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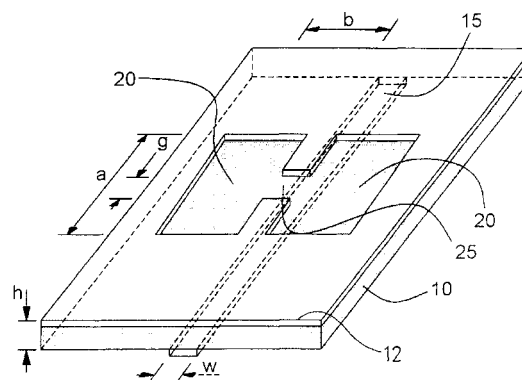
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(54) **Transmission line resonator with dielectric substrate having an etched structure on the ground plane**

(57) A resonator having a defected ground structure (DGS) coupling an electronic element at the position of a gap in a DGS cell formed on a ground plane of a dielectric substrate is provided, to thereby control the Q factor and the resonant frequency of the resonator smoothly. The resonator includes a dielectric substrate formed of a dielectric material, a ground plane having an etched portion including a gap forming an electric field density portion on either inner side, with a conductive film coated on one surface of the dielectric substrate, a transmission line coated at the gap position on the surface opposing the ground plane on the dielectric substrate, to thereby transmit a signal, and an electronic element whose either end is connected with either end of the ground plane.

FIG. 1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a resonator having a defected ground structure (DGS) on a dielectric, and more particularly, to a resonator having a defected ground structure in which one or more electronic elements are coupled to a partially etched defected structure on a conductive ground plane of a dielectric substrate, to thereby simply control a Q factor and a resonant frequency of the resonator.

Description of the Related Art

[0002] Recently, the structure of a DGS circuit in which a defected pattern is etched on a conductive ground plane of a dielectric substrate, and one or more transmission lines are formed on the rear surface of the conductive ground plane is applied to a microwave band and a millimeter wave band, which is vividly being researched.

[0003] As shown in FIG. 18, a transmission line 15 having the structure of artificial periodic defects 21a-21e on a ground plane 12 of a dielectric substrate 10 represents a low loss slow-wave characteristic and a stop band characteristic at a particular frequency band (see Y. Qian, F. G. Yang, and T. Itoh, "Characteristics of microstrip lines on a unipolar compact PBG ground plane" APMC '98 Dig., pp. 589-592. Dec. 1998, and V. Radisic, Y. Qian, R. Coccioli, and T. Itch, "Novel 2-D photonic bandgap structure for microstrip lines" IEEE Microwave Guide Wave Lett., vol. 8, No. 2, pp. 69-71, Feb. 1998).

[0004] Also, these characteristics are applied in various forms to an increase of the efficiency and the output power of a power amplifier, an improvement of the radiation pattern of an antenna, a filter and a power distributor for removing harmonics (see M. P. Kesler, J. G. Maloney, and B. L. Shirley, "Antenna design with the use of photonic bandgap material as all dielectric planar reflectors" Microwave Opt. Tech. Lett. vol. 11, No. 4, pp. 169-174, Mar. 1996, and V. Radisic, Y. Qian, R. Coccioli, and T. Itch, "Novel 2-D photonic bandgap structure for microstrip lines" IEEE Microwave Guide Wave Lett., vol. 8, No. 2, pp. 69-71, Feb. 1998). See also the following paper (C. S. Kim, J. S. Park, D. Ahn and K. Y. Kim, "A design of 3dB power divider using slow-wave characteristic" Korean Electronic Wave Association, paper vol. 10, No. 5, pp. 694-700, 1999, and J. I. Park, C. S. Kim, J. S. Park, Y. Qian, D. Ahn, and T. Itoh, "Modeling of photonic bandgap and its application for the low-pass filter design" APMC '99, Dig., vol. 2, pp. 331-334, Nov. 1999).

[0005] As a resonator is designed using the DGS circuit having the above periodic array structure, the cell

size or the gap interval formed on the center of the cell in the DGS circuit formed by etching the defect structure on the ground plane of the dielectric substrate should be set.

[0006] A possible circuit using the DGS cell is shown in FIG. 18. A conventional example of FIG. 18 shows a filter designed by using a resonant characteristic set by each DGS cell in which a number of DGS cells 21a-21e have a periodic array on a one-dimensional plane.

[0007] As described above, the parameters such as areas and intervals of the gap of the DGS cells should be set to define a resonant characteristic, to thereby form a resonator using the DGS cell. Since it is difficult to design a filter having a desired characteristic using a single DGS cell in practice, the resonant characteristic should be set through a periodic array of a one-dimensional or two-dimensional array.

[0008] Thus, in the case that a DGS cell is applied to a filter in the conventional way, the values of an inductance L_{in} , a capacitance C_{in} and an impedance Z_0 of a unit DGS cell in a resonator (hereinafter referred to as a DGS circuit) using the etched defected structure formed on the ground plane of the dielectric substrate in order to set a resonant frequency, are determined by the width of a microstrip being a transmission line and the area and gap of the etched defect. Accordingly, since a Q factor of the resonator is low, it is difficult to use it in an actual circuit, and it is very difficult to control a resonant frequency in various forms.

[0009] Also, since a resonant circuit using an existing PBG (Photonic Band Gap) structure can be designed by changing the size and gap of the PBG structure only with a periodic array method, the modeling is limited at present. Also, although the resonator circuit can be applied to the improvement of the radiating pattern of the antenna and the band pass filter, using the PBG structure, only the attenuation band and the group delay characteristic of the PBG structure are ascertained. Thus, its imperfect characteristic is improper for application in an actual frequency element.

SUMMARY OF THE INVENTION

[0010] To solve the above problems, it is an object of the present invention to provide a resonator having defected gap structure (DGS) on a ground plane of a dielectric, in which one or more electronic elements are coupled on a ground plane of a DGS circuit, to thereby simply control a Q factor and a resonant frequency of the resonator, and a power applied ratio is heightened to reduce a power loss ratio at minimum, to thereby enlarge an application field to a high-frequency circuit such as a resonator and a filter.

[0011] To accomplish the above object of the present invention, there is provided a resonator comprising: a dielectric substrate formed of a dielectric material; a ground plane having an etched portion including a gap forming an electric field density portion on either inner

side, with a conductive film coated on one surface of the dielectric substrate; a transmission line coated at the gap position on the surface opposing the ground plane on the dielectric substrate, to thereby transmit a signal; and an electronic element whose either end is connected with either end of the ground plane.

[0012] The electronic element is a resistor, in which a resistance value is adjusted to simply thereby control a Q factor of the resonator, or is a capacitor in which a resonant frequency of the resonator is varied according to variation in the capacitance of the capacitor.

[0013] The electronic element is an inductor in which a resonant frequency of the resonator is varied according to variation in the inductance of the inductor.

[0014] The electronic element is a varactor diode, in which a voltage applied to both ends of the varactor diode is controlled to vary a capacitance, to thereby vary a resonant frequency of the resonator.

[0015] The resonator further comprises a signal input line and a signal output line formed on the surface opposing the ground plane, spaced apart a predetermined interval from the transmission line, in which the front end of the transmission line is connected with the ground plane via a pin hole.

[0016] As described above, the electronic element is coupled on the gap position of the DGS cell formed on the ground plane on the dielectric substrate in the present invention. As a result, the resonator can be applied as a frequency controlled element in various forms in which a Q factor and a resonant frequency can be controlled smoothly, and a power loss rate is reduced at minimum.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The object and other advantages of the present invention will become more apparent by describing in detail the structures and operations of the present invention with reference to the accompanying drawings, in which:

FIG. 1 shows the structure of a general DGS cell for explaining the present invention;

FIG. 2 is a graph showing the simulation characteristics of the DGS cell shown in FIG. 1;

FIG. 3 shows an electric field distribution of the DGS cell shown in FIG. 1;

FIG. 4 is an equivalent circuit diagram of the DGS cell shown in FIG. 1;

FIG. 5 shows the structure of an embodiment of the present invention, for controlling a Q factor;

FIG. 6 is an equivalent circuit diagram of the embodiment shown in FIG. 5;

FIG. 7 is a graph showing the measured results with respect to the influence of an external resistor in the embodiment shown in FIG. 5;

FIG. 8 shows the structure of a parallel DGS resonator in which an external inductor or capacitor is

connected according to an embodiment of the present invention;

FIG. 9 is an equivalent circuit diagram of the embodiment shown in FIG. 8;

FIG. 10 is a graph showing the measured results in the case that a capacitor is connected as an external element in the embodiment shown in FIG. 8;

FIG. 11 is a graph showing the measured results in the case that an inductor is connected as an external element in the embodiment shown in FIG. 8;

FIGs. 12A and 12B show a top view and a bottom view of a quarter wave DGS resonator in the embodiment of the present invention;

FIG. 13 shows the structure of a unit DGS cell for designing a RF switch;

FIG. 14 is an equivalent circuit diagram of the unit DGS cell shown in FIG. 13;

FIG. 15 shows the structure of a RF switch using the unit DGS cell shown in FIG. 13;

FIGs. 16A and 16B show a top view and a bottom view of a DGS RF switch shown in FIG. 15;

FIG. 17 shows the measured results of the switching characteristics of the RF switch using the unit DGS cell shown in FIG. 13; and

FIG. 18 shows an example of a filter in which conventional DGS cells are periodically arrayed.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0018] Preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

[0019] Referring to FIGs. 1-4, the basic structure of a DGS circuit will be described.

[0020] As shown in FIG. 1, the basic structure of the DGS circuit that is used in the present invention is formed by etching a DGS cell 20, that is, a defect pattern on a ground plane 12 of a dielectric substrate 10.

[0021] The ground plane 12 is formed of a conductive metallic film coated on the dielectric substrate 10.

[0022] Thus, the DGS cell 20 is formed by etching part of the conductive metallic film forming the ground plane 12 on the dielectric substrate 10. When the DGS cell 20 is formed on the ground plane 12, the middle portion of the DGS cell 20 is not etched, to thereby form a gap 25.

[0023] A microstrip 15 is formed for playing a role of a transmission line on the surface opposing the ground plane 12 on the dielectric substrate 10. The microstrip 15 is formed by coating a conductive metallic film by a predetermined width w on one surface of the dielectric substrate 10.

[0024] When a signal is applied to one end of the microstrip 15 of the DGS circuit having the above structure, and a signal is output from the other end, a resonance occurs at a portion where the DGS cell 20 is located, with a result that the microstrip 15 plays a role of a resonator.

[0025] In order to obtain an equivalent circuit of the

basic DGS circuit shown in FIG. 1, the simulated results are illustrated in FIG. 2. The simulation was performed by using an EM simulator which is Ansoft-HFSS V. 6.0 of Ansoft Korea.

[0026] As shown in FIG. 2, it can be seen that an attenuation pole turns up around 8GHz in the case of a DGS cell having the FIG. 1 structure. As shown in FIG. 3, it can be seen that the strongest electric field distribution appears at the position of the gap 25 of the DGS cell 20 formed below the microstrip 15.

[0027] RT/Duroid 5880 of Rogers having a dielectric ratio of 2.2 and a thickness (h) of 31mil (0.7874mm) was used as a substrate used for fabricating the DGS cell shown in FIG. 1. In the parameters of the DGS cell, the width (a) and length (b) of the DGS cell were designed as 5mm, respectively and the gap interval (g) were designed as 0.5mm.

[0028] The width of the transmission line, that is, the microstrip 15 were designed as 2.4mm in which the characteristic impedance was 50 ohm in order to be same as that of the existing structure.

[0029] As described above, when the DGS circuit is used as a filter having a specific resonance frequency, a resonant frequency is determined by the area of the DGS cell 20 which is an area defined by "a" and "b", the interval g of the gap 25, the width w of the microstrip 15, the dielectric ratio of the dielectric substrate 10, and the thickness h of the dielectric substrate 10. The equivalent circuit of the unit DGS cell as shown in FIG. 1 is shown in FIG. 4 in general.

[0030] In the equivalent circuit shown in FIG. 4, an inductance L_{in} , a capacitance C_{in} and an impedance Z_0 forming a general resonator are determined by each parameter forming the DGS cell 20 of FIG. 1, and the general resonator has an attenuation pole due to the resonant frequency of the general parallel LC circuit.

[0031] In the DGS circuit having the basic structure, an external resistor, an inductor, or a capacitor is coupled at the position of the gap 25 in the DGS cell 20. Accordingly, the characteristic of the resonator can be enhanced to thereby simply control a Q factor and a resonant frequency, which will be described below according to each embodiment.

[0032] The first embodiment of the present invention is a circuit for simply controlling a Q factor of the resonator through an external resistor (R_{ex}) 30 that is connected at the position of the gap 25 in the DGS circuit having the above basic structure as shown in FIG. 1, which will be described with reference to FIGs. 5-7.

[0033] FIG. 5 shows the structure of an embodiment of the present invention, for controlling a Q factor, among the embodiments of the DGS circuit in which an electronic element is coupled. FIG. 6 is an equivalent circuit diagram of the embodiment shown in FIG. 5. FIG. 7 is a graph showing the measured results with respect to the influence of an external resistor in the embodiment shown in FIG. 5.

[0034] In the first embodiment shown in FIG. 5, an ex-

ternal resistor (R_{ex}) 30 formed of a chip resistor is coupled at the position of the gap 25 in the DGS cell 20 formed on the ground plane 12 of the dielectric substrate 10, of which the equivalent circuit is shown in FIG. 6.

[0035] In the equivalent circuit of FIG. 6, an inductance L_{in} , a capacitance C_{in} and an impedance Z_0 are determined by the parameters of the DGS cell 20, that is, an area (a x b) of the DGS cell 20, an interval (g) of the gap 25, and the width (w) of the microstrip 15, in addition to the external resistor (R_{ex}) 30 in the equivalent circuit. The first embodiment provides the same effect as that of the case that the external resistor (R_{ex}) 30 is connected in parallel to the inductance L_{in} and the capacitance C_{in} of the DGS cell 20.

[0036] The variation of the Q factor according to the change in the resistance of the external resistor (R_{ex}) 30 is shown in FIG. 7. It can be seen that the Q factor is lowered according to the decrease in the resistance of the external resistor (R_{ex}) 30, as in the cases that an external resistor (R_{ex}) 30 is not inserted, that is shown as a DGS cell having the same structure as that of FIG. 1, an external resistor (R_{ex}) 30 of 100 ohm is connected, that is shown as a 100 ohm curve, and an external resistor of 300 ohm is connected, that is shown as a 300 ohm curve.

[0037] Thus, if a negative resistor (-R) is connected at the position of the gap 25 in the general DGS circuit having the FIG. 1 structure, a remarkably enhanced Q factor can be obtained in comparison to that of the DGS circuit of FIG. 1.

[0038] If the negative resistor (-R) is connected, a parallel mixture resistance with the internal resistor (R_{in}) is $R_{in} \times (-R_{ex}) / \{R_{in} + (-R_{ex})\}$, in which the denominator can be formed close to zero. Accordingly, the resistance is made an infinite magnitude theoretically, to thereby set the Q factor infinitely.

[0039] The second embodiment of the present invention is a resonant circuit for simply setting and resonating a desired resonant frequency of the resonator in which a capacitor (C_{ex}) 35 or an inductor (L_{ex}) 35 is connected at the position of the gap 25 in the DGS circuit having the above basic structure as shown in FIG. 1, which will be described with reference to FIGs. 8-12.

[0040] FIG. 8 shows the structure of a parallel DGS resonator in which an external inductor or capacitor is connected according to an embodiment of the present invention. FIG. 9 is an equivalent circuit diagram of the embodiment shown in FIG. 8. FIG. 10 is a graph showing the measured results in the case that a capacitor is connected as an external element in the embodiment shown in FIG. 8. FIG. 11 is a graph showing the measured results in the case that an inductor is connected as an external element in the embodiment shown in FIG. 8. FIGs. 12A and 12B show a top view and a bottom view of a quarter wave DGS resonator in the embodiment of the present invention.

[0041] In the second embodiment of FIG. 8, feed lines 16a and 16b each having a predetermined width (w) are

formed in either side of one end of the microstrip 15 in the basic structure of the DGS circuit of FIG. 1. The feed lines 16a and 16b are formed in either side of one end of the microstrip 15 so as to keep a predetermined interval (s) with respect to the microstrip 15.

[0042] The other end of the microstrip 15 is connected to the ground plane 12 with a lead wire through a via hole 40.

[0043] The via hole 40 means a hole formed on the dielectric substrate 10.

[0044] The second embodiment having the above structure forms the same resonant circuit as that of the equivalent circuit shown in FIG. 9.

[0045] Referring to FIG. 9, in/out coupling capacitors C_1 and C_2 connected to the lines, that is, the input/output ends of the feed lines 16a and 16b are capacitors C_1 and C_2 formed by an interval (s) between one end of the microstrip 15 and a pair of feed lines 16a and 16b.

[0046] The via hole 40 plays a role of grounding one end of the parallel resonant circuit formed by the DGS cell 20, and the external inductor (L_{ex}) 35 or the capacitor (C_{ex}) 35 on the ground plane 12.

[0047] The inductor (L_{in}) and the capacitor (C_{in}) in the equivalent circuit is a resonant circuit formed by the DGS cell 20. The external inductor (L_{ex}) 35 or the capacitor (C_{ex}) 35 is connected at the position of the gap 25 in the DGS cell 20. The resonant circuit has been constructed so that the value of the inductance of the inductor (L_{in}) or the capacitance of the capacitor (C_{in}) is varied.

[0048] Thus, the parallel resonant circuit using the DGS circuit shown in FIG. 8 can determine a resonant frequency by connecting the external inductor (L_{ex}) 35 or the capacitor (C_{ex}) 35 at the position of the gap 25 in the DGS cell 20.

[0049] Therefore, the value of the external inductor (L_{ex}) 35 or the capacitor (C_{ex}) 35 has only to be controlled variably in order to control a resonant frequency.

[0050] Examples of the resonant frequency control will be described with reference to FIGs. 10 and 11, according to the cases of the external inductor (L_{ex}) and the capacitor (C_{ex}).

[0051] The graph shown in FIG. 10 illustrates variation of the resonant frequency according to the capacitance variation of the external capacitor (C_{ex}) 35 connected when the external capacitor (C_{ex}) 35 is connected in parallel to the parallel resonant circuit (C_{in} , L_{in}) in the DGS cell 20 in order to control the resonant frequency.

[0052] Referring to FIG. 10, in the case that a basic resonant frequency of a short-circuited $1/4$ wavelength ($\lambda/4$) parallel resonator having no etched pattern on the ground plane 12 of the dielectric substrate 10 is about 3GHz, a DGS resonator having no external capacitor (C_{ex}) 35 which is the basic structure of the DGS circuit shown in FIG. 1 forms a basic resonant frequency at 2.4GHz because of a slow-wave effect of the DGS cell.

[0053] Also, if an external capacitor (C_{ex}) 30 is added

in the DGS cell 20, it can be seen that a resonant frequency is reduced since the capacitance of the capacitor (C_{in}) in the resonator (C_{in} , L_{in}) of the DGS cell 20 is increased.

[0054] That is, if the external capacitors (C_{ex}) 35 each having 0.5pF, 2pF and 3pF are connected, it can be seen from FIG. 10 that a resonant frequency is controlled downwards according to the increase in the capacitance of the external capacitor (C_{ex}).

[0055] Meanwhile, in the case that the external inductor (L_{ex}) 35 is connected to the resonator (C_{in} , L_{in}) formed by the DGS cell 20, the total inductance is reduced owing to the parallel connection of the external inductor (L_{ex}) 35 and the inductor (L_{in}) of the DGS cell.

[0056] Thus, as the inductance of the external inductor (L_{ex}) 35 decreases, it can be seen that the resonant frequency increases as shown in FIG. 11.

[0057] That is, if the external inductors (L_{ex}) 35 each having 4.7nH and 2.7nH are connected, it can be seen from FIG. 11 that a resonant frequency is controlled upwards according to the decrease in the total inductance.

[0058] Here, when the external inductor (L_{ex}) 35 is connected, a phenomenon of lowering the Q factor of the resonator has occurred since the external inductor is made of a chip inductor and thus contains a parasitic resistance. Because of a limit to the inductance, a relatively large resonant frequency has not moved as in the case of the capacitance (FIG. 10).

[0059] FIGs. 12A and 12B show a top view and a bottom view of a quarter wave ($\lambda/4$) DGS resonator that is used in the embodiment of the present invention, respectively.

[0060] The third embodiment of the present invention is a circuit that can be used as a RF switch using the DGS circuit having the above basic structure as shown in FIG. 13, which will be described with reference to FIGs. 13-17.

[0061] FIG. 13 shows the structure of a unit DGS cell for designing a RF switch. FIG. 14 is an equivalent circuit diagram of the unit DGS cell shown in FIG. 13. FIG. 15 shows the structure of a RF switch using the unit DGS cell shown in FIG. 13. FIGs. 16A and 16B show a top view and a bottom view of a DGS RF switch shown in FIG. 15. FIG. 17 shows the measured results of the switching characteristics of the RF switch using the unit DGS cell shown in FIG. 13.

[0062] FIG. 13 shows a unit DGS cell 20 etched on the ground plane 12 of the dielectric substrate 10 in order to embody a RF switch using a DGS cell, of which equivalent circuit is shown in FIG. 14.

[0063] In FIG. 13, a shaded portion is a transmission line of a microstrip 15. The width (w) of the microstrip 15 has been realized with 1.5mm having a characteristic impedance of 50 ohm of the basic structure, and the variables (a) and (b) of FIG. 13 used in the simulation and fabrication are 5mm and 0.5mm, respectively.

[0064] CER-10 of Taconic having a dielectric constant of 10 and a thickness of 62mil has been used as the

dielectric substrate 10.

[0065] In the result of the simulation of the unit DGS cell using a simulator of HFSS V. 6.0 EM of Ansoft Korea, an attenuation pole of 4GHz or so and a cut-off frequency characteristic of 3dB have appeared.

[0066] Thus, the characteristic of the RF switch using the DGS cell according to the present invention can be regarded as a 1-pole Butterworth low-pass filter and a circuit having a single attenuation pole. From the above characteristic, the equivalent circuit of the DGS circuit shown in FIG. 13 is shown in FIG. 14, in which the inductance of the inductor (L_{in}) is 3.1191mH, and the capacitance of the capacitor (C_{in}) is 0.4951pF.

[0067] The following Table 1 shows an attenuation pole frequency according to variation of the capacitance of diodes, that is, varactor diodes 21a-21e that are a control elements located in the DGS cell. It can be seen that an attenuation pole is sharply lowered according to the increase in the capacitance.

Table 1

Capacitance	Resonant frequency
0.495 pF	4.06 GHz
11.495 pF	840 MHz

[0068] The shift of the resonant frequency means a variation of a pass band, which means that a switching operation can be performed at a particular band.

[0069] Thus, the DGS cell can be used as a switch at a particular frequency band through the variation in the capacitance of the varactor diodes 24a-24c.

[0070] In FIGs. 16A and 16B, a TPST switch in which three DGS cells 22a-22c are connected in cascade, and varactor diodes 24a-24c are attached, is shown.

[0071] The capacitance is 0.495pF when the RF switch is turned on, and the former is 11.4951pF when the latter is turned off.

[0072] FIG. 17 shows the simulation results of the on/off operation states of the RF switch whose center frequency is 840MHz, and illustrates a pass band from 800MHz to 900MHz.

[0073] As shown in FIGs. 16A and 16B, the varactor diodes 24a-24c being the control elements of the RF switch are located on the DGS cell which is located just below the transmission line of the microstrip 15. This becomes the portion where the electric field density distribution is strongest on the ground plane 12.

[0074] ISV229 of Toshiba has been used as the varactor diodes 24a-24c. The capacitance characteristic corresponding to the reverse voltage is 10pF at 5V and 5pF at 12V.

[0075] As described above, the parallel resonant circuit and the RF switch have been described, which can control the Q factor of the resonator using a resistor or simply control the resonant frequency using an inductor or a capacitor, in the DGS circuit. However, the DGS

circuit where an electronic element is coupled according to the present invention can be applied to a low-pass filter, a high-pass filter, a band-pass filter, a tunable filter, a phase shifter, a power distributor, and a directional coupler, as well as the improvement of the radiation pattern for an antenna and the harmonic removal for a filter.

[0076] As described above, the present invention provides a frequency control element coupling the electronic element at the position of the gap in the DGS cell formed on the ground plane of the dielectric substrate, to thereby control the Q factor and the resonant frequency of the resonator smoothly, and reduce a power loss ratio at minimum, which can be used for a low-pass filter, a high-pass filter, a band-pass filter, a tunable filter, a phase shifter, a power distributor, and a directional coupler. Also, the present invention can be used for the improvement of the radiation pattern for an antenna and the harmonic removal for a filter.

[0077] As described above, the present invention has been described according to preferred embodiments. However, the present invention is not limited to the particularly preferred embodiments. It is apparent to one skilled in the art that there are many various modifications and variations without departing off from the spirit or the technical scope of the appended claims.

Claims

1. A resonator having a defected ground structure on a ground plane of a dielectric substrate, the resonator comprising:

a dielectric substrate formed of a dielectric material;

a ground plane having an etched portion including a gap forming an electric field density portion on either inner side, with a conductive film coated on one surface of the dielectric substrate;

a transmission line coated at the gap position on the surface opposing the ground plane on the dielectric substrate, to thereby transmit a signal; and

an electronic element whose either end is connected with either end of the ground plane.

2. The resonator of claim 1, wherein said electronic element is a resistor, in which a resistance value is adjusted to simply thereby control a Q factor of the resonator.
3. The resonator of claim 1, wherein said electronic element is a capacitor in which a resonant frequency of the resonator is varied according to variation in the capacitance of the capacitor.
4. The resonator of claim 1, wherein said electronic

element is an inductor in which a resonant frequency of the resonator is varied according to variation in the inductance of the inductor.

5. The resonator of claim 1, wherein said electronic element is a varactor diode, in which a voltage applied to both ends of the varactor diode is controlled to vary a capacitance, to thereby vary a resonant frequency of the resonator.

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FIG. 1

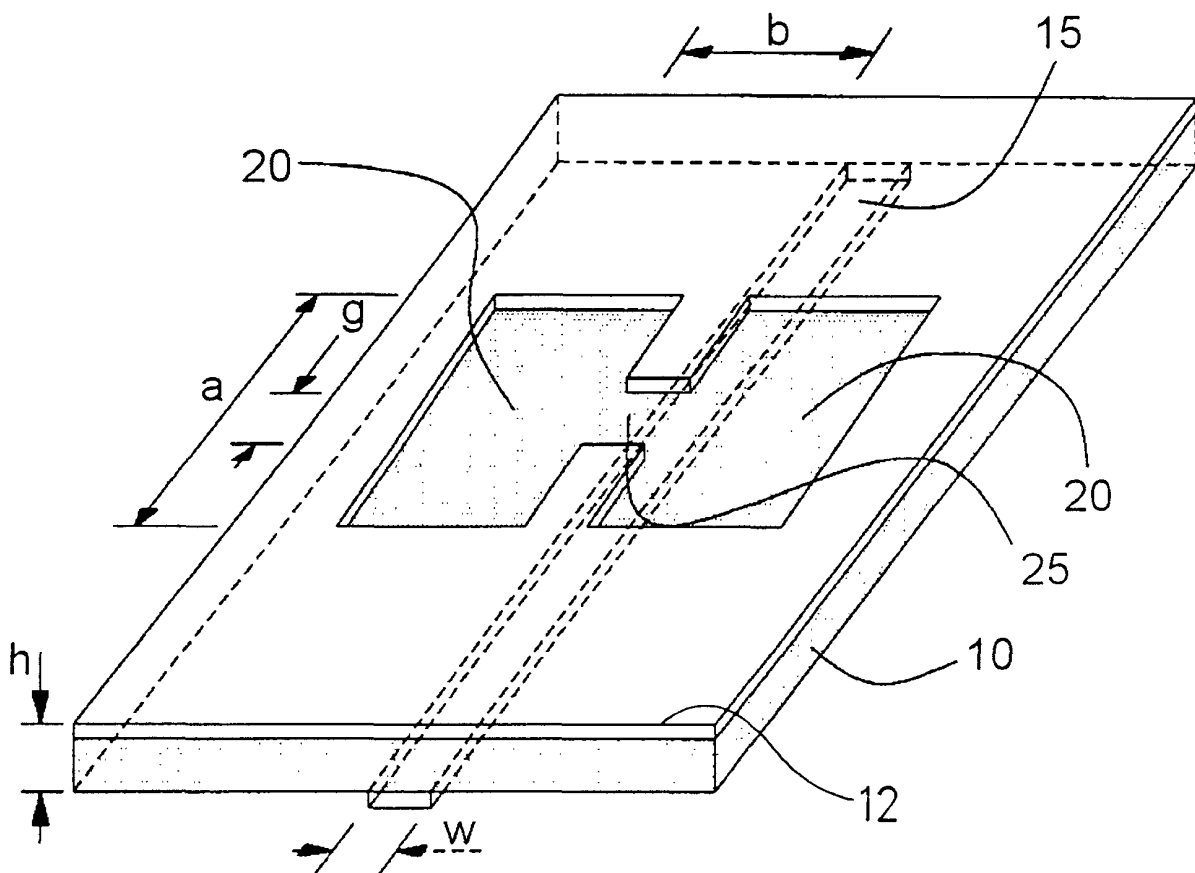


FIG. 2

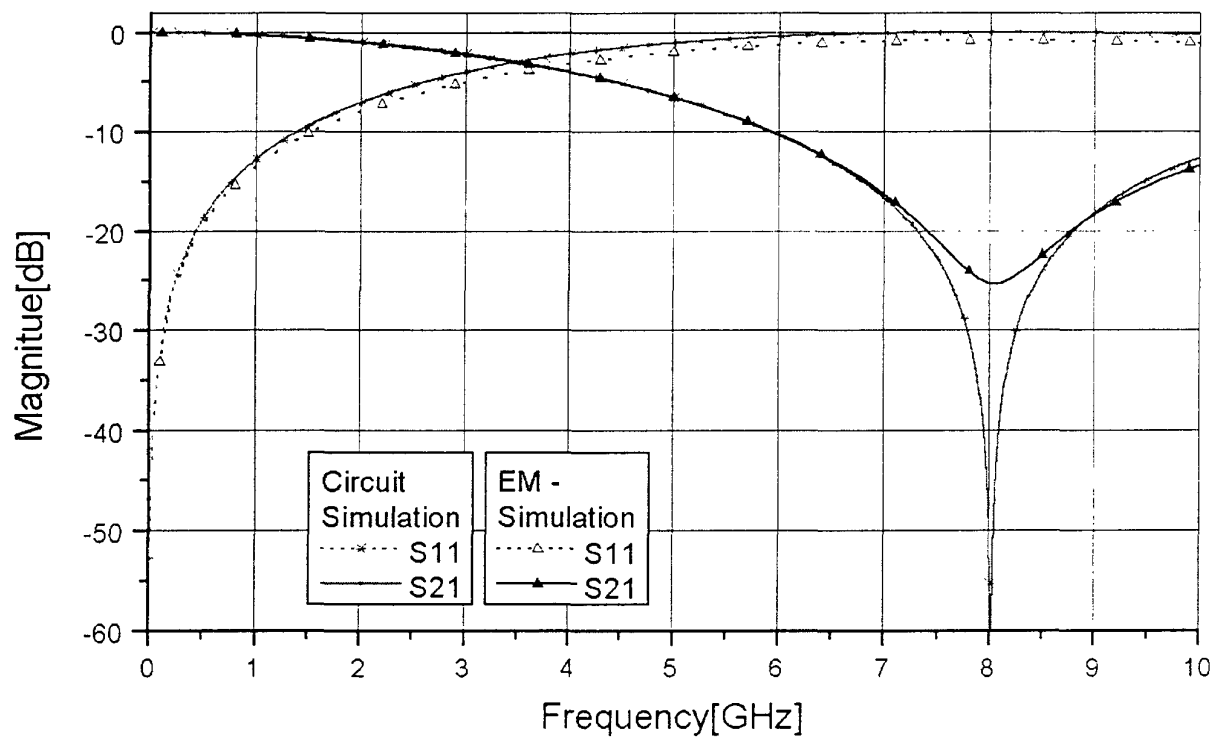


FIG. 3

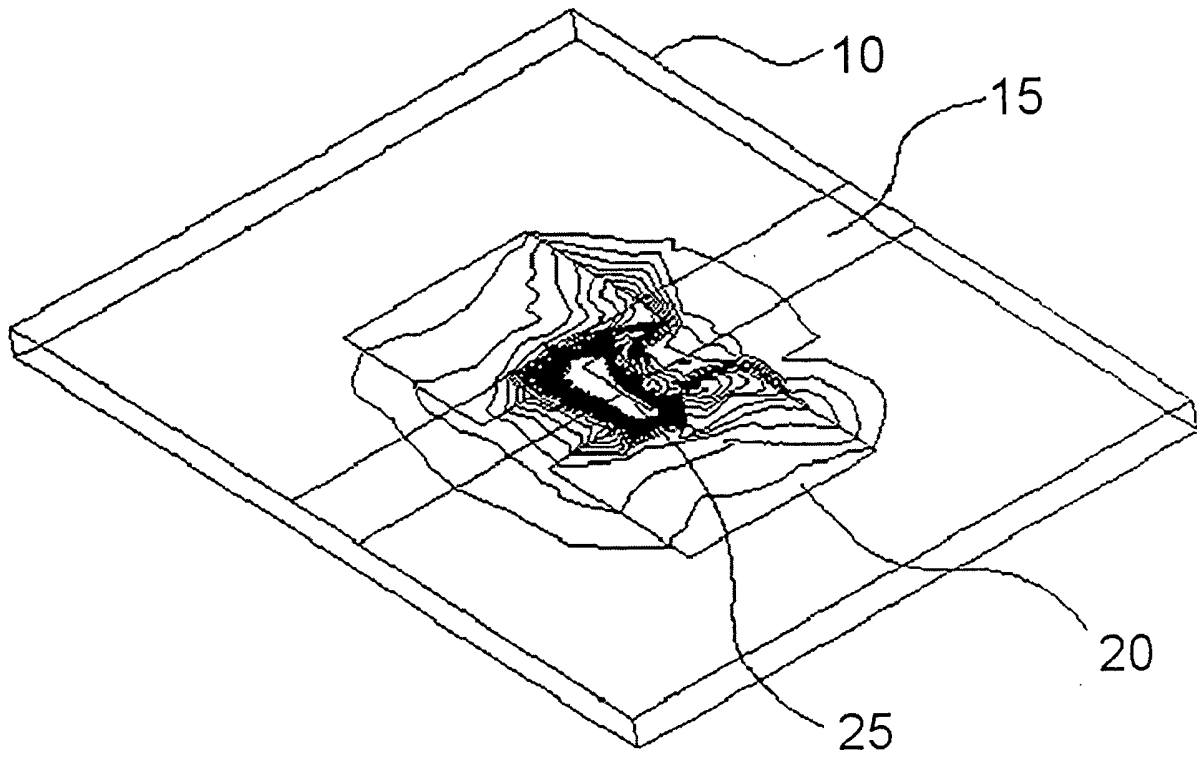


FIG. 4

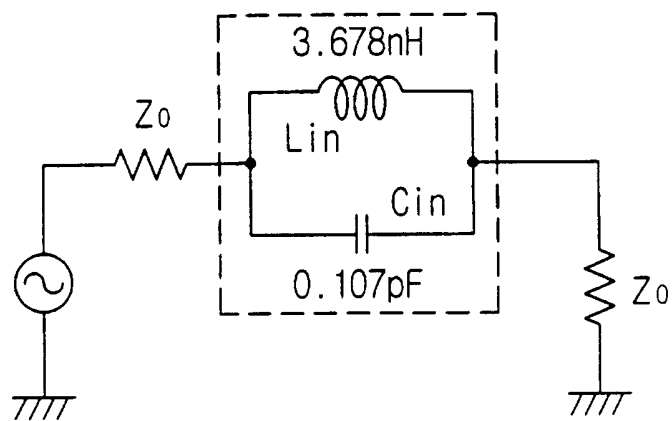


FIG. 5

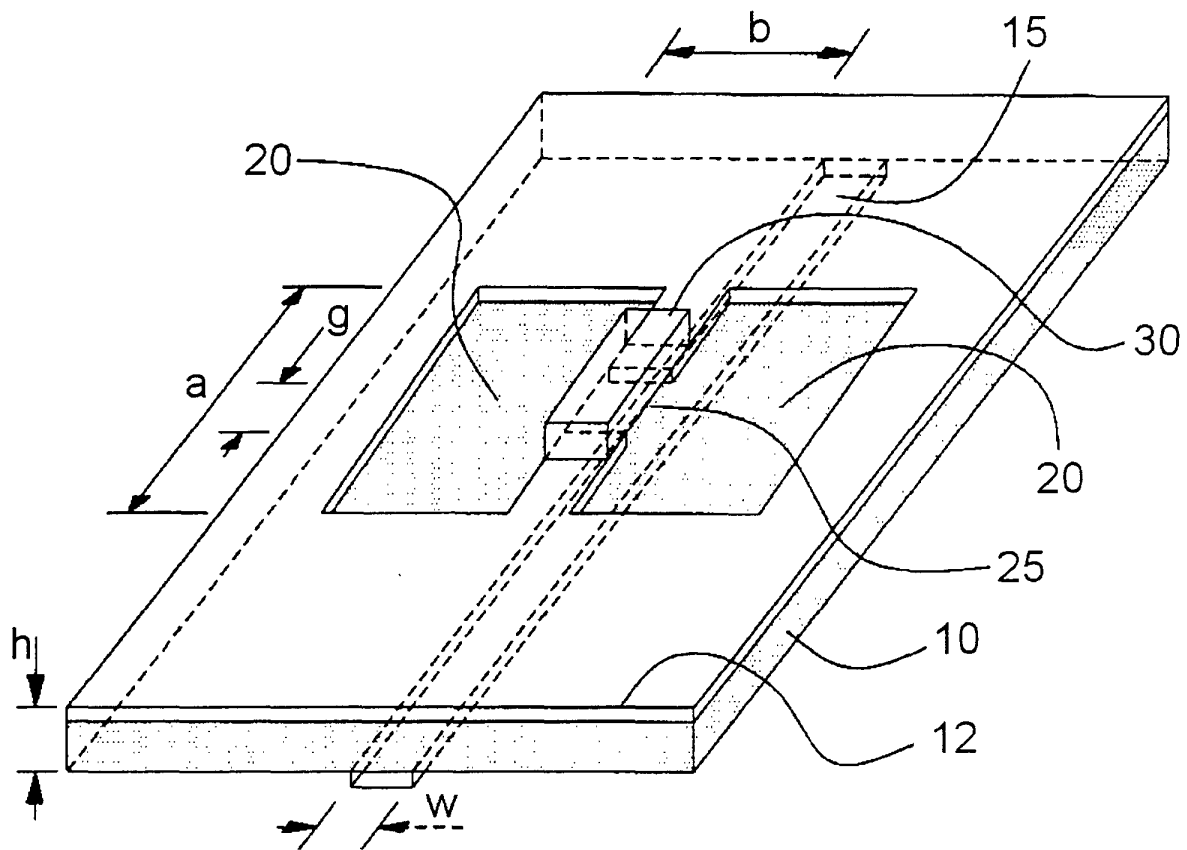


FIG. 6

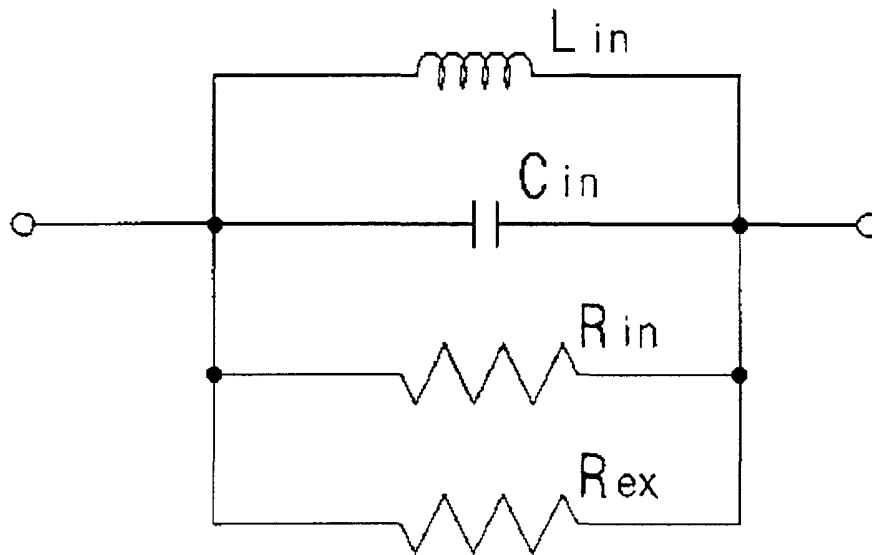


FIG. 7

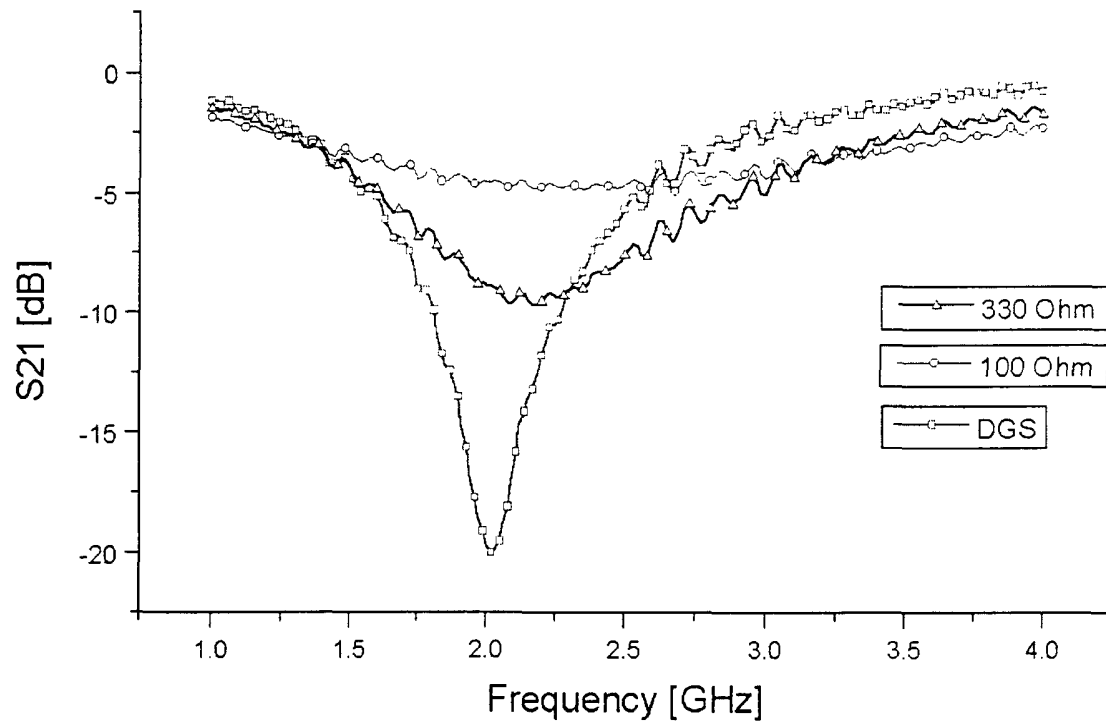


FIG. 8

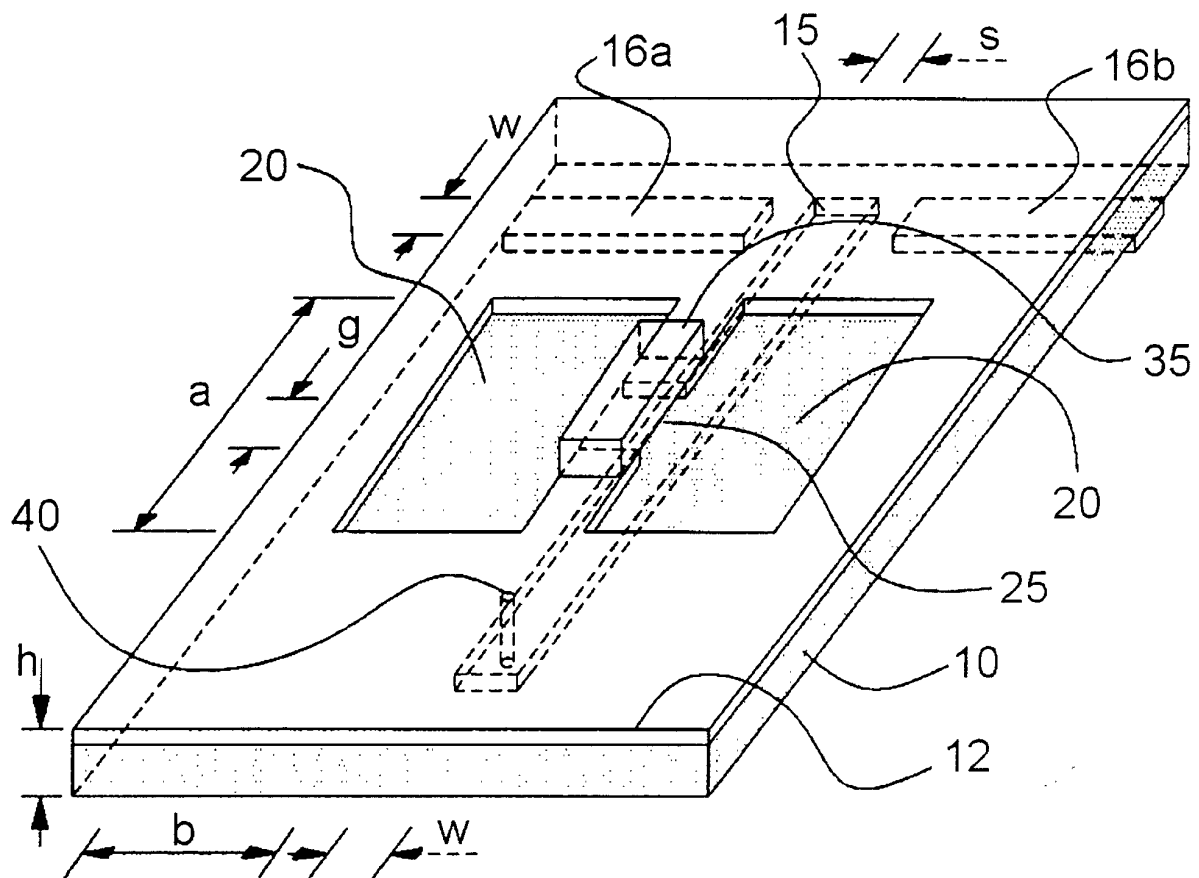


FIG. 9

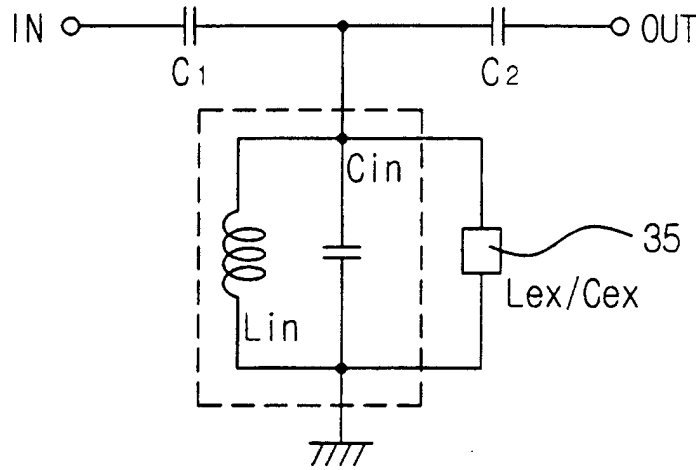


FIG. 10

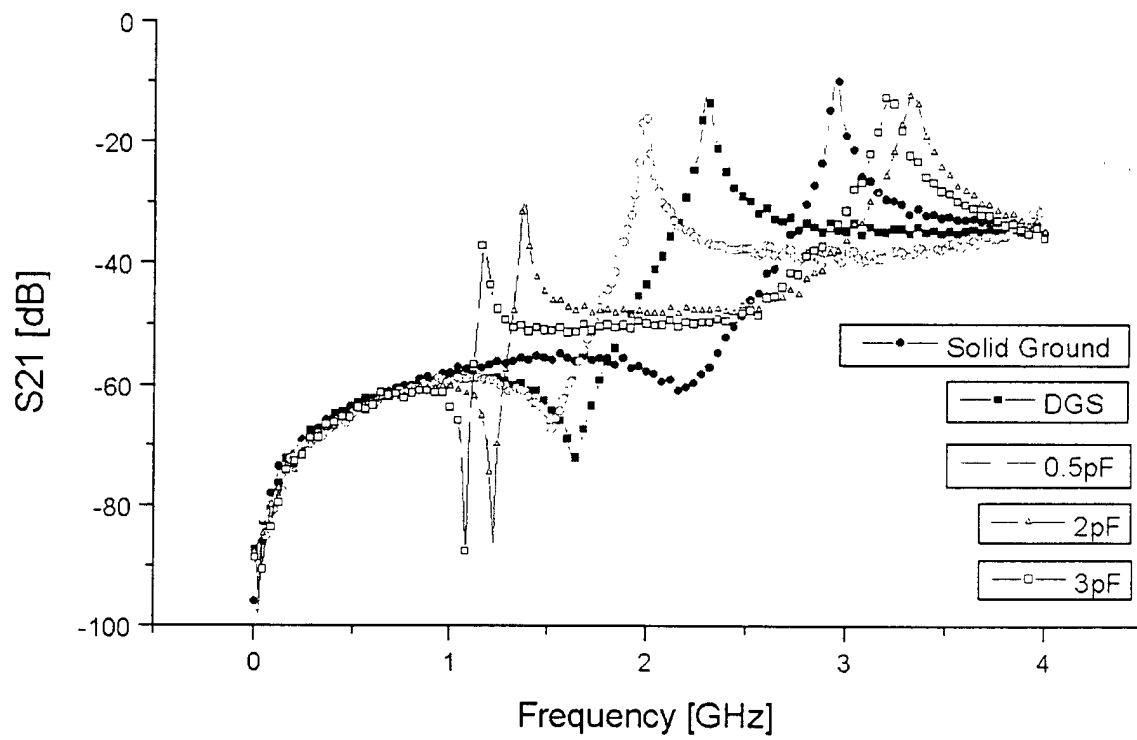


FIG. 11

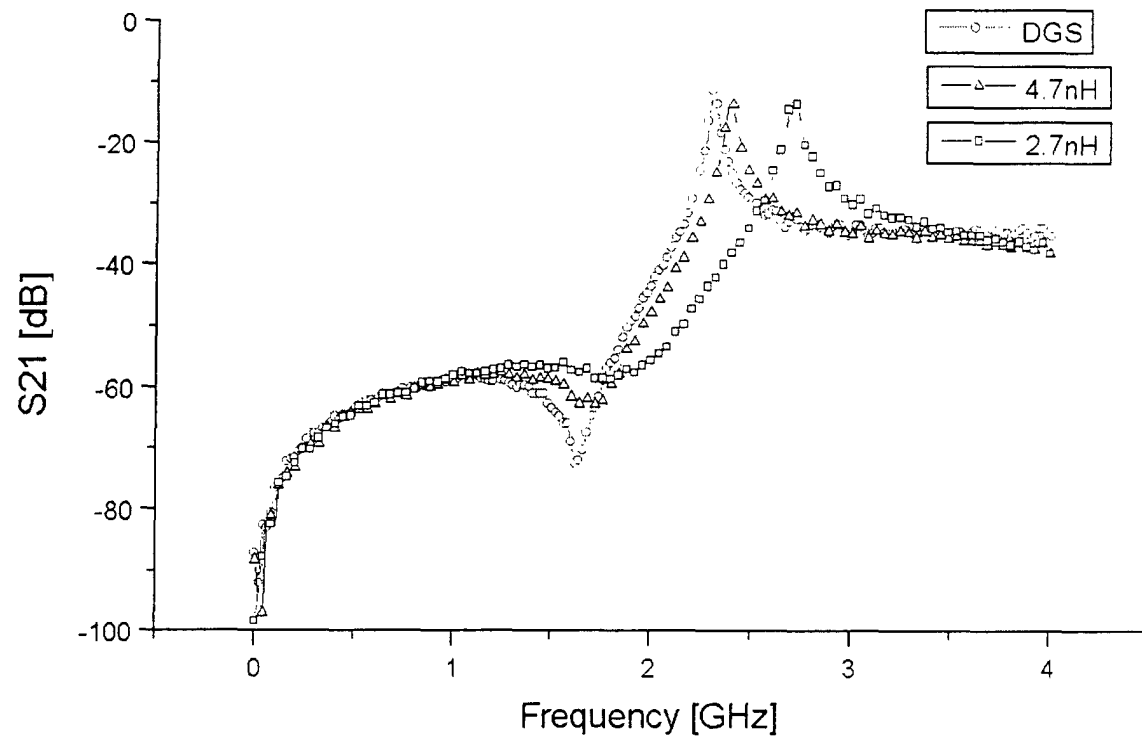


FIG. 12a

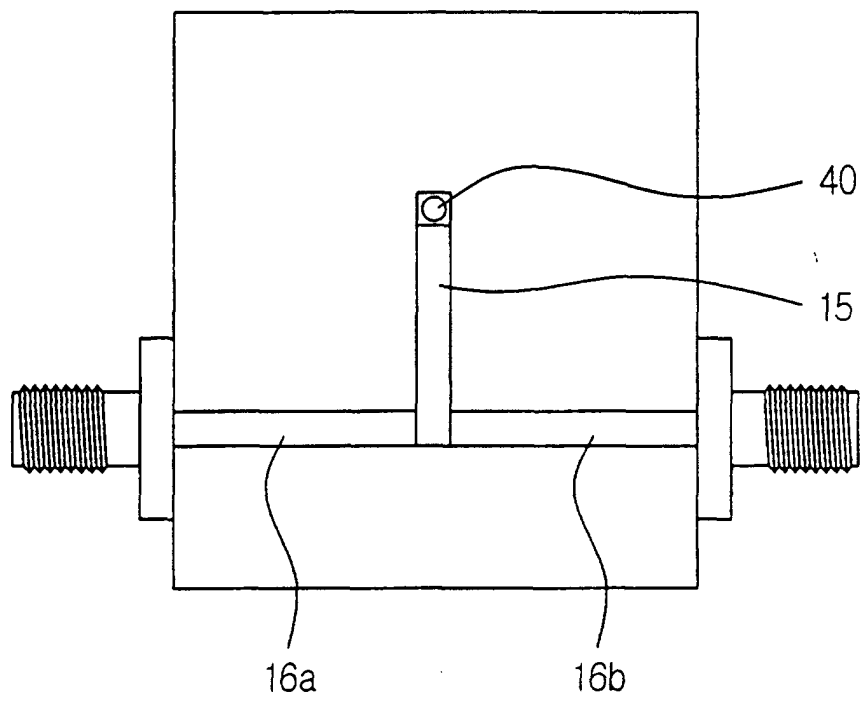


FIG. 12b

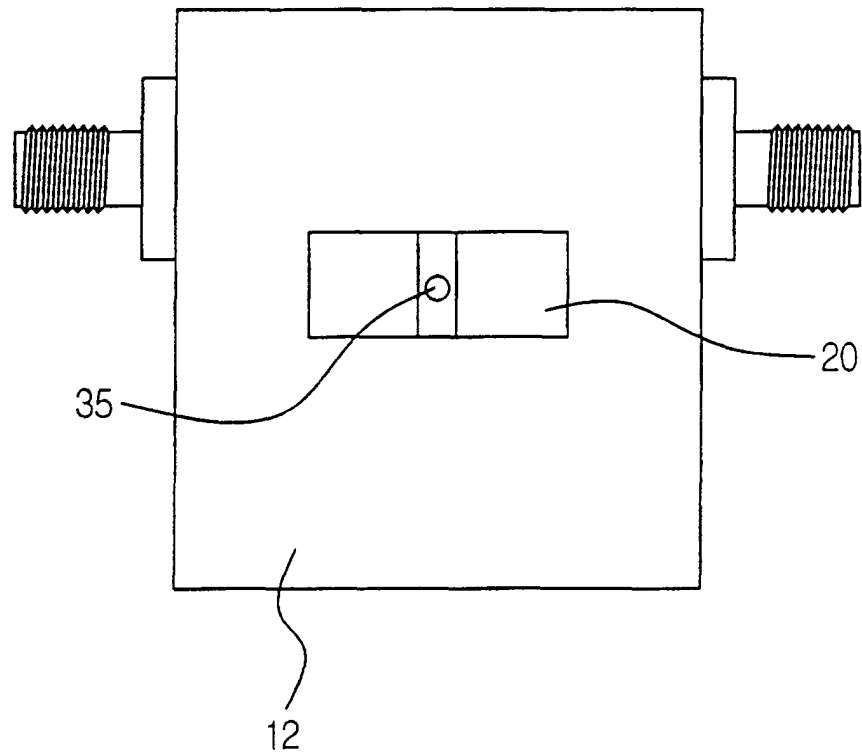


FIG. 13

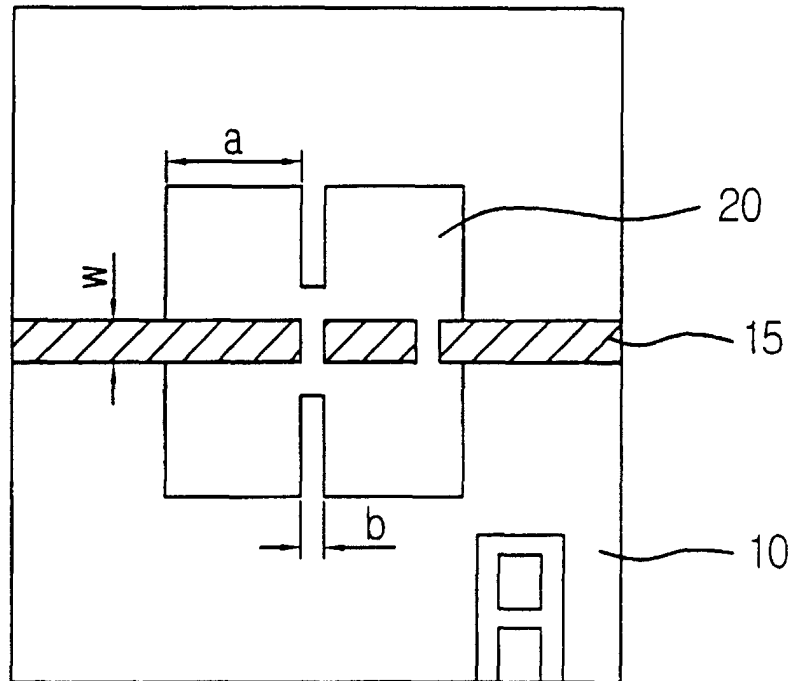


FIG. 14

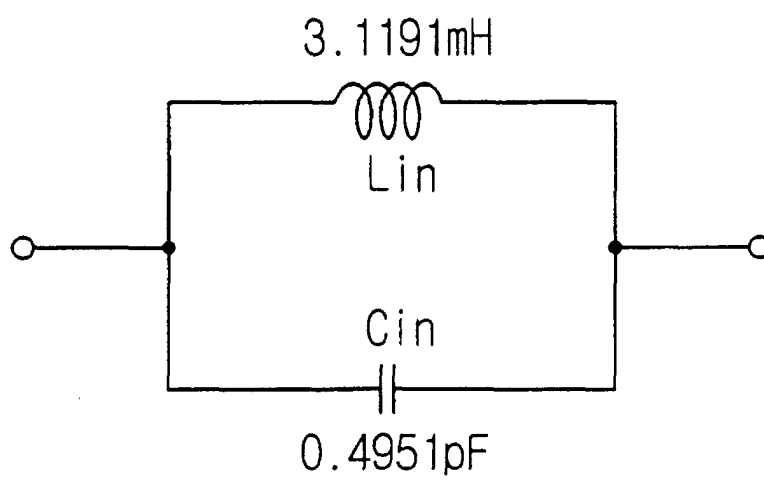


FIG. 15

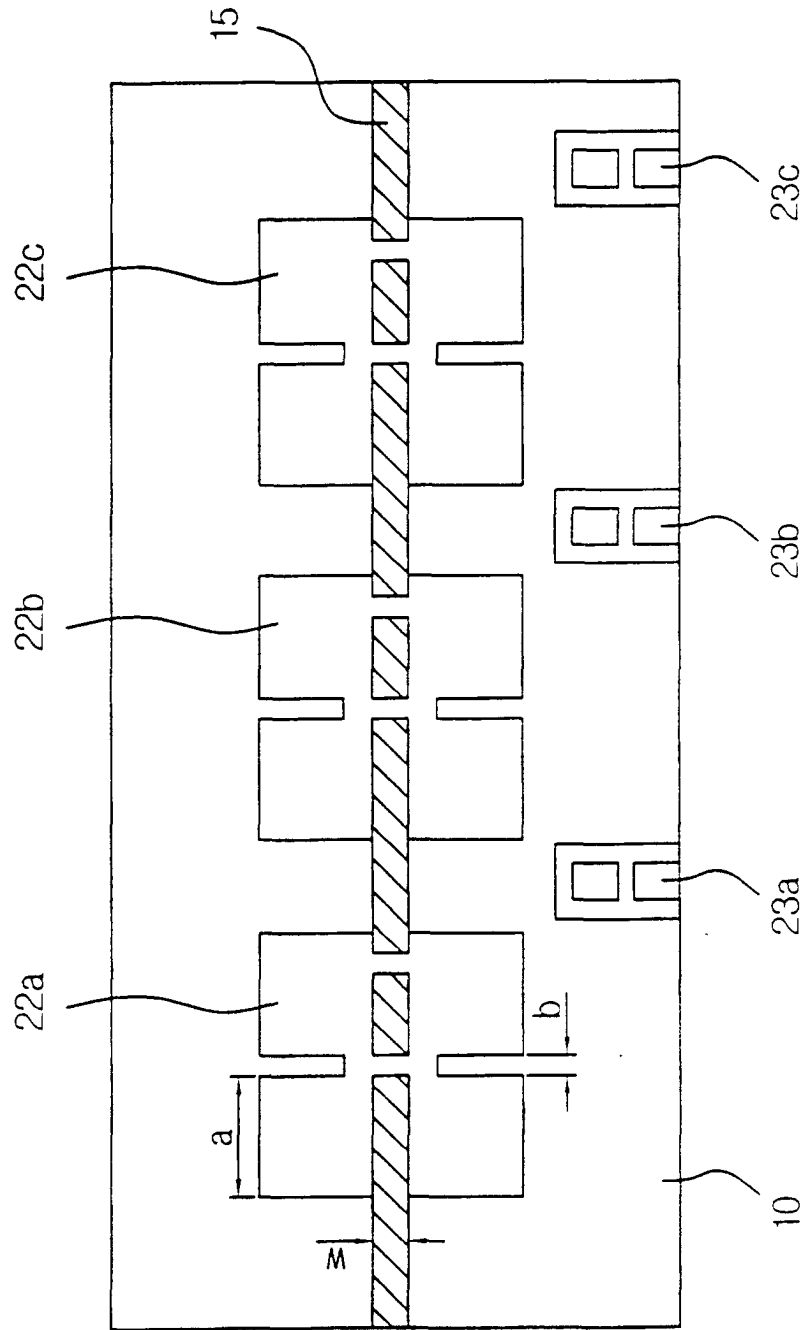


FIG. 16a

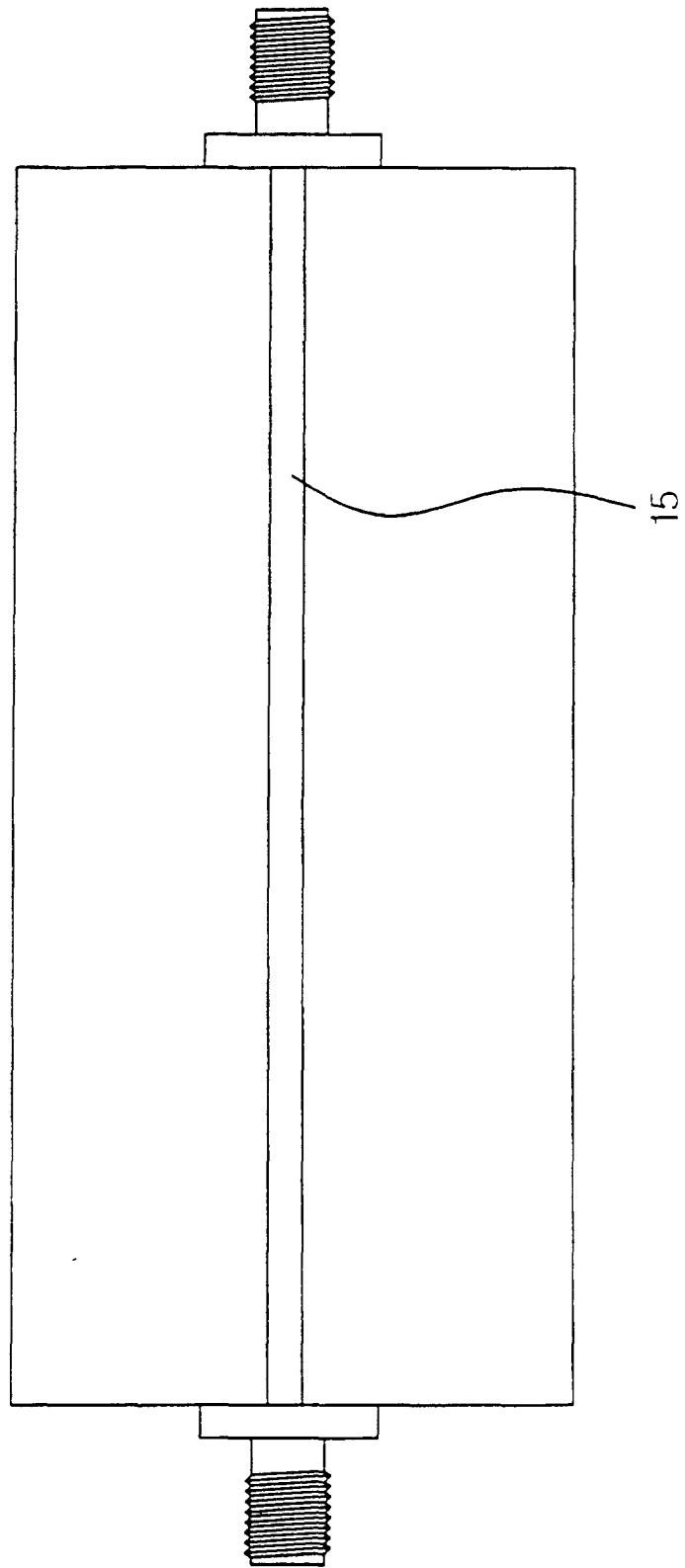


FIG. 16b

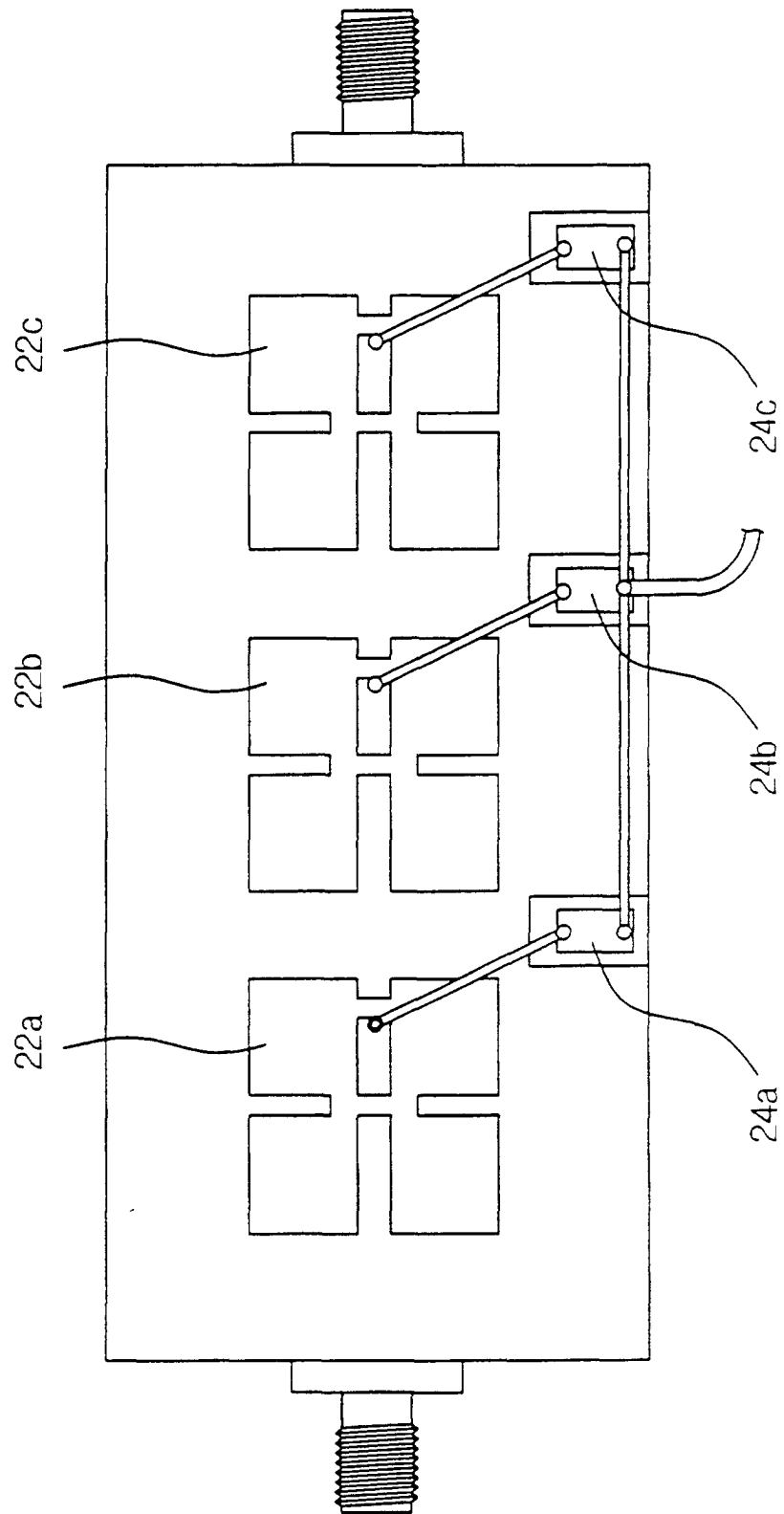


FIG. 17

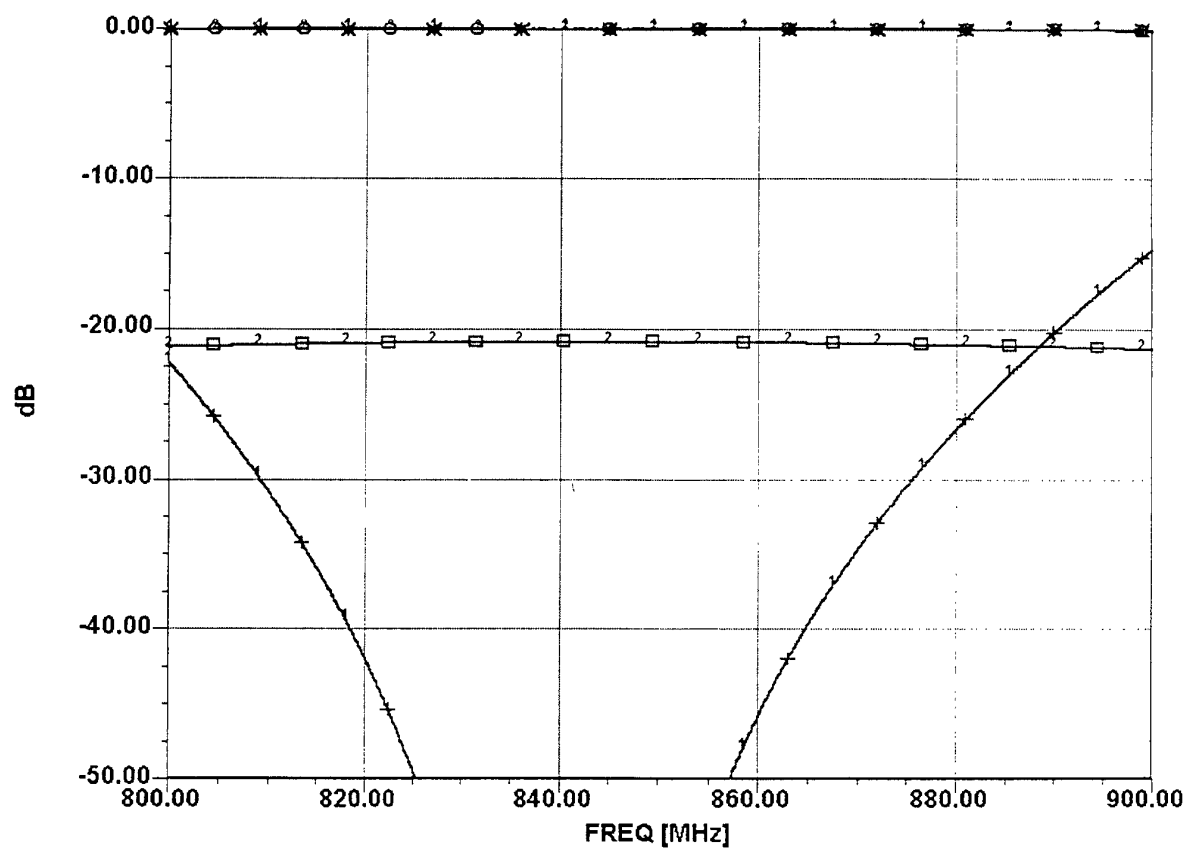
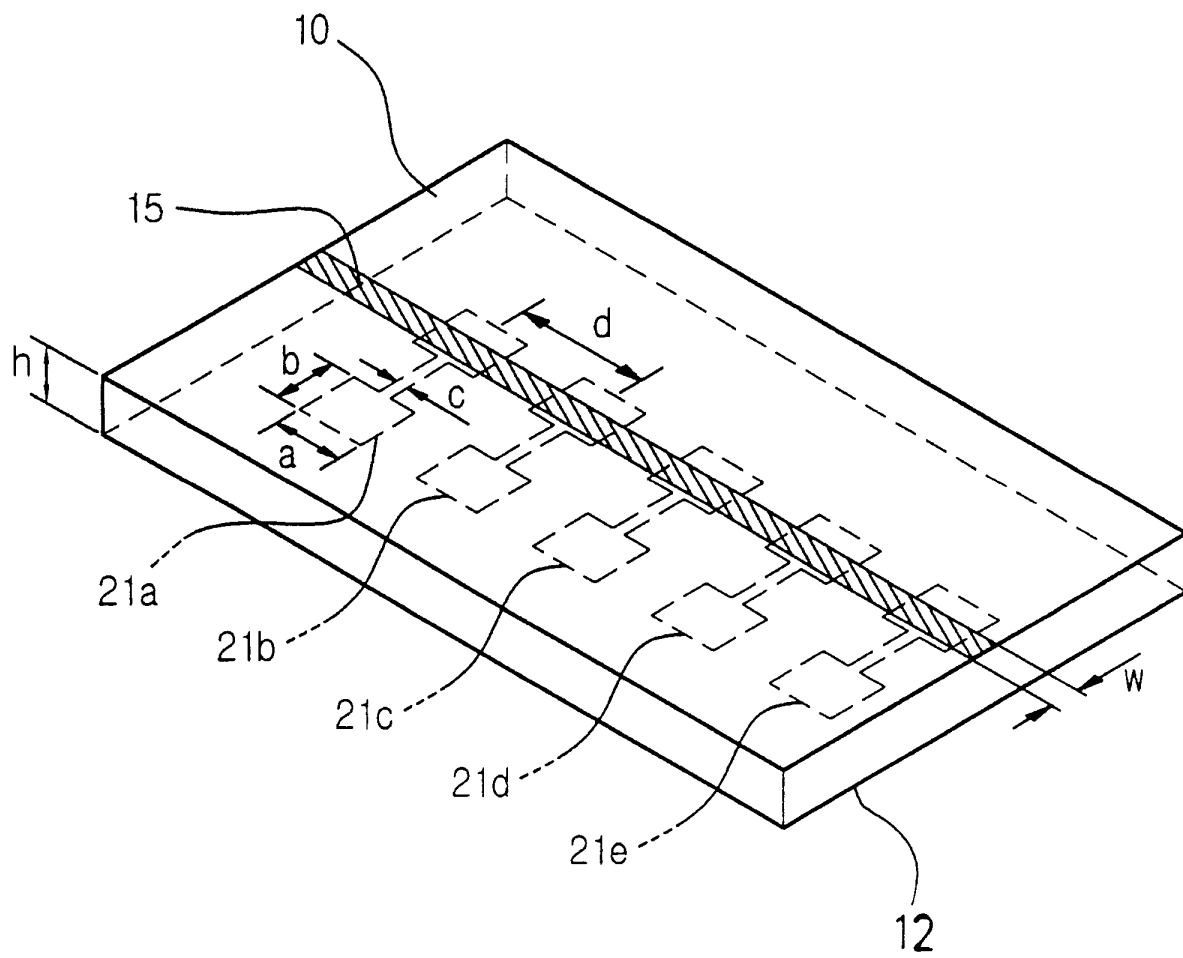


FIG. 18





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 00 12 5431

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 4 211 987 A (PAN JING-JONG) 8 July 1980 (1980-07-08) * abstract; figures 2,4 * * column 4, line 37-50 * * column 5, line 32-36 * ---	1	H01P1/203 H01P7/08 H01P1/15
A	US 4 875 025 A (BUOLI CARLO) 17 October 1989 (1989-10-17) * abstract; figure 1 * ---	1	
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 8 October 2001	Examiner Cordeiro, J-P
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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