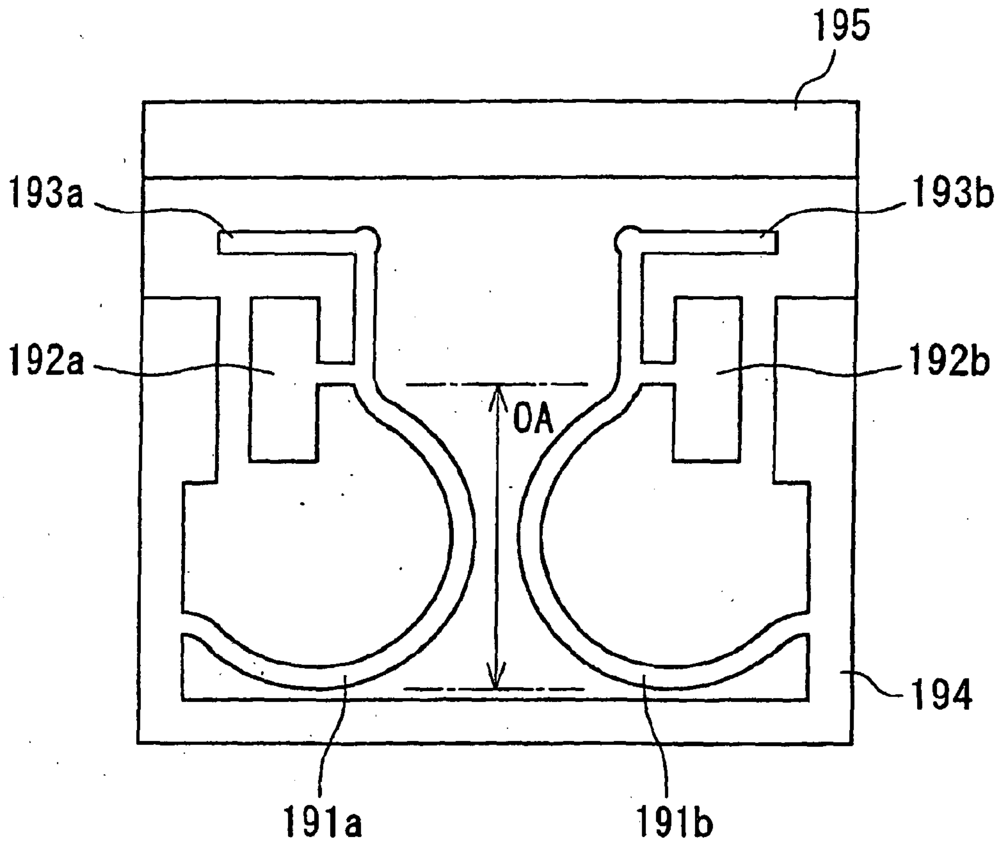
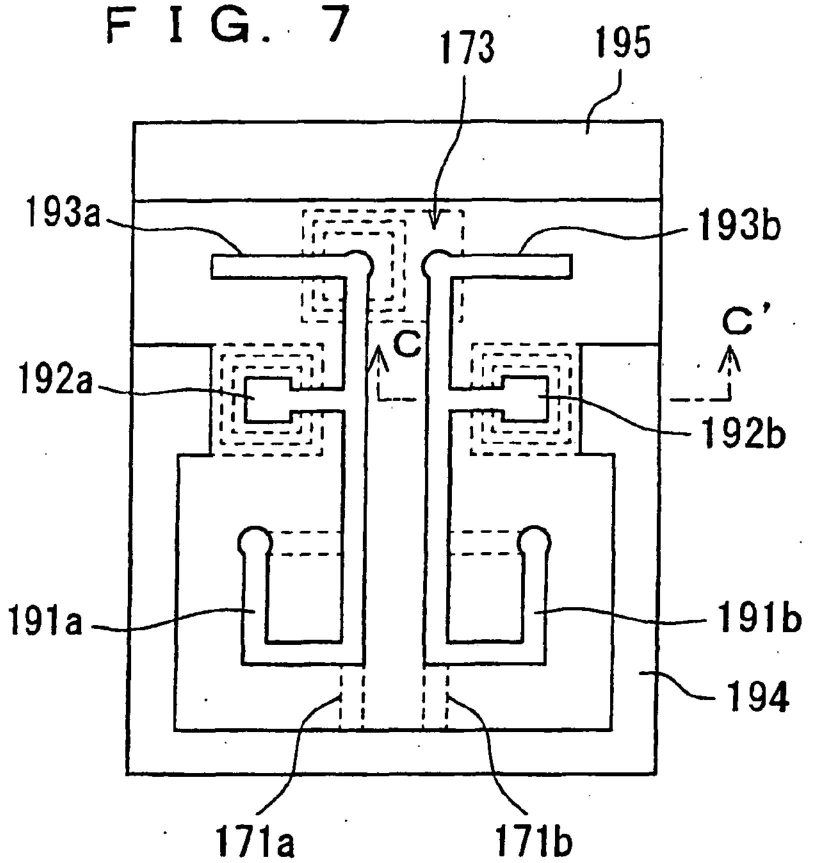


FIG. 6



F I G. 7


173
195
193a
193b
C
C'
192a
192b
191a
191b
194
171a
171b

F I G. 8

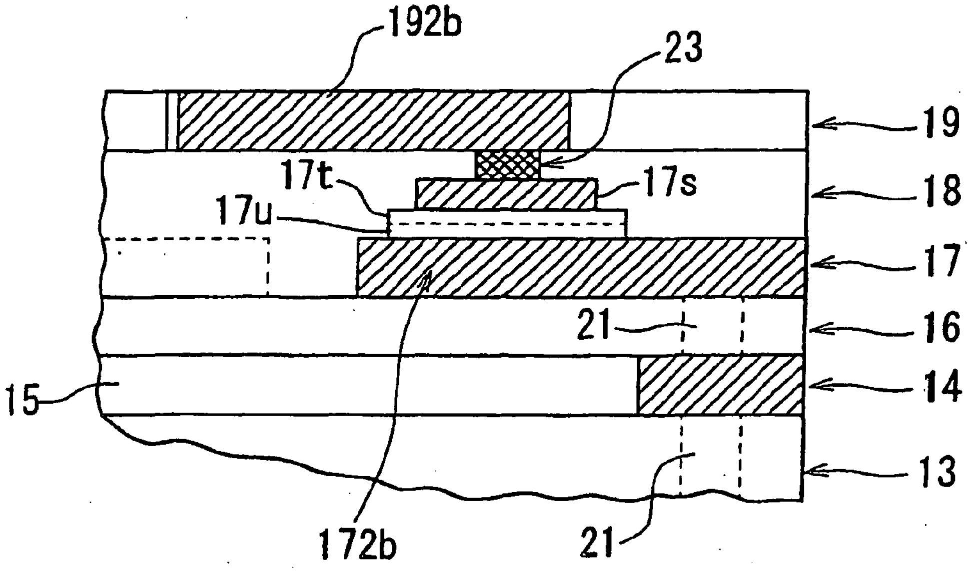

192b
23
19
17t
17s
18
17u
17
21
16
15
14
13
172b
21

FIG. 9

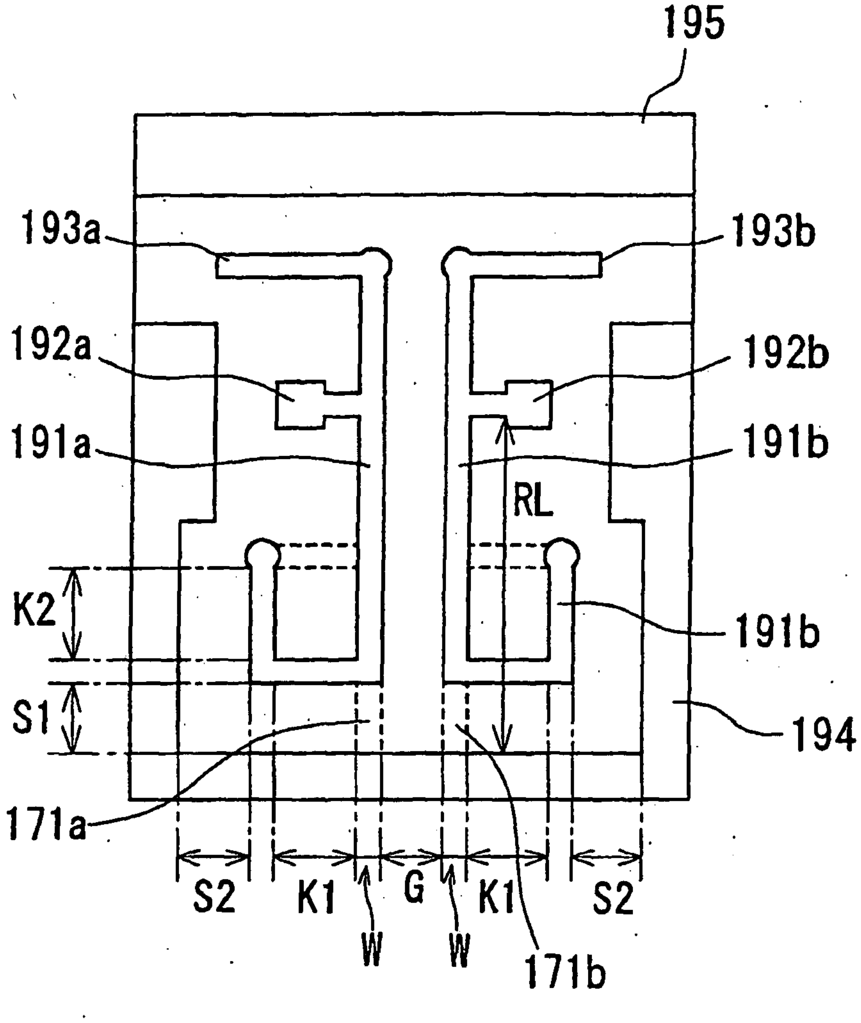

195
193a
193b
192a
192b
191a
191b
RL
191b
K2
S1
194
171a
S2
K1
W
G
W
K1
S2
171b

FIG. 10

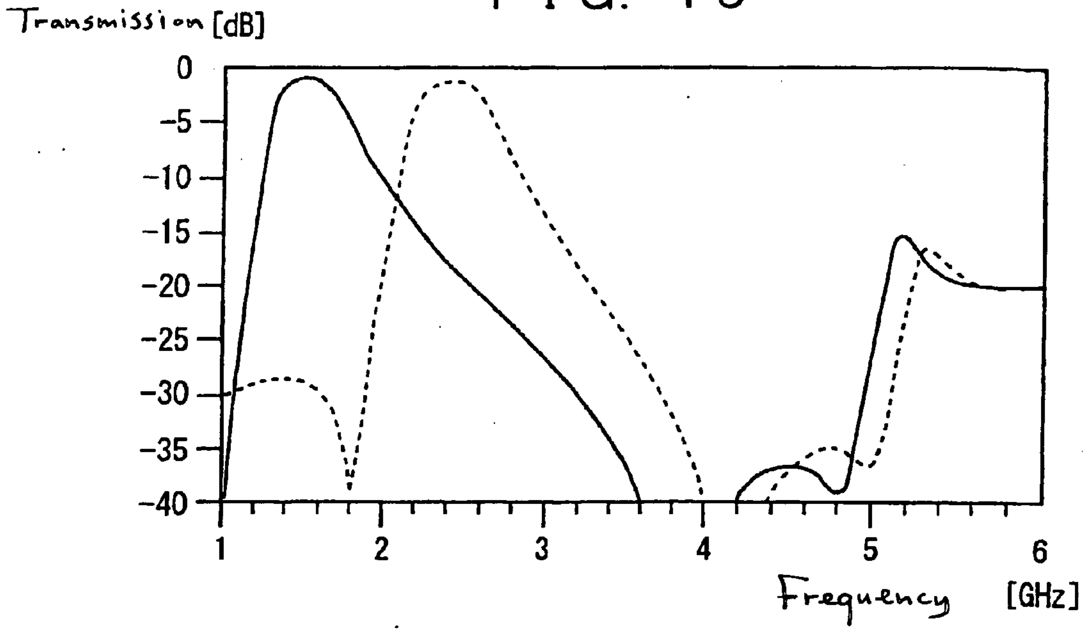
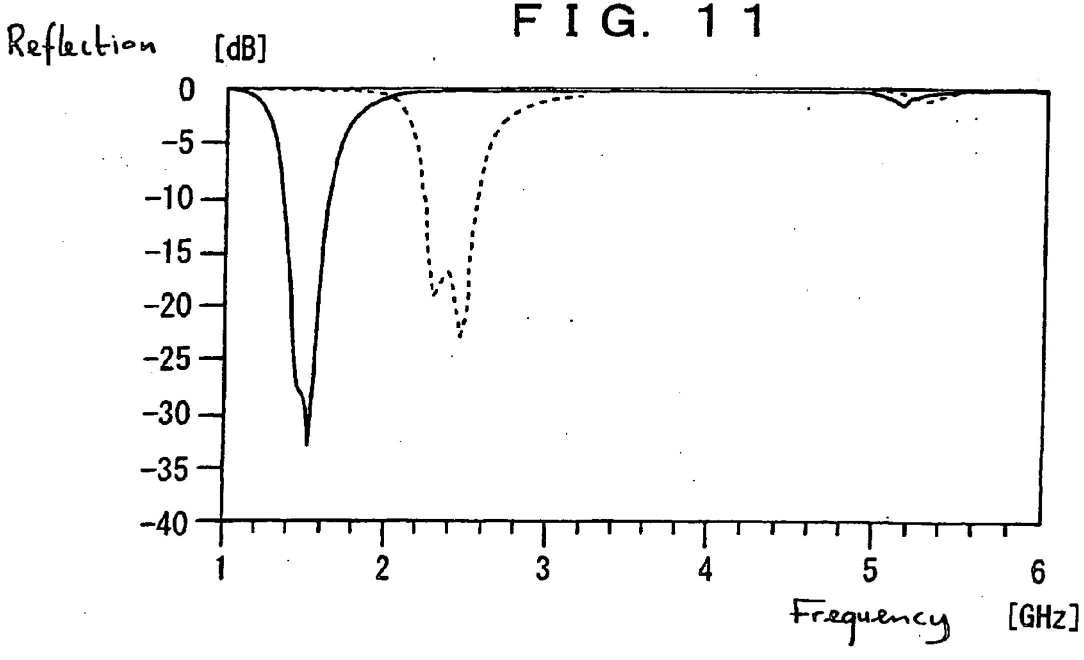

Transmission [dB]
0
-5
-10
-15
-20
-25
-30
-35
-40
1
2
3
4
5
6
Frequency [GHz]

FIG. 11


Reflection [dB]
0
-5
-10
-15
-20
-25
-30
-35
-40
1
2
3
4
5
6
Frequency [GHz]

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 5777533 A **[0001] [0007]**