A variable resonator that comprises a loop line (902) to which two or more switches (903) are connected and N of reactance circuits (102) (N≥3), in which switches (903) are severally connected to different positions on the loop line (902), the other ends of the switches are severally connected to a ground conductor, and the switches are capable of switching electrical connection/non-connection between the ground conductor and the loop line (902), the reactance circuits (102) severally have the same reactance value, the loop line (902) has a circumference corresponding to one wavelength or integral multiple thereof at a resonance frequency corresponding to each reactance value of each reactance circuit, and the reactance circuits (102) are electrically connected to the loop line (902) as branching circuits along the circumference direction of the loop line (902) at equal electrical length intervals.
In view of such circumstances, it is an object of the present invention to provide a variable resonator, a tunable filter and an electric circuit device, which can be manufactured in an arbitrary size while capable of significantly changing bandwidth.

[0009] The variable resonator of the present invention comprises: a line body where one or a plurality of lines are constituted in a loop shape; a ground conductor; at least two switches; and at least three reactance circuits, wherein the switches have one ends electrically connected to different positions on the line body and the other ends electrically connected to the ground conductor, and are capable of switching electrical connection/non-connection between the ground conductor and the line body. The line section has a line length corresponding to one wavelength or integral multiple thereof at a resonance frequency which is determined corresponding to each reactance value of each reactance circuit, and the reactance circuit is electrically connected to the line body at predetermined intervals based on an electrical length at the resonance frequency. Hereinafter, the variable resonator is called a variable resonator X.

[0010] The variable resonator X may adopt the constitution that the line body is a single loop line and the reactance circuits are electrically connected to the loop line as branching circuits along the circumference direction of the loop line. Hereinafter, the variable resonator is called a variable resonator A.

[0011] The variable resonator A may adopt the constitution that the reactance circuits severally have the same reactance value and are connected to the loop line at the equal electrical length intervals.

[0012] The variable resonator A may adopt the constitution that the total number of the reactance circuits is M where M is an even number of 4 or larger, the reactance circuits severally have the same reactance value: M/2-1 reactance circuits are connected clockwise to a part of the loop line between a position K1 arbitrarily set on the loop line and a position K2 half the electrical length of one circumference of the loop line except the position K1 and the position K2 so as to divide the part at the equal electrical length intervals; M/2-1 reactance circuits are connected counter-clockwise to a remaining part of the loop line between the position K1 and the position K2 except the position K1 and the position K2 so as to divide the remaining part at the equal electrical length intervals, and two reactance circuits are connected to the position K2 of the loop line.

[0013] The variable resonator A may adopt the constitution that the total number of the reactance circuits is M-1 where M is an even number of 4 or larger, M-2 reactance circuits out of M-1 reactance circuits (hereinafter, referred to as first reactance circuits) severally have the same reactance value and remaining one reactance circuit (hereinafter, referred to as second reactance circuit) has half the value of the reactance value of each first reactance circuit; M/2-1 first reactance circuits are connected clockwise to a part of the loop line between a position K1 arbitrarily set on the loop line and a position...
The electric circuit device of the present invention comprises: at least one variable resonator X and a transmission line, wherein the variable resonator is connected electrically to the ground conductor by any one of the switches.

The tunable bandwidth filter of the present invention comprises: at least one variable resonator X and a transmission line, wherein the variable resonator is connected electrically to the transmission line.

The passband width of a signal can be changed significantly by using the above-described variable resonator X, and furthermore, since the size of the variable resonator can be decided by the reactance value of each reactance circuit, the tunable bandwidth filter can be manufactured in an arbitrary size by constituting a reactance circuit having an appropriate reactance value.

The tunable bandwidth filter may adopt the constitution that at least two variable resonators are provided, wherein each of the variable resonators is connected to the transmission line as a branching circuit via a switch (hereinafter, referred to as a second switch) at the same coupled portion; and the transmission line is capable of being connected electrically to all or a part of the variable resonators by the selected second switch(es).

The electric circuit device of the present invention comprises: at least one variable resonator X and a transmission line T having a bent portion, wherein the bent portion of the transmission line T is connected electrically to the variable resonator.

The electric circuit device may adopt the constitution that a part of the variable resonator on an area value and remaining one reactance circuit (hereinafter, referred to as a second reactance circuit) has a value twice the reactance value of each first reactance circuit; one first reactance circuit is connected between an i-th line and an (i+1)-th line where i is an integer satisfying $1 \leq i < M/2$; the second reactance circuit is connected between an (M/2)-th line and an (M/2+1)-th line; one first reactance circuit is connected between an i-th line and an (i+1)-th line where i is an integer satisfying $M/2+1 \leq i < M-1$; one first reactance circuit is connected between an (M-1)-th line and the 1st line; an electrical length from a position K arbitrarily set on the 1st line to an end portion of the 1st line which is closer to the 2nd line and an electrical length of the i-th line where i is an integer satisfying $1 \leq i \leq M/2$ are equal; and an electrical length from the position K to an end portion of the 1st line which is closer to the (M-1)-th line and each electrical length of the i-th line where i is an integer satisfying $1 \leq i \leq M-1$ are equal.
where the bent portion of the transmission line \( T \) and the variable resonator are electrically connected and in the vicinity of the area is not parallel with the transmission line \( T \).

**EFFECT OF THE INVENTION**

[0025] According to the present invention, by a selecting of a switch to be turned to the ON state (electrically connected state) from a plurality of switches, it is possible to freely change the bandwidth while its resonance frequency (center frequency in the filter) sustains at a constant value. Further, since the size of the variable resonator can be decided by the reactance value of each reactance circuit, the variable resonator can be manufactured in an arbitrary size by constituting a reactance circuit having an appropriate reactance value. Note that the tunable bandwidth filter and the electric circuit device, which use the variable resonator of the present invention, can also enjoy the effect.

[0026] Further, in the variable resonator of the present invention, loss of signal at the resonance frequency is dominated by the parasitic resistances of the conductor line which mainly constitutes a variable resonator and the reactance circuits, influence of insertion loss by switches or the like is small. For this reason, the loss of a signal in the passband can be suppressed even if the tunable bandwidth filter is constituted of using switches or the like having large loss for the variable resonator.

[0027] Further, in the electric circuit device of the present invention, a bandwidth straddling the resonance frequency can be significantly changed, and additionally, an insertion loss caused by coupling with the variable resonator can be suppressed by using the variable resonator of the present invention.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0028]

Fig. 1 is a plan view of a variable resonator 100a to which reactance circuits 102 are branching-connected;

Fig. 2 is a plan view of a variable resonator 100b to which the reactance circuits 102 are branching-connected;

Fig. 3 is a variable resonator when the number of the reactance circuit 102 is set to 2 (conventional example);

Fig. 4 is a graph showing the frequency characteristics of the variable resonator (conventional example) shown in Fig.3;

Fig. 5A is a plan view of the variable resonator 100a when the number of the reactance circuits 102 being capacitors is set to 36 and a set of graphs showing the frequency characteristics of the variable resonator 100a when every capacitance of the capacitors is changed;

Fig. 5B is a plan view of the variable resonator 100a when the number of the reactance circuits 102 being capacitors is set to 10 and a set of graphs showing the frequency characteristics of the variable resonator 100a when every capacitance of the capacitors is changed;

Fig. 5C is a plan view of the variable resonator 100a when the number of the reactance circuits 102 being capacitors is set to 4 and a set of graphs showing the frequency characteristics of the variable resonator 100a when every capacitance of the capacitors is changed;

Fig. 5D is a plan view of the variable resonator 100a when the number of the reactance circuits 102 being capacitors is set to 3 and a set of graphs showing the frequency characteristics of the variable resonator 100a when every capacitance of the capacitors is changed;

Fig. 5E is a plan view of the variable resonator 100a when the number of the reactance circuits 102 being capacitors is set to 2 and a set of graphs showing the frequency characteristics of the variable resonator 100a when every capacitance of the capacitors is changed;

Fig. 5F is a plan view of the variable resonator 100a when the number of the reactance circuits 102 being capacitors is set to 1 and a set of graphs showing the frequency characteristics of the variable resonator 100a when every capacitance of the capacitors is changed;

Fig. 6A is a plan view of a variable resonator 100b when the number of the reactance circuits 102 being capacitors is set to 36 and a set of graphs showing the frequency characteristics of the variable resonator 100b when every capacitance of the capacitors is changed;

Fig. 6B is a plan view of the variable resonator 100b when the number of the reactance circuits 102 being capacitors is set to 6 and a set of graphs showing the frequency characteristics of the variable resonator 100b when every capacitance of the capacitors is changed;

Fig. 6C is a plan view of the variable resonator 100b when the number of the reactance circuits 102 being capacitors is set to 4 and a set of graphs showing the frequency characteristics of the variable resonator 100b when every capacitance of the capacitors is changed;

Fig. 7 is a plan view of a variable resonator 100c when the reactance circuits 102 are inductors 11;

Fig. 8 is a plan view of a variable resonator 100d when the reactance circuit 102 are inductors 11 (switches 903 are not shown);

Fig. 9 is a graph showing the frequency characteristics of the variable resonator 100c shown in Fig. 7;

Fig. 10 is a plan view of a variable resonator 100e in the constitution that each of the reactance circuits 102 is a transmission lines 12 (switches 903 are not
Fig. 30 is one embodiment of a tunable bandwidth filter on the premise of the constitution of the variable

Fig. 28 is a plan view of the tunable bandwidth filter shown in Fig. 27 in the case where each reactance circuits 102 is a transmission lines 12 (switches 903 are not shown);

Fig. 19 is a constitution example of a phase variable circuit device shown in Fig. 42A (switches 903 are not shown);

Fig. 41A is a plan view of an electric circuit device which comprises a loop line having an elliptic shape (switches 903 are not shown);

Fig. 36A is one embodiment of a tunable bandwidth filter 402 in the case of magnetic field coupling (switches 903 are not shown);

Fig. 32 is a plan view of a variable resonator when a resistor lies between the switch 903 and a ground conductor on the premise of the constitution of the variable resonator 100a;

Fig. 33 is a plan view of a variable resonator using a switching device that performs switching of a case of connecting to a ground conductor via a resistor and a case of connecting to a ground conductor without a resistor on the premise of the constitution of the variable resonator 100a;

Fig. 34 is one embodiment of a tunable bandwidth filter 401 in the case of electric field coupling (switches 903 are not shown);

Fig. 35 is one embodiment of a tunable bandwidth filter 402 in the case of magnetic field coupling (switches 903 are not shown);

Fig. 36B is one embodiment of a tunable bandwidth filter 405 that uses variable resonators having the same resonance frequency and different characteristic impedances (switches 903 are not shown);

Fig. 37 is one embodiment of a tunable bandwidth filter (combination of series circuits only) (switch 903 is not shown);

Fig. 38 is one embodiment of the tunable bandwidth filter which comprises a combination of a series circuit and a branching circuit (switches 903 are not shown);

Fig. 39 is one embodiment of the variable resonator which comprises a loop line having an elliptic shape (switches 903 are not shown);

Fig. 40 is one embodiment of the variable resonator which comprises a loop line having a bow shape (switches 903 are not shown);

Fig. 41A is a plan view of an electric circuit device having a coupling construction of a transmission line and a variable resonator having a loop line of a circular shape (switches 903 are not shown);

Fig. 41B is a plan view of an electric circuit device having a coupling construction of the transmission line and the variable resonator having a loop line of an elliptic shape (switches 903 are not shown);

Fig. 42A is a plan view of an electric circuit device with a multilayer structure having a coupling construction of the transmission line and the variable resonator (switches 903 are not shown);

Fig. 42B is a view for explaining the relationship between a first layer and a second layer in the electric circuit device shown in Fig. 42A (switches 903 are not shown);

Fig. 42C is a view for explaining the relationship be-
between the second layer and a third layer in the electric circuit device shown in Fig. 42A (switches 903 are not shown); Fig. 43A is a first example of the sectional constitution of the electric circuit device shown in Fig. 42A; Fig. 43B is a second example of the sectional constitution of the electric circuit device shown in Fig. 42A; Fig. 43C is a third example of the sectional constitution of the electric circuit device shown in Fig. 42A; Fig. 43D is a fourth example of the sectional constitution of the electric circuit device shown in Fig. 42A; Fig. 43E is a fifth example of the sectional constitution of the electric circuit device shown in Fig. 42A; Fig. 43F is a sixth example of the sectional constitution of the electric circuit device shown in Fig. 42A; Fig. 44A is a plan view of an electric circuit device having a coupling construction of a variable resonator and a transmission line having a bent portion (switches 903 are not shown); Fig. 44B is a plan view of an electric circuit device having a coupling construction of a variable resonator and the transmission line having a bent portion (switches 903 are not shown); Fig. 45 is a plan view of an electric circuit device having a coupling construction of a variable resonator and the transmission line having a bent portion (switches 903 are not shown); Fig. 46 is a plan view of an electric circuit device having a coupling construction of the variable resonator and the transmission line (switches 903 are not shown); Fig. 47A is a plan view of a variable resonator 900a; Fig. 47B is a plan view of a variable resonator 900b; and Fig. 47C is a cross-sectional view of a switch portion of the variable resonator 900a.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0029] Fig. 1 shows the variable resonator 100a being one embodiment of the present invention in the case where the resonator is constituted as a microstrip line structure. The variable resonator 100a comprises a loop line body 101 being a closed circuit and N reactance circuits 102 (N is an integer satisfying N ≥ 3). Fig. 1 exemplifies the variable resonator 100a in the case of N=3. As the loop line body 101, a variable resonator 900 disclosed in Japanese Patent Application Number: 2006-244707 (filed and undisclosed) may be employed. So, the outline of the variable resonator 900 will be described first, and description will be made next for the reactance circuits 102.

[Circular line body]

[0030] As two specific modes of the variable resonator 900, a variable resonator 900a and a variable resonator 900b are exemplified respectively in Fig. 47A and Fig. 47B. Hereinafter, when both the variable resonator 900a and the variable resonator 900b are acceptable, reference numeral 900 is allocated and it is called the variable resonator 900. Herein, description will be made for the variable resonator 900 that is constituted as the microstrip line structure.

[0031] The variable resonator 900 is made up of a conductor line 902 (hereinafter, also simply called a "line" or a "loop line") and two or more of switches 903. The line 902 is formed on one surface of a dielectric substrate 905 by a conductor such as metal. In the dielectric substrate 905, a ground conductor 904 is formed by a conductor such as metal and is formed on a surface (referred to as a rear surface) on the opposite side of the surface on which the line 902 is provided. In each switch 903, as shown in Fig. 47C, one end 931 of the switch 903 is electrically connected to the ground conductor 904 on the rear surface of the dielectric substrate 905 via a conductor 933 and a via hole 906. Since the shape of the conductor 933 or the like is not limited at all, illustration of the conductor 933 is omitted in Fig. 47A and Fig. 47B. Arrangement of switches 903 is not limited to be at equal intervals, but may be designed arbitrarily in order to obtain a desired bandwidth. Further, not limited to each switches 903, switches in this specification are not limited to a contact-type switch, but may be a so-called switching element having a switching function of circuit without providing a contact in a circuit network, which uses diodes, transistors or the like, for example. A switching diode or the like is cited as a specific example.

[0032] The line 902 is a loop line which has a length of a phase change of 2π (360 degrees) at a desired resonance frequency, that is a length of one wavelength or integral multiple thereof at the resonance frequency. In the variable resonator 900 shown in Fig. 47A and Fig. 47B, the line is exemplified as a loop line of a round shape. The "loop" here means a so-called simple closed curve. In short, the line 902 is a line whose starting point and ending point match and does not cross itself halfway.

[0033] Herein, the "length" means the circumference of the loop line, and is a length from a certain position on the line to this position after making a full circle.

[0034] Herein, the "desired resonance frequency" is one element of performance generally required in a resonator, and is an arbitrary design matter. Although the variable resonator 900 may be used in an alternating-current circuit and a subject resonance frequency is not particularly limited, it is useful when the resonance frequency is set to a high frequency of 100kHz or higher, for example.

[0035] In the present invention, it is desirable that the line 902 is a line having uniform characteristic impedance. Herein, "having uniform characteristic impedance" means that when the loop line 902 is cut with respect to
a circumference direction so as to be fragmented into segments, these segments have several characteristic impedance values. Making the characteristic impedance precisely become completely the same value is not an essential technical matter, and manufacturing the line 902 so as to set the characteristic impedance to substantially the same value is enough from a practical viewpoint. Assuming that a direction orthogonal to the circumference direction of the line 902 is referred to as the width of the line 902, in the case where the relative permittivity of the dielectric substrate 905 is uniform, the line 902 formed to have substantially the same width at any point has a uniform characteristic impedance.

[0036] A difference between the variable resonator 900a and the variable resonator 900b is whether the other end 932 of the switch 903 is provided inside the line 902 or provided outside thereof. The other end 932 of the switch 903 is provided outside the line 902 in the variable resonator 900a, and the other end 932 of the switch 903 provided inside the line 902 in the variable resonator 900b.

[0037] Hereinafter, description will be made on the assumption that the loop line body 101 is the variable resonator 900. Further, to prevent drawings from becoming complicated, illustration of the switches 903 may be omitted in showing the circular line body 101.

[Reactance circuits]

[0038] Assuming that an impedance Z is expressed in $Z = R + jX$ (j is an imaginary unit), the reactance circuit 102 is a reactance circuit with $R = 0$ regarding the impedance $Z_L$ of the reactance circuits itself, ideally. Although $R = 0$ holds practically, it does not affect the basic principle of the present invention. As a specific example of the reactance circuit 102, a circuit element such as a capacitor, a inductor and a transmission line, a circuit where a plurality of same type items out of them are combined, a circuit where a plurality of different type items out of them are combined and the like are cited. In this specification, an appellation “circuit” is used for the “reactance circuit” even in the case where it is constituted of a single circuit element such as a case where the circuit is constituted of one capacitor, for example, due to the organic relation with the line 902.

[0039] It is necessary that N reactance circuits 102 severally take the same or substantially the same reactance value. Herein, the reason why “substantially the same” reactance value should be enough, in other words, setting N reactance circuits 102 to completely the same reactance value is not strictly requested as a design condition as is follows. The fact that the reactance values of N reactance circuits 102 are not completely the same causes a small deviation of the resonance frequency (in short, a desired resonance frequency cannot be sustained). However, the fact causes no problem practically since the deviation of the resonance frequency is absorbed into bandwidth. In the following, as a technical matter including this meaning, it is assumed that N reactance circuits 102 take the same reactance values.

[0040] The above-described conditions commonly apply to various reactance circuits 102 that will be described later. For this condition, although it is desirable that N reactance circuits 102 are all the same type, they may not necessarily be reactance circuits of the same type as long as it is possible to achieve the condition that the same reactance value is taken as described above. Herein, description will be made by allocating the same reference numeral 102 to the reactance circuits on the assumption that this content is included. [Variable resonator]

[0041] N reactance circuits 102 are connected electrically to the line 902 as branching circuits at equal intervals based on the electrical length at a resonance frequency whose one wavelength or integral multiple thereof corresponds to the circumference of the line 902 regarding the circumference direction of the line 902. In actual designing, the resonance frequency whose one wavelength or integral multiple thereof corresponds to the circumference of the line 902 should only be the resonance frequency of the variable resonator 900 to which no reactance circuit 102 is connected, for example. However, although description will be made in detail later, it must be noted that the resonance frequency of the variable resonator 100a, where the reactance value of each reactance circuit is not infinity, is different from the resonance frequency of the variable resonator 900. In the case where the relative permittivity of the dielectric substrate 905 is uniform, the equal electrical length intervals match equal intervals based on the physical length. In such a case and when the line 902 is a circular shape, N reactance circuits 102 are connected to the line 902 at intervals where each central angle formed by the center O of the line 902 and each connection point of adjacent arbitrary reactance circuits 102 becomes an angle obtained by dividing 360 degrees by N (refer to Fig. 1). In the example shown in Fig. 1, end portions of reactance circuits 102 on the opposite side of the end portions, which are connected to the line 902 are grounded by electrical connection to the ground conductor 904. However, as described later, since the reactance circuits 102 may be constituted of using a transmission line, for example, grounding the end portions of the reactance circuits 102 on the opposite side of the end portions which are connected to the line 902 is not essential.

[0042] Note that the connection points of the switches 903 to the line 902 are set such that desired bandwidths can be obtained. Therefore, connecting the switch 903 to a position where the reactance circuit 102 is connected is allowed.

[0043] Fig. 2 shows a variable resonator 100b being one embodiment of the present invention constituted as a microstrip line structure, which is different from the variable resonator 100a. The variable resonator 100b has different connection points of the reactance circuits 102
to the line 902 from those of the variable resonator 100a.

[0044] In the variable resonator 100b, M reactance circuits 102(M is an even number of 4 or larger) are electrically connected to the line 902 as branching circuits. In more details, at the resonance frequency whose one wavelength or integral multiple thereof corresponds to the circumference of the line 902, M/2-1 the reactance circuits 102 are connected clockwise along the circumference direction at the intervals of equal electrical lengths from a certain position K1 arbitrarily set on the line 902 to a position K2 half the electrical length of the full loop of the line 902. It is to be noted that the equal electrical length intervals here mean equal electrical length intervals on the condition that the reactance circuits 102 are not provided on the position K1 and the position K2. Similarly, M/2-1 reactance circuits 102 out of the remaining reactance circuits 102 are connected counter-clockwise along the circumference direction at the intervals of equal electrical length from the position K1 to the position K2. It is to be noted that the equal electrical length intervals here also mean equal electrical length intervals on the condition that the reactance circuits 102 are not provided on the position K1 and the position K2 as described above. Then, the remaining two reactance circuits 102 are connected to the position K2. Herein, it is assumed that "clockwise" and "counter-clockwise" refer to circling directions when seen from the front page surface of the drawings (the same applies below). Similar to the variable resonator 100a, in actual design, the resonance frequency whose one wavelength or integral multiple thereof corresponds to the circumference of the line 902 should be the resonance frequency of the variable resonator 900 to which no reactance circuit 102 is connected, for example. However, although description will be made in detail later, it must be noted that the resonance frequency of the variable resonator 100b where the reactance value of each reactance circuit is not infinity is different from the resonance frequency of the variable resonator 900.

[0045] In the case where the relative permittivity of the dielectric substrate 905 is uniform, the equal electrical length intervals match the equal intervals based on the physical length. In such a case, from the certain position K arbitrarily set on the line 902 (corresponding to position K1) to a position half the circumference L of the line 902 along the circumference direction of the line 902 (corresponding to position K2), M/2 reactance circuits 102 are connected at positions remote from the position K by the distance of (L/M) x m (m is an integer satisfying 1≤m≤M/2) clockwise along the line 902. Similarly, from the position K to the position half the circumference L of the line 902 along the circumference direction of the line 902 (corresponding to position K2), the remaining M/2 reactance circuits 102 are connected at positions remote from the position K by the distance of (LM) x m (m is an integer satisfying 1≤m≤M/2) counter-clockwise along the line 902. In short, the reactance circuit 102 is not connected to the position K, but two reactance circuits 102 are connected to the position remote from the position K by the distance of (L/M) x M/2 clockwise or counter-clockwise along the line 902.

[0046] Particularly in the case where the line 902 is a circular shape, M reactance circuits 102 are connected to positions remote by m times an angle obtained by dividing 360 degrees by M from the certain position K arbitrarily set on the line 902 clockwise along the route of the line 902 and to positions remote from the position K by m times the angle obtained by dividing 360 degrees by M counter-clockwise along the route of the line 902, seen from the center O of the line 902 (refer to Fig. 2). At this point, a position remote from the position K by M/2 times the angle obtained by dividing 360 degrees by M clockwise along the route of the line 902 matches a position remote by M/2 times the angle obtained by dividing 360 degrees by M counter-clockwise along the route of the line 902, and two reactance circuits 102 are connected on at the position (regarding the case of M=4, refer to the dotted-line framed portion α of Fig. 2). In the example shown in Fig. 2, end portions of reactance circuits 102 on the opposite side of the end portions on the side that is connected to the line 902 are grounded by electrical connection to the ground conductor 904. However, similar to the case of the variable resonator 100a, since the reactance circuits 102 may be constituted of using a transmission line, for example, grounding the end portions of reactance circuits 102 on the opposite side of the end portions that are connected to the line 902 is not essential. Further, connecting the switch 903 to a position where the reactance circuit 102 is connected is allowed.

[0047] It is necessary that all of the M reactance circuits 102 take the same or substantially the same reactance value. The meaning of "substantially the same" is as described above. However, the circuit configuration at the position where the two reactance circuits 102 are connected (corresponding to the above-described the position K2), that is, the portion shown by the dotted-line framed portion α of Fig. 2, may be changed to the circuit configuration that the two reactance circuits 102 electrically connected to the position are replaced with a single reactance circuit 102a (for example, refer to dotted-line framed portion P of Fig. 2). At this point, since the reactance value of the reactance circuit 102a corresponds to the combined reactance of the two reactance circuits 102, it must be noted that the reactance value of reactance circuit 102a is set to a value half the reactance value of each of the reactance circuits 102 electrically connected to positions other than the position K2. In this case, the total number of the reactance circuits 102 becomes M-1 naturally.

[0048] In the description below and each drawings, for the convenience of description and illustration, description and illustration will be made based on the case where the electrical length is not influenced on the line 902, that is, the case where the equal electrical length intervals match the equal intervals based on the physical length.
Not only technical characteristics understood from the drawings, technical characteristics made clear from the following description not only applies to the case where the equal electrical length intervals match the equal intervals based on the physical length, but also applies to the case where the reactance circuits 102 are at the above-described connection points based on the electrical length.

[0049] Regarding the above-described variable resonator 100a and variable resonator 100b, description will be made for a mechanism for changing bandwidth and a mechanism for changing resonance frequency by referring to Fig. 3 to Fig. 6.

[0050] Since frequency characteristics of the variable resonator 100a and the variable resonator 100b are shown as circuit simulation results in Fig. 5 to Fig. 6, each drawing shows the variable resonator 100a or the variable resonator 100b which is connected as a branching circuit to a signal input/output line 7 being a transmission line shown by Port 1-Port 2. A line connecting the input/output line 7 with the variable resonator 100a or the variable resonator 100b expresses that the input/output line 7 and the line 902 are electrically connected in a circuit to be simulated.

[0051] First, the mechanism for changing bandwidth will be described.

[0052] Although the details are written in Japanese Patent Application Number: 2006-244707, in the loop line body 101, that is, the variable resonator 900, the positions of transmission zeros that occur around a resonance frequency whose one wavelength or integral multiple thereof corresponds to the circumference of the line 902 can be moved by selecting a single switch 903 to be turned to a conduction state (hereinafter, also referred to as an ON state). Herein, the transmission zero is a frequency where the transmission coefficient of the circuit where the input/output line 7 is connected to the loop line body 101 (Transmission Coefficient: unit is decibel [dB]) becomes minimum, that is, an insertion loss becomes maximum. Since a bandwidth is decided by the positions of the transmission zeros, the bandwidth of the loop line body 101 can be significantly changed in response to the selection of the switch 903 to be turned to the conduction state.

[0053] Further, by employing the loop line 902, the loop line body 101 has characteristics that the signal at the resonance frequency whose one wavelength or integral multiple thereof corresponds to the circumference of the circular line 902 is not influenced by the parasitic resistance and the parasitic reactance of the switches 903. For this reason, in the case where a bandpass filter is formed by using the variable resonator 900 provided with the switches 903 having parasitic resistance, for example, the insertion loss of the bandpass filter is not influenced by the resistance of the switch 903 at a resonance frequency being a passband, so that the insertion loss can be made smaller.

[0054] Next, description will be made for the relation-ship between the reactance value of the reactance circuit 102 and the resonance frequency.

[0055] According to the reference literature given below, by making a resonator having the constitution that a circular line 802 is cut at two positions symmetrical with respect to the center of the line and capacitors 10 being as the reactance circuits are inserted each in cut area, the resonance frequency of the resonator can be made different in response to the capacitance of each capacitor 10. Therefore, by applying the technology to the variable resonator 900 capable of significantly changing bandwidth, it seems to be possible to realize a variable resonator whose resonance frequency is determined corresponding to the reactance value while being capable of significantly changing bandwidth. However, even if the technology is applied to the variable resonator 900 capable of significantly changing bandwidth, it is impossible to realize the variable resonator whose resonance frequency is determined corresponding to the reactance value while being capable of significantly changing bandwidth.

This will be described by using a variable resonator 850 where the technology is applied to the variable resonator 900 capable of significantly changing bandwidth (refer to Fig. 3). The circuit shown in Fig. 3 is the variable resonator 850 that is connected as a branching circuit to the input/output line 7 being the transmission line shown by Port 1-Port 2.


[0056] Fig. 4 shows the frequency characteristics of a signal transmitting from Port1 to Port2 regarding the variable resonator 850 shown in Fig. 3 in the case where the total line length L of two lines 852 arranged in a circular shape is set to one wavelength at 5GHz and both capacitances of the two capacitors 10 inserted in two connection positions of the lines 852 in series are set to 1 pF. Resistances of conductors constituting the lines 852, conductors forming via holes 906, and a ground conductor 904 are set to 0. Further, the port impedance of the input/output line 7 is set to 50 Ω. Note that the switches 903 are omitted for convenience, and selecting of the switch 903 to be conducted is simulated by changing the position of the via holes 906 for grounding instead.

[0057] A thick line indicated by the sign of 10 degrees in Fig. 4 shows frequency characteristics in the case where a position S1 at 10 degrees of center angle measured counterclockwise from a position G' symmetrical with respect to the center O of the two lines 852 arranged in a circular shape to a connection position G where the variable resonator 850 is connected to the input/output line 7 (the position S1: a position of 17/36 of the circumference of the lines 852 counter-clockwise from the connection position G) is grounded via the via hole 906 as shown in Fig. 3. Similarly, a narrow line indicated by the sign of 30
degrees in Fig. 4 shows frequency characteristics in the case where a position $S_2$ at 30 degrees of center angle measured clockwise from the position $G'$ (the position $S_2$: a position of 5/12 of the circumference of the lines 852 counter-clockwise from the connection position $G$) is grounded via the via hole 906 as shown in Fig. 3.

[0058] When the position of the switch 903 in the conduction state is changed from 10 degrees to 30 degrees in order to change only the bandwidth without changing the resonance frequency in a state where the switch 903 in the conduction state is placed at the 10-degree position to obtain a center frequency of 5.0 GHz and a certain bandwidth with every capacitance of the inserted two capacitors 10 set to a certain value (1 pF in this example), Fig. 4 shows that the resonance frequency changes to 5.3 GHz on a higher frequency side simultaneously with a significant change of the bandwidth. In other words, it is impossible for the constitution of the variable resonator 850 to sustain the resonance frequency. The same applies to the case where one ends of the capacitors 10 are connected to the circular line which is formed by the two lines 852 integrally and the other ends of the capacitors 10 are grounded.

[0059] The inventors got a conception from the foregoing that three or more reactance circuits 102 were required in order to realize a variable resonator whose resonance frequency is determined corresponding to the reactance value while being capable of significantly changing bandwidth. Then, description will be made for the fact that three or more reactance circuits 102 are required by showing the frequency characteristics of the circuit simulations of the variable resonator 100a and the variable resonator 100b in the case where various numbers of the reactance circuits 102 are electrically connected to the line 902.

[0060] Fig. 5A to Fig. 5F show the circuit constitutions and the frequency characteristics of the circuit constitution when 36 pieces (Fig. 5A), 10 pieces (Fig. 5B), 4 pieces (Fig. 5C), 3 pieces (Fig. 5D), 2 pieces (Fig. 5E) and 1 piece (Fig. 5F) of capacitors are used as the reactance circuits 102 in the constitution of the variable resonator 100a.

[0061] The arrangement and capacitance $C$ of the capacitors in circuit simulation are as shown in Fig. 5A to Fig. 5F. The switches 903 were omitted for convenience and selecting of the switch 903 to be conducted was simulated by changing the position of the via hole 906 for grounding instead. The position of the via hole 906 was a position at $x$ degree of center angle measured clockwise from the position $G'$ symmetrical with respect to the center $O$ of the line 902 to the connection position $G$ the variable resonator 100a was connected to the input/output line 7 similarly to the case shown in Fig. 3. The circumference of the loop line 902 was set to one wavelength at 5 GHz. To simulate the frequency characteristics of the variable resonator, the variable resonator was connected to the input/output line 7 as a branching circuit, and port impedance, the characteristic impedance of the input/output line 7, and the characteristic impedance of the loop line 902 were all set to 50Ω.

[0062] Each frequency characteristics shown by the circuit simulations is the transmission coefficient of a signal when the signal inputted from Port 1 is transmitted to Port 2, and it is expressed in a dB unit. The resonance frequency should be a frequency when the impedance of the variable resonator takes infinity, and it is a frequency when the insertion loss takes a minimum in the frequency characteristics shown in Fig. 5A to Fig. 5F. There are some cases where a plurality of frequencies at which the insertion loss takes a minimum appears in the frequency characteristics shown in Fig. 5A to Fig. 5F, and the resonance frequency at these cases is defined as follows.

[0063] "When the capacitance of each capacitor 10 is 0 pF, in other words, when the capacitors 10 are not connected, the length of the loop line 902 is set such that the frequency at which insertion loss takes a minimum becomes 5.0 GHz. When the capacitance of each capacitor 10 is continuously changed from 0 pF, the frequency at which the insertion loss takes a minimum continuously changes from 5 GHz to a lower frequency side in response to the change of the capacitance. A frequency at which the continuously changed insertion loss takes a minimum is the resonance frequency discussed here".

[0064] Fig. 5A to Fig. 5F show that the resonance frequency was changed to the lower frequency side in all variable resonators 100a when the capacitance of the capacitor 10 was increased. Fig. 5A to Fig. 5D show that the resonance frequency did not change but transmission zeros (where the transmission coefficients are minimum) around the frequency changed when the position of the via hole 906 (grounding position) was changed while the capacitance of each capacitor 10 was fixed to an arbitrary value, in a variable resonator provided with three or more capacitors 10 being as the reactance circuit. In other words, the resonance frequency is not influenced by the position of the switch 903 turned to be the conduction state in these cases. On the other hand, Fig. 5E and Fig. 5F show that the resonance frequency changed in response to the movement of the position of the via hole 906 (grounding position) was changed while the capacitance of each capacitor 10 was fixed to an arbitrary value, in a variable resonator provided with three or more capacitors 10 being as the reactance circuits. In other words, the resonance frequency is influenced by the position of the switch 903 turned to be the conduction state in these cases. The above description indicates that the resonance frequency is influenced by the position of the switch 903 turned to be the conduction state unless the resonator is provided with three or more capacitors 10, that is, the reactance circuits.

[0065] Fig. 6A to Fig. 6C show the circuit constitution and the frequency characteristics of the circuit constitutions when 36 pieces (Fig. 6A), 6 pieces (Fig. 6B) and 4 pieces (Fig. 6C) of capacitors are used as the reactance circuits 102 in the constitution of the variable resonator 100b.
Accompanying circuits such as the input/output port and the input/output line are similar to the circuits shown in Fig. 5A to Fig. 5F, and the frequency characteristics is also the transmission coefficients of a signal transmitting from Port 1 to Port 2 similar to the cases of Fig. 5A to Fig. 5F. In each circuit constitution, two capacitors 10 surrounded by a dotted line α may be replaced with a single capacitor set to the capacitance twice that of each of the other capacitors. In this case, the number of the capacitors 10 is 35 pieces, 5 pieces and 3 pieces respectively in Fig. 6A to Fig. 6C.

As it is clear from Fig. 6A to Fig. 6C, in the case of four or more capacitors 10 or the case of three or more capacitors and one piece out of them is set to the capacitance twice that of each of the other capacitors 10, the resonance frequency is not influenced by the position of the switch 903 turned to be the conduction state. The case where the number of the capacitors 10 is 2 or 1 is similar to the cases shown in Fig. 5E and Fig. 5F, and in these cases, the resonance frequency is influenced by the position of the switch 903 turned to be the conduction state as described above.

The above description gives the findings that at least three reactance circuits 102 are necessary in order to prevent the resonance frequency from being influenced by selecting the switch 903 turned to be the conduction state in the variable resonator 100a and the variable resonator 100b. In the above description, the characteristic impedance of the loop line 902 of the variable resonator 100a or the variable resonator 100b was set to 50Ω same as that of the input/output line and the input/output port, it is not particularly limited to this, but is a design parameter decided corresponding to the performance characteristics required.

Although the capacitor is used on behalf of the reactance circuits 102 in the above description, a similar effect is obtained when a circuit element such as an inductor and a transmission line, a circuit where a plurality of the same type items out of them are combined, a circuit where a plurality of different type items out of them are combined or the like is used instead of the capacitor.

Fig. 7 shows a variable resonator 100c in the case of having a structure of the same type as the variable resonator 100a and using inductors 11 as the reactance circuits 102. Fig. 8 shows a variable resonator 100d in the case of having a structure of the same type as the variable resonator 100b and using the inductors 11 as the reactance circuits 102. In each drawing, the switches 903 or the like are not shown for simple illustration. An inductor 11a surrounded by a dotted line in Fig. 8 is an inductor that two inductors 11 are replaced with similar to the dotted line β shown in Fig. 2, and its inductance is set to half the value of each of the other inductors 11. Comparing to the case of using the capacitors 10, the resonance frequency shifts to a higher frequency side when the inductors are used. For example, Fig. 9 shows the frequency characteristics of the variable resonator 100c shown in Fig. 7, where the resonance frequency moves to the higher frequency side by 0.34 GHz by setting the inductances of the inductors to 5 nH, and the resonance frequency moves to the higher frequency side by 1.15 GHz by setting the inductances of the inductors to 1 nH. Note that the position x shown in Fig. 7 should be the same as the one described in Fig. 5.

Herein, description will be made for the effect that a change of the resonance frequency of the variable resonator by a reactance circuit such as a capacitor and an inductor from a resonance frequency which is determined by the length of a loop line gives to the size of a variable resonator.

First, description will be made for the case where a capacitive reactance circuit, e.g., a capacitor, is loaded as a reactance circuit. Referring to Fig. 5D as a case of the variable resonator 100a, the circumference L of the loop line 902 that constitutes the variable resonator 100a is one wavelength in 5 GHz in the example shown as described above. Therefore, the resonance frequency of the resonator is 5 GHz when the capacitor is not loaded, but the variable resonator 100a is the variable resonator having the resonance frequency of 3.6 GHz because the capacitors having 1.0 pF are loaded (refer to the graph on the bottom of Fig. 5D). In short, the variable resonator 100a shown in Fig. 5D, by loading the capacitors having 1.0 pF, operates as a variable resonator having the resonance frequency of 3.6 GHz while it is provided with the loop line 902 having the circumference L of one wavelength at 5 GHz. Meanwhile, the circumference L of the loop line 902 has one wavelength at 3.6 GHz in the case where the variable resonator resonating at 3.6 GHz is constituted without loading a capacitor, that is, in the case of the constitution of the variable resonator 900. In the case of manufacturing the resonator by a dielectric substance having the thickness of 0.5 mm, an alumina substrate having the relative permittivity of 9.6, and employing a microstrip structure, the circumference L of the loop line 902 of the variable resonator 900 is 32 mm. Compared to this, in the variable resonator 100a using the loop line 902 having one wavelength at 5 GHz and the capacitor having 1.0 pF, which is described earlier, the circumference L of the loop line 902 is about 23 mm under the same condition. This makes it possible to realize a circumference shorter by about 1 cm with the same performance, and its area is about half that of the case where the capacitor is not loaded, assuming that the loop line 902 is a complete round. In the case where the capacitors are loaded in this manner, the size of the variable resonator can be reduced while the resonator sustains to have the same performance.

Next, description will be made for the case where an inductive reactance circuit, e.g., an inductor, is loaded as a reactance circuit. In the constitution similar to Fig. 7, the length of the loop line 902 should be one wavelength at 10 GHz. At this point, the inductance...
of the inductor is set to 1 nH, the resonance frequency is approximately 21 GHz. In short, the variable resonator 100c in Fig. 7, by loading the inductors having 1 nH, operates as a variable resonator having the resonance frequency of 21 GHz while it is provided with the loop line 902 having the circumference L of one wavelength at 10 GHz. Meanwhile, the circumference L of the loop line 902 has one wavelength 21 GHz in the case where the variable resonator resonating at 21 GHz is constituted without loading inductors, that is, in the case of the constitution of the variable resonator 900. In the case of manufacturing the resonator by the dielectric substance having the thickness of 0.5 mm, the alumina substrate having the relative permittivity of 9.6, and employing the microstrip structure, the circumference L of the loop line 902 of the variable resonator 900 is 5 mm. In the case of using 10 switches 903 in the loop line 902 having this circumference, it is necessary to provide the switches 903 at the intervals of 0.5 mm or less, and it could be difficult depending on a manufacturing technology Compared to this, in the variable resonator 100c using the loop line 902 having one wavelength at 10 GHz and the inductors having 1 nH, which is described earlier, the circumference L of the loop line 902 becomes about 12 mm, so that the switches 903 should be provided at the intervals of 1.2 mm or less if 10 switches 903 are used similarly, and this significantly loosens design conditions from the former case and manufacturing of resonator becomes easier.

As described above, since the bandwidth can be significantly changed in response to the selection of the switch 903 to be turned to the ON state, and the circumference of the line 902 is set so as to achieve a desired resonance frequency based on the correlation with each reactance value of each reactance circuit 102, the variable resonator can be manufactured in an arbitrary size by appropriately designing the reactance circuit 102.

Fig. 10 shows a variable resonator 100e in the case of having a structure of the same type as the variable resonator 100a and using transmission lines as reactance circuits 102. In the drawing, the switches 903 or the like are not shown for simple illustration.

One ends of the transmission lines 12 are connected to the line 902, and the other ends of the transmission lines 12 are open-circuited. However, leaving the other ends of the transmission lines 12 open is not an essential technical matter, but may be grounded, for example.

Fig. 11 shows a variable resonator 100f in the case of having a structure of the same type as the variable resonator 100b and using the transmission lines as the reactance circuits 102.

The constitution of the reactance circuit 102 is the same as that of the reactance circuit 102 in the variable resonator 100e shown in Fig. 10. However, the constitution itself of the reactance circuit 102a shown in Fig. 11 is the same as the constitution of the reactance circuit 102, but the characteristic impedance of the transmission line is set to Z/2. Of course, two reactance circuits 102 may be connected to a position at which the reactance circuit 102a is connected to the line 902.

Fig. 13 shows the frequency characteristics of the variable resonator 100e shown in Fig. 10 in the case of using open-circuited transmission lines 12 as the reactance circuits 102. The position x (grounding portion) of the via hole 906 was set to the position of x=10°. Note that the position x shown in Fig. 10 should be similar to the one described in Fig. 5. The resonance frequency is 4.79 GHz in the case of the transmission line 12 having the length of 20 degrees of the phase at 5 GHz, where the frequency changes to a lower frequency side only by 0.21 GHz comparing to the case of using no transmission line 12. This is because the impedance of the transmission line 12 loaded at a connection position between the transmission line 12 loaded as the reactance circuit 102 and the loop line 902 is capacitive. This impedance is determined by the length of the transmission line 12, the termination mode of the tip of the transmission line 12 (open-circuited, short-circuited, or connecting any type of reactance element or the like), and they are design parameters to be appropriately set. Even the case of using the transmission line 12 for the reactance circuit 102 has the similar effect of the case of using the capacitor or the inductor for the reactance circuit 102 described above with respect to the size of a variable resonator.

In the above-described variable resonator 100a and the same type structure thereof, a connected portion between the input/output line 7 and the variable resonator 100a, that is, a supply point of a signal is at the center of the two reactance circuits 102 sandwiching the supply point, but a position off from the center may be set as a supply point of a signal as shown in Fig. 14. For that matter, an arbitrary position on the loop line 902 may be set to the supply point. However, the positions of the switches 903 need to be set such that a desired bandwidth variation can be obtained as a design matter. Further, the same applies to the supply point of a signal regarding the above-described variable resonator 100b and the same type structure thereof, a position off from the center may be set as the supply point of a signal as shown in Fig. 15, and an arbitrary position on the loop line 902 may be set to the supply point. The same applies to the positions of the switches 903 where the positions need to be set such that a desired bandwidth variation can be obtained as a design matter.

In the above-described variable resonator 100a and the same type structure thereof, each reactance circuit 102 is electrically connected to the loop line 902 as a branching circuit, but as shown in Fig. 16, the constitution is acceptable that the loop line 902 is cut at positions where the reactance circuits 102 are connected.
to the circular line 902 in parallel and divided into a plurality of fragment lines (which correspond to lines 902a, 902b, 902c in the drawing), and the reactance circuits 102 are electrically connected in series between adjacent fragment lines at each cut portion.

[0082] Similarly, in the above-described variable resonator 100b and the same type structure thereof, each reactance circuit 102 is electrically connected to the circular line 902 as a branching circuit, but as shown in Fig. 17, the constitution is acceptable that the loop line 902 is cut at positions where the reactance circuits 102 are connected in parallel to the loop line 902 and divided into a plurality of fragment lines (which correspond to lines 902a, 902b, 902c in the drawing), and the reactance circuits 102 are electrically connected in series between adjacent fragment lines at each cut portion.

[0083] In each drawing, the circumference of the loop line before cutting is the same as the sum of the lengths of the fragment lines after cutting in both cases. In the example shown in Fig. 16, the line lengths of the lines (902a, 902b, 902c) are the same, and the sum of the lengths is equal to the circumference L of the loop line 902. In the example shown in Fig. 17, the line lengths of the lines (902b, 902c) are the same, the sum of the line lengths of the lines (902b, 902c) is equal to the line length of the line 902a, and the sum of the line lengths of the lines (902a, 902b, 902c) is equal to the circumference L of the loop line 902. Note that Fig. 16 and Fig. 17 exemplify the case of the variable resonator 100a or the variable resonator 100b.

[0084] Connection points of the switches 903 to the line 902 are set such that a desired bandwidth is obtained, and the connection points sustain without change even in each cut line after cutting. Therefore, one or more fragment lines to which no switch 903 is connected may exist.

[0085] From a different perspective, each variable resonator shown in Fig. 16 is that the fragment lines and the reactance circuits 102 constitute an annularly-shaped variable resonator. In short, although each line (902a, 902b, 902c) is set as a line that is obtained by cutting the loop line 902 at positions where the reactance circuits 102 are connected to the loop line 902, N lines (N is an integer satisfying N≥3) may be generally used, and arranging them annular and electrically connecting with one reactance circuit 102 in series between the lines make an annularly-shaped variable resonator. Note that the line lengths of the fragment lines should be equal in the electrical length at a resonance frequency whose one wavelength or integral multiple thereof corresponds to the sum of the line lengths of the fragment lines. In the case where the relative permittivity of the dielectric substrate 905 is uniform, the resonator may be constituted based on the physical length instead of the electrical length.

[0086] Similarly, from a different perspective, the variable resonator shown in Fig. 17 is that the fragment lines and the reactance circuits 102 constitute an annularly-shaped variable resonator. Describing the constitution in a generalized manner, by using M-1 lines and M reactance circuits 102 where M is an even number of 4 or larger, one reactance circuit is connected in series between an i-th line and an (i+1)-th line where i is an integer satisfying 1≤i≤M/2, two reactance circuits in series connection are connected in series between the (M/2+1)-th line and the (M/2+1)-th line, one reactance circuit is connected in series between the i-th line and the (i+1)-th line where i is an integer satisfying M/2+1≤i≤M-1, one reactance circuit is connected in series between the (M-1)-th line and the first line (i=1), and thus forming an annularly-shaped variable resonator. Regarding the line length of each line, a resonance frequency whose one wavelength or integral multiple thereof corresponds to the sum of the line lengths of the lines the electrical length from the certain position K arbitrarily set on the first line to the end portion thereof, which is closer to the second line (i=2), and the electrical length of the i-th line (i is an integer of 1≤i≤M/2) should be equal; and the electrical length from the position K on the first line to the end portion thereof, which is closer to the (M-1)-th line, and the electrical length of the i-th line (i is an integer of M/2+1≤i≤M-1) should be equal. In case where the relative permittivity of the dielectric substrate 905 is uniform, the resonator may be constituted based on the physical length instead of the electrical length.

[0087] Particularly in the variable resonator 100b which employed the constitution of series connection shown in Fig. 17 and the same type structure thereof where two reactance circuits 102 are connected in series in the dotted-line framed portion α, it needs to be the reactance circuit 102a set to a reactance value twice that of each of the reactance circuits 102 as shown in the dotted-line framed portion β in the drawing when they are replaced with a single reactance circuit 102a. For example, the capacitance of the capacitor as the reactance circuit 102a needs to be set to C/2 when the reactance circuit 102 is a capacitor set to a capacitance C, and the inductance of the inductor of the reactance circuit 102a needs to be set to I when the reactance circuit 102 is an inductor set to an inductance value I.

[0088] Hereinafter, when either the variable resonator 100a or the same type structure thereof or the variable resonator 100b or the same type structure thereof is acceptable, reference numeral 100 allocated and the resonator will be called a variable resonator 100.

[0089] Fig. 18 shows a tunable bandwidth filter (tunable bandpass filter) 200 where two of the above-described variable resonator 100 are used (the variable resonator 100a is exemplified in Fig. 18) and a variable phase shifter 700 being a phase variable circuit inserted into an area sandwiched by positions where the variable resonator 100 are connected to the input/output line 7 as branching circuits. Generally, when two or more resonators are used and adjacent resonators are connected by a line whose phase changes by 90 degrees at the resonance frequency of the resonator (the line having quarter wavelength at the resonance frequency), a bandpass fil-
ter is obtained. Although it is desirable to connect the variable resonators 100 by the line having quarter wavelength at the resonance frequency of the variable resonator 100, the line is not limited to this. However, in the case where the resonators are connected by a line having a length other than the quarter wavelength or other than a wavelength having the odd multiple thereof, a pass-band appears in a band off from the resonance frequency of the variable resonator unless the characteristics of the variable resonators 100 are equal. This is because the resonance frequency (center frequency) of the entire circuit becomes the resonance frequency of each variable resonator when the resonators are connected by a line having the quarter wavelength or the odd multiple thereof, whereas a signal transmits at a series resonance frequency of the entire circuit made up of the variable resonators and the input/output line in order cases. Based on the reason, the tunable bandpass filter 200 is realized by using the variable resonator 100a and the variable phase shifter 700. Further, in the case where the appearance of passband in a band off from the resonance frequency of the variable resonator may be allowed, characteristics in the passband can be changed by changing phase between resonators, so that the variable phase shifter may be also used for this object. The tunable bandpass filter 200 is constituted of using two variable resonators 100 in the example shown in Fig. 18, but the tunable bandpass filter may be constituted of using two or more variable resonators 100. In this case, the variable phase shifter 700 should be inserted between areas where the adjacent variable resonators 100 are connected to the input/output line 7.

[0090] In addition, without inserting the variable phase shifter 700, a tunable bandwidth filter is also acceptable in which the positions where the variable resonators 100 are connected to the input/output line 7 are connected by a line of quarter wavelength at the resonance frequency of the variable resonator 100.

[0091] Fig. 19 to Fig. 25 show examples of a phase variable circuit that may be used in the tunable bandpass filter 200.

[0092] [1] Two single-pole r-throw switches 77 are provided where r is an integer of 2 or larger, both r-throw side terminals select the same one transmission line out of r transmission lines 181 to 18r, whose lengths are different and thus signal phase between ports (R1, R2) is made variable (refer to Fig. 19).

[2] Two or more variable capacitors 19 are connected along the transmission line 18, and the end portion of the variable capacitors 19 on the opposite side of the end port which are connected to the transmission line 18 are grounded. By appropriately changing the capacitance of each variable capacitor 19 as a design matter, a signal phase between the ports (R1, R2) is made variable (refer to Fig. 20).

[3] Two or more switches 20 are connected along the transmission line 18, and the end portions of the switches 20 on the opposite side of the end portions which are connected to the transmission line 18 are connected to a transmission line 21. By appropriately changing the conduction state of each switch 20 as a design matter, a signal phase between the ports (R1, R2) is made variable (refer to Fig. 21).

[4] By appropriately changing the capacitance of the variable capacitor 19 between the ports (R1, R2) as a design matter, a signal phase between the ports (R1, R2) is made variable (refer to Fig. 22).

[5] The variable capacitor 19 is connected to the input/output line 7 between the ports (R1, R2) as a branching circuit. An end portion of the variable capacitor 19 on the opposite side of the end portion, which is connected to the input/output line 7 is grounded. By appropriately changing the capacitance of the variable capacitor 19 as a design matter, a signal phase between the ports (R1, R2) is made variable (refer to Fig. 23).

[6] By appropriately changing the inductance of a variable inductor 11 between ports (R1, R2) as a design matter, a signal phase between ports (R1, R2) is made variable (refer to Fig. 24).

[7] The variable inductor 11 is connected to the input/output line 7 between the ports (R1, R2). An end portion of the variable inductor 11 on the opposite side of the end portion, which is connected to the input/output line 7 is grounded. By appropriately changing the inductance of the variable inductor 11 as a design matter, a signal phase between the ports (R1, R2) is made variable (refer to Fig. 25).

[0093] Fig. 26 shows a tunable bandwidth filter 300 where two of the above-described variable resonator 100 are used (the variable resonator 100a is exemplified in Fig. 26), and variable impedance transform circuits 600 are severally inserted into an area sandwiched by positions where the variable resonators 100 are connected to the input/output line 7 as branching circuits, an area between the input port and a position where one variable resonator 100 is connected to the input/output line 7 as a branching circuit, and an area between the output port and a position where the other variable resonator 100 is connected to the input/output line 7 as a branching circuit. Generally, by using one or more resonators, it is possible to constitute a filter by connecting between the resonator and the input port/output port, and furthermore between resonators when there is a plurality of resonators, by using a variable impedance transform circuit such as a J-inverter and a K-inverter. Based on the principle, the tunable bandwidth filter 300 is realized by using the variable resonators 100a and the variable impedance transform circuits 600. The tunable bandwidth filter 300 is constituted of using two variable resonators 100 in the example shown in Fig. 26, but it is possible to constitute the tunable bandwidth filter 300 by using two or more variable resonators 100. In this case, each variable impedance trans-
form circuit 600 should be inserted into areas sandwiched by the positions where adjacent variable resonators 100 are connected to the input/output line 7.

[0094] Although the above-described each tunable bandwidth filter bused two or more variable resonators 100, it is possible to constitute the tunable bandwidth filter by using single variable resonator 100. In constituting the tunable bandwidth filter by using one variable resonator 100, the filter becomes as exemplified in Fig. 5A to Fig. 5F and Fig. 6A to Fig. 6C, for example. In short, the variable resonator 100 should only be electrically connected as a branching circuit to the input/output line 7 being a transmission line. With this constitution, a signal can be propagated at a bandwidth straddling the resonance frequency, it operates as a tunable bandwidth filter.

[0095] The above-described tunable bandwidth filter has the constitution that a single signal supply point at which the variable resonator 100 is connected to the input/output line 7 exists 1, and the variable resonator 100 is connected to the input/output line 7 as a branching circuit. However, as shown in Fig. 27, the constitution of the tunable bandwidth filter 400 that the variable resonator 100 is connected to the input/output line 7 in series is also possible. Although Fig. 27 shows the example where the variable resonator 100a is used as the variable resonator 100 and is connected to the input/output line 7 in series, the variable resonator 100b may be used as the variable resonator 100 (refer to Fig. 30).

[0096] The frequency characteristics of the tunable bandwidth filter 400 employing the constitution is shown in Fig. 28 and Fig. 29. The tunable bandwidth filter shown in Fig. 28 is a filter where the reactance circuits 102 of the variable resonator 100 are capacitors. Fig. 29 shows the frequency characteristics of the tunable bandwidth filter shown in Fig. 28. The length of the loop line 902 was set to one wavelength at 5GHz and the impedance of the input/output line 7, the loop line 902 and the input/output port was set to 50Ω. Fig. 29 makes it clear that the center frequency of the tunable bandwidth filter is moved to the lower frequency side by changing the capacitances of the variable capacitors from 0 pF to 0.5 pF. Further, the graph also shows that bandwidth can be changed without changing the center frequency even if the position of the switch 903 is changed to the conduction state (Fig. 29 shows the example of 10, 20 and 30 degrees) is changed at each capacitance. In short, it is understood that the center frequency is not influenced by the change of the position of the switch 903 in the conduction state.

[0097] As described above, at least three reactance circuits 102 of the variable resonator 100 are necessary. From the viewpoint of miniaturization, it seems to be preferable that the number of the reactance circuits 102 is as small as possible. However, a constitution provided with a large number of the reactance circuits 102 has an advantage, and it will be described by employing the case of using capacitors as an example.

[0098] Referring to Fig. 5A and Fig. 5B, in the case where capacitors having the capacitance of 0.1 pF are loaded, the graphs show that the larger the number of capacitors loaded, the more significantly the resonance frequency changes under the same condition. This means that the capacitance per 1 piece may be smaller as the number of capacitors to be loaded becomes larger when an attempt of changing the resonance frequency to the same value. For this reason, if it is difficult to load one capacitor having a large capacitance on a substrate in fabricating a variable resonator, there is a possibility of obtaining an equal result by providing a large number of capacitors having a small capacitance instead. Particularly, it is easily realized when a technology such as an integrated circuit manufacturing process which is good at manufacturing a large number of the same device is used.

[0099] Further, description will be made for an effect produced by the fact that the resonance frequency of the variable resonator 100 changes by the reactance circuits 102 such as the capacitor, the inductor and the transmission lines from a resonance frequency, which is determined by the length of the circular line 902.

[0100] Not limited to the variable resonator 100, there are cases where the relative permittivity of a substrate for fabricating a resonator is not constant among substrates or even in the same substrate depending on the conditions in manufacturing the resonator despite the same material and the same manufacturing method. For this reason, even if resonators having the same dimensions are formed on the substrate, the phenomenon occurs that the resonance frequencies of the resonators are different. Therefore, there are cases where adjustment work is required in a general filter using a resonator. In a resonator using a transmission line, adjusting the resonance frequency by trimming the length of the transmission line is generally done, but it is impossible for the resonator provided with the loop line. Further, although adjusting the resonance frequency by adding a reactance element such as a capacitor is also generally done, such an adjustment method is not versatile depending on the design environment of resonator. In a resonator capable of significantly changing only the bandwidth at a certain center frequency, adjustment cannot be performed by adding the reactance element without thorough consideration in many cases. Under the existing circumstances, the variable resonator 100 can enjoy advantageous effect. For example, in the case where no reactance circuit
102 is connected, if the variable resonator 100 designed to resonate at a resonance frequency being a design value resonates at a higher frequency than the design resonance frequency due to a lower relative permittivity of the actual substrate than the relative permittivity of a substrate used during designing, the frequency can be easily adjusted to the design resonance frequency by connecting the reactance circuit 102 having an appropriate reactance value to the variable resonator 100. Then, the change of the position of the switch 903 to be turned to the conduction state does not influence resonance frequency in the variable resonator 100.

[0101] Hereinafter, description will be made for a modified example according to an embodiment of the present invention.

[0102] Regarding the variable resonator 100, by turning the switch 903 to the ON state which is at a position w times (w=0,1,2,3,...) the electrical length $\pi$ at the design resonance frequency from the signal supply point along the line 902, input impedance at the signal supply point can be brought to 0. Therefore, in the case of constituting the tunable bandwidth filter by using the variable resonator 100, a signal of the design resonance frequency is prevented from passing the filter by turning the switch 903 to the ON state which is at a position w times the electrical length $\pi$ at the design resonance frequency. On the other hand, by turning the switch 903 at the position to the OFF state, the signal of the design resonance frequency is allowed to pass the filter. Then, when the tunable bandwidth filter is constituted not aiming at signal elimination but passing the signal of a desired frequency, there is no need to provide the switches 903 at the positions of integral multiple of the electrical length $\pi$ in the design resonance frequency. As shown in Fig. 31 as an example, in the case where the line 902 is a circular shape and its length is one wavelength in the design resonance frequency, a position R symmetrical to the signal supply point with respect to the center O of the line 902 is a position of integral multiple of the electrical length $\pi$, and the constitution that switches are not provided on these two positions is possible.

[0103] When the switch 903 at the position w times the electrical length $\pi$ at the design resonance frequency from the signal supply point along the line 902 at the design resonance frequency is not turned to the ON state, input impedance in the signal supply point can be brought to infinity in the variable resonator 100. For this reason, characteristics having a low insertion loss is obtained even if the switch 903 of a relatively large resistance is used as shown in Fig. 32 as an example.

[0104] Thus, a constitution positively utilizing resistors may be also employed. For example, the case of positively utilizing resistors such as switching the case where the line 902 is connected to the ground conductor 904 directly by a switch 35 being a switching device having a low resistance and the case where the line 902 is connected to the ground conductor 904 by the switch 35 via a resistor 70 having several ohms to several tens ohms which is higher than the resistance of the switch 35, are possible (refer to Fig. 33). In this case, by laying the resistor 70 having several ohms to several tens ohms, it becomes possible to select the case of suppressing signal propagation in a band influenced by the resistor and the case of allowing a signal near the band influenced by the resistor to propagate by bringing the resistance as low as possible.

[0105] Although the case of using resistors has been shown here, not limited to the resistor, a passive element exemplified by a variable resistor, an inductor, a variable inductor, a capacitor, a variable capacitor, a piezoelectric element and the like, for example, may be used.

[0106] It is possible to constitute a tunable bandwidth filter by executing electrical connection between the variable resonator 100 and the transmission line 30 based on electric field coupling or magnetic field coupling. Fig. 34 exemplifies the case of constituting a tunable bandwidth filter 401 by electric field coupling, and Fig. 35 exemplifies the case of constituting a tunable bandwidth filter 402 by magnetic field coupling. Note that the variable resonator 100a is exemplified as the variable resonator 100 in Fig. 34 and Fig. 35.

[0107] A tunable bandwidth filter 404 shown in Fig. 36A is constituted of the two variable resonators 100 having the same resonance frequency, a switch 33 and a switch 34, which are provided between each variable resonator and the input/output line 7 being the transmission line. A tunable bandwidth filter 405 shown in Fig. 36B also has the similar constitution to the tunable bandwidth filter 404. However, the tunable bandwidth filter 404 uses two variable resonators having the same characteristic impedance, whereas the tunable bandwidth filter 405 uses two variable resonators having different characteristic impedances. Herein, reference numerals attached to the variable resonators should be 100X and 100Y conveniently.

[0108] In the case of the tunable bandwidth filter 404, selecting of the switches (33, 34) realizes a state where only one variable resonator 100X is connected or the other state where both of the variable resonators 100X are connected. The resonance frequencies are the same in both states, whereas frequency characteristics are different in each state. When both of the variable resonators 100X are connected to the input/output line 7, an attenuation amount of a signal at a frequency further from the resonance frequency becomes larger comparing to the case of connecting only one variable resonator 100X to the input/output line 7. This is because the characteristic impedance of the variable resonators 100X becomes half equivalently. In short, the characteristic impedance of each variable resonator to the input/output line 7 is switched by changing the ON or OFF state of the switches (33, 34), and the frequency characteristics of the tunable bandwidth filter 404 can be changed corresponding to the two states above.

[0109] In the case of the tunable bandwidth filter 405, selecting of the switches (33, 34) realizes three states: a first state where only one variable resonator X is con-
nected, a second state where only one variable resonator Y is connected and a third state where both of the variable resonators (X, Y) are connected. The resonance frequencies are the same in all states, whereas frequency characteristics are different in each state. In short, in the tunable bandwidth filter 405, the characteristic impedance of each variable resonator to the input/output line 7 is switched by changing the ON or OFF state of the switches (33, 34) similar to the case of the tunable bandwidth filter 404, and the frequency characteristics of the tunable bandwidth filter 404 can be changed corresponding to the three states above.

[0110] Although the tunable bandwidth filter 400 shown in Fig. 27 shows the case of using one variable resonator 100, it may have the constitution that a plurality of the variable resonators 100 are connected in series as shown in Fig. 37 or the constitution that a part of a plurality of the variable resonators 100 is connected to the input/output line 7 as a branching circuit and the remaining variable resonators 100 are connected to the input/output line 7 in series as shown in Fig. 38, where each drawing exemplifies the case of using two variable resonators.

[0111] All of the variable resonators 100 shown above are in the circular shape, but the present invention is not intended particularly to the circular shape. The essence of the present invention is in [1] constituting the variable resonator in a loop shape (refer to Fig. 1, Fig. 2, Fig. 16 and Fig. 17) and [2] the arrangement of the reactance circuits 102 electrically connected to the variable resonator, but not in the shape of the line 902. Therefore, when the line 902 is constituted of a transmission line having the same characteristic impedance, for example, the line may be an elliptic shape as shown in Fig. 39 or may be a bow shape as shown in Fig. 40. Note that the illustration of the switches 903 and the reactance circuits 102 is omitted in each drawing of Fig. 39 to Fig. 46.

[0112] Fig. 41A shows the case where the variable resonator having the loop line 902 of the circular shape is connected to the transmission line 7. Fig. 41B shows the case where the variable resonator having the loop line 902 of the elliptic shape is connected to the transmission line 7.

[0113] Generally, low insertion loss can be obtained by the constitution shown in Fig. 41B than the constitution shown in Fig. 41A. In the case where magnetic field coupling occurs between the transmission line and the loop line, reflection of an input signal due to the reduction of impedance in the connection area could be a cause of the loss. The reason why the low insertion loss is obtained in the constitution shown in Fig. 41B is because magnetic field coupling between the transmission line 7 and the loop line 902 is reduced by connecting the variable resonator to the transmission line such that the long diameter of the ellipse being the shape of the loop line is made orthogonal to the transmission line 7.

[0114] Further, if a multilayer structure is allowed, the constitution shown in Fig. 42A, for example, may be employed. Assuming that the front is an upper layer followed by lower layers backward sequentially when the page surface of Fig. 42 is seen from the front, a L-type transmission line 7a is disposed on the upper layer as shown in Fig. 42B, the variable resonator is disposed on the lower layer thereof, and the transmission line 7a and the line 902 of the variable resonator overlap on a part (reference symbol S). Further, as shown in Fig. 42C, a L-type transmission line 7b is further disposed on the lower layer, and the transmission line 7b and the line 902 of the variable resonator overlap on the part (reference symbol S). A via hole is provided on the portion shown by the reference symbol S, and the transmission line 7a, the line 902 and the transmission line 7b are electrically connected mutually

[0115] Description will be added to several modes of the multilayer structure by referring to the cross-sectional views along the line XI - XI in the visual line direction shown in Fig. 42A. Note that it is assumed that the plan view of the multilayer structure is as shown in Fig. 42A. Further, it is assumed that the upper side of the drawing paper is the upper layer and the lower side of the drawing paper is the lower layer in each cross-sectional view shown in Fig. 43A to Fig. 43F. To show the sectional constitution simply, the switches 903 or the like are not shown.

[0116] A first example of the multilayer structure should have the constitution that the ground conductor 904 being the lowest layer and the dielectric substrate 905 being the upper layer thereof are arranged in a contacted manner, and furthermore, the dielectric substrate 905 and the transmission line 7a being the upper layer thereof are arranged in a contacted manner as shown in Fig. 43A. The transmission line 7a and the transmission line 7b of the variable resonator are fixed in the dielectric substrate 905 in an embedded manner. The loop line 902 is arranged on an upper layer than the transmission line 7b. Then, a via hole 66 is provided on the portion shown by the reference symbol S to electrically connect the transmission line 7a, the line 902 and the transmission line 7b. Each via hole 67 is for securing electrical connection between the switch 903 of the loop line 902 fixed in the dielectric substrate 905 in an embedded manner and the outside of the dielectric substrate for operating the switch 903 from outside, for example, and the via hole 67 is electrically connected to conductors 330 on the uppermost layer which are arranged in a contacted manner with the dielectric substrate 905. Note that Fig. 43A does not show a via hole 906, a conductor 933 and the like shown in Fig. 47, and it must be noted that the via hole 67 does not have the same object/function as the via hole 906.

[0117] A second example of the multilayer structure should have the constitution that the ground conductor 904 being the lowest layer and the dielectric substrate 905 being the upper layer thereof are arranged in a contacted manner, and furthermore, the dielectric substrate 905 and the loop line 902 on the upper layer thereof are arranged in a contacted manner as shown in Fig. 43B.
The transmission line 7b is fixed in the dielectric substrate 905 in an embedded manner. The transmission line 7a is arranged on an upper layer than the loop line 902, and is supported by a support body 199. In Fig. 43B, the support body 199 lies between the transmission line 7a and the dielectric substrate 905, but the embodiment is not limited to such a constitution, and other constitutions are acceptable as long as an object of supporting the transmission line 7a is achieved. The material of the support body 199 may be appropriately employed depending on the arrangement constitution of the support body 199, and it may be either metal or dielectric material in the example of Fig. 43B. Then, the via hole 66 is provided on the portion shown by the reference symbol S to electrically connect the transmission line 7a, the line 902 and the transmission line 7b mutually.

A third example of the multilayer structure should have the constitution that the ground conductor 904 being the lowest layer and the dielectric substrate 905 being the upper layer thereof are arranged in a contacted manner, and furthermore, the dielectric substrate 905 and the transmission line 7b and conductors 331 which are on the upper layer of the substrate are arranged in a contacted manner as shown in Fig. 43C. The loop line 902 is supported by the support bodies 199 on an upper layer than the transmission line 7b and the conductors 331. Further, the transmission line 7a is supported on an upper layer than the loop line 902 by a support body 198 which lies between the transmission line 7a and the transmission line 7b. In the constitution shown in Fig. 43C, the material of the support body 198 should be a dielectric material to prevent electrical connection between the transmission line 7a and the transmission line 7b. The conductors 331 and conductor posts 68 are provided between the loop line 902 and the dielectric substrate 905 corresponding to the position of the switches 903. Then, the via hole 66 is provided on the portion shown by the reference symbol S to electrically connect the transmission line 7a, the line 902 and the transmission line 7b mutually.

A fourth example of the multilayer structure should have the constitution that the ground conductor 904 being the lowest layer and the dielectric substrate 905 being the upper layer thereof are arranged in a contacted manner, and furthermore, the dielectric substrate 905 and the transmission line 7b on the upper layer thereof are arranged in a contacted manner as shown in Fig. 43D. The loop line 902 on the upper layer is arranged in a contacted manner as shown in Fig. 43E. The transmission line 7a and the loop line 902 may be either formed integrally into a single piece or electrically joined as separate members as seen in the constitutions shown in Fig. 41A, Fig. 41B or the like, for example. Then, the via hole 66 is provided on the portion shown by the reference symbol S to electrically connect the transmission line 7a, the line 902 and the transmission line 7b mutually.

A fifth example of the multilayer structure should have the constitution that the ground conductor 904 being the lowest layer and the dielectric substrate 905 being the upper layer thereof are arranged in a contacted manner, and furthermore, the dielectric substrate 905 and the transmission line 7a and the loop line 902 which are on an upper layer of the dielectric substrate 905 are arranged in a contacted manner as shown in Fig. 43F. The transmission line 7a and the loop line 902 may be either formed integrally into a single piece or electrically joined as separate members as described above. The transmission line 7a is supported on an upper layer than the circular line 902 and the transmission line 7b and by the above-described support body 198 which lies between the transmission line 7a and the transmission line 7b. Then, the via hole 66 is provided on the portion shown by the reference symbol S to electrically connect the transmission line 7a, the line 902 and the transmission line 7b mutually.

A sixth example of the multilayer structure should have the constitution that the ground conductor 904 being the lowest layer and the dielectric substrate 905 being the upper layer thereof are arranged in a contacted manner, and furthermore, the dielectric substrate 905 and the transmission line 7a and the loop line 902, which are on an upper layer of the dielectric substrate 905 are arranged in a contacted manner as shown in Fig. 43F. The transmission line 7a and the loop line 902 may be either formed integrally into a single piece or electrically joined as separate members as described above. The transmission line 7a is supported on an upper layer than the circular line 902 and the transmission line 7b and by the above-described support body 198 which lies between the transmission line 7a and the transmission line 7b. Then, the via hole 66 is provided on the portion shown by the reference symbol S to electrically connect the transmission line 7a, the line 902 and the transmission line 7b mutually.

Further, as shown in Fig. 44A, the constitution that a bent portion (reference symbol T) is provided on a part of the transmission line 7 and the bent portion and the line 902 of the variable resonator are connected is also possible. Thus, an increased distance between the transmission line 7 and the line 902 can reduce the insertion loss.

In view of the convenience or the like of a circuit constitution provided with a plurality of variable resonators, a constitution with a connection between the variable resonator and the transmission line as shown in Fig. 44B is also possible.

Fig. 44A and Fig. 44B exemplify the line 902 and the transmission line 7 as a single piece formed integrally or as separate members electrically joined in the same layer, but it is also possible to constitute them as a multilayer structure as shown in Fig. 42A is also possible.
Further, as a modified example of the constitution of the connection shown in Fig. 44, the constitution is also acceptable that the bent portion (reference symbol T) of the transmission line 7 is connected to a bent portion (reference symbol U) of the line 902 of the variable resonator, which is in a teardrop shape, as shown in Fig. 45.

A low insertion loss can be obtained by the constitution shown in Fig. 45 comparing to the constitution shown in Fig. 44.

This is because, in addition to the fact that a positional relation between the transmission line 7 and the line 902 of the variable resonator is remote, the line 902 has an exceedingly short line portion approximately parallel with the transmission line 7 in the vicinity of a connection area between the transmission line 7 and the line 902 in the case of the constitution shown in Fig. 45, so that magnetic field coupling is even difficult to occur. Therefore, the line 902 takes the teardrop shape in Fig. 45, but it is not limited to such a shape, and it should have a constitution of connection between the transmission line 7 and the line 902 which prevents the occurrence of magnetic field coupling.

Further, the foregoing embodiments are shown by using the microstrip line structure, but the present invention is not intended to limit it to such a line structure, and other line structures such as a coplanar waveguide may be used.

Fig. 46 exemplifies the case by the coplanar waveguide. A ground conductor 1010 and a ground conductor 1020 are arranged on the same surface of the dielectric substrate, and the transmission line 7 to which the variable resonator is connected is arranged in an interval between the ground conductors. Further, a ground conductor 1030 is arranged inside the line 902 of the variable resonator in a non-contact manner with the line 902. Air bridges 95 are bridged between the ground conductor 1020 and the ground conductor 1030 to align electric potentials and the ground conductors are electrically connected. The air bridges 95 are not an essential constituent element in the case of the coplanar waveguide, but a constitution may be also acceptable that a rear ground conductor (not shown) is arranged on a surface on the opposite side of the surface of the dielectric substrate on which the ground conductor 1010, the transmission line 7 and the like are arranged, the ground conductor 1030 and the rear ground conductor are electrically connected via a via hole, the ground conductor 1020 and the rear ground conductor are electrically connected via a via hole, and electric potentials of the ground conductor 1020 and the ground conductor 1030 are aligned, for example.

Claims

1. A variable resonator, comprising:

- a line body where one or a plurality of lines are constituted in a loop shape;
- a ground conductor;
- at least two switches; and
- at least three reactance circuits, wherein said switches have one ends electrically connected to different positions on said line body and the other ends electrically connected to said ground conductor, and are capable of switching electrical connection/non-connection between said ground conductor and said line body;
- said line body has a line length corresponding to one wavelength or integral multiple thereof at a resonance frequency which is determined corresponding to each reactance value of each said reactance circuit; and
- said reactance circuits are electrically connectable to said line body at predetermined intervals based on an electrical length at said resonance frequency.

2. The variable resonator according to Claim 1, wherein said line body is a single loop line; and said reactance circuits are electrically connected to said loop line as branching circuits along the circumference direction of said loop line.

3. The variable resonator according to Claim 2, wherein said reactance circuits severally have the same reactance value and are connected to said loop line at the equal electrical length intervals.

4. The variable resonator according to Claim 2, wherein the total number of said reactance circuits is M where M is an even number of 4 or larger; said reactance circuits severally have the same reactance value; M/2-1 said reactance circuits are connected clockwise to a part of said loop line between position K1 arbitrarily set on said loop line and a position K2 half the electrical length of one circumference of said loop line except said position K1 and said position K2 so as to divide said part at the equal electrical length intervals; M/2-1 said reactance circuits are connected counter-clockwise to a remaining part of said loop line between said position K1 to said position K2 except said position K1 and said position K2 so as to divide said remaining part at the equal electrical length intervals; and two said reactance circuits are connected to said position K2 of said loop line.

5. The variable resonator according to Claim 2, wherein the total number of said reactance circuits is M-1 where M is an even number of 4 or larger; M-2 reactance circuits out of M-1 said reactance circuits (hereinafter, referred to as first reactance cir-
The variable resonator according to Claim 6, wherein

7. The variable resonator according to Claim 1, wherein said line body is constituted of at least three lines; said switches have one ends electrically connected to any one of said lines at different positions and the other ends electrically connected to said ground conductor, and are capable of switching electrical connection/non-connection between said ground conductor and said line; the sum of the line lengths of said lines corresponds to one wavelength or integral multiple thereof at the resonance frequency in response to each reactance value of each said reactance circuit; each said line has a predetermined electrical length at said resonance frequency and at least said one said reactance circuit is electrically connected in series between adjacent said lines.

8. The variable resonator according to Claim 6, wherein the total number of said lines is M-1 and the total number of said reactance circuits is N where N is an integer of 3 or larger; said reactance circuits severally have the same reactance value; each said line has the same electrical length; and one said reactance circuit is connected between adjacent said lines.

9. The variable resonator according to Claim 6, wherein the total number of said lines is M-1 and the total number of said reactance circuits is M-1 where M is an even number of 4 or larger; M/2 reactance circuits out of M-1 said reactance circuits (hereinafter, referred to as first reactance circuits) severally have the same reactance value and remaining one reactance circuit (hereinafter, referred to as second reactance circuit) has half the reactance value of each said first reactance circuit; one said first reactance circuit is connected between an i-th line and an (i+1)-th line where i is an integer satisfying 1 ≤ i < M/2; said second reactance circuit is connected between an (M/2)-th line and an (M/2+1)-th line; one said reactance circuit is connected between said an i-th line and an (i+1)-th line where i is an integer satisfying M/2+1 ≤ i ≤ M-1; one said reactance circuit is connected between an (M-1)-th line and said 1st line; an electrical length from a position K arbitrarily set on said 1st line to an end portion of said 1st line which is closer to said 2nd line and each electrical length of said i-th line where i is an integer satisfying 1 ≤ i ≤ M/2 are equal; and an electrical length from said position K to an end portion of said 1st line which is closer to said (M-1)-th line and each electrical length of said i-th line where i an integer satisfying M/2+1 ≤ i ≤ M-1 are equal.

9. The variable resonator according to Claim 1; and

10. The variable resonator according to any one of Claims 1 to 9, wherein said line body is connected electrically to said ground conductor by any one of said switches.

11. A tunable bandwidth filter, comprising:

   at least one variable resonator according to Claim 1; and

   a transmission line,
wherein said variable resonator is connected electrically to said transmission line.

12. The tunable bandwidth filter according to Claim 11, comprising:

at least two said variable resonators, wherein each said variable resonator is connected to said transmission line as a branching circuit via a switch (hereinafter, referred to as a second switch) at the same coupled portion, and said transmission line is capable of being connected electrically to all or a part of the variable resonators by said selected second switch(es).

13. An electric circuit device, comprising:

one variable resonator according to Claim 1; and a transmission line T having a bent portion, wherein said bent portion of said transmission line T is connected electrically to said variable resonator.

14. The electric circuit device according to Claim 13, wherein a part of said variable resonator on an area where the bent portion of said transmission line T and said variable resonator are electrically connected and in the vicinity of said area is not parallel with said transmission line T.
FIG. 3
PRIOR ART

FIG. 4
PRIOR ART
FIG. 5E

C = 0.1 pF, f = 4.77(10°), 4.79(20°), 4.82(30°) GHz

C = 0.5 pF, f = 4.04(10°), 4.09(20°), 4.19(30°) GHz

C = 1.0 pF, f = 3.45(10°), 3.50(20°), 3.60(30°) GHz
FIG. 29

f_1 = 4.18 GHz  f_0 = 5.0 GHz

Transmission Coefficient [dB]

20°  30°  x = 10°  20°

x = 10°
C = 0.5 pF

C = 0 pF

Frequency [GHz]

FIG. 30

Port 1

90°  90°

Port 2

Z_L  102

Z_L  102a
## DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 5 479 142 A (TAKAHASHI KAZUAKI [JP] ET AL) 26 December 1995 (1995-12-26) * column 38, lines 1-16; figure 24 *</td>
<td>1-14</td>
<td>INV. H01P1/203 H01P7/08</td>
</tr>
</tbody>
</table>

The present search report has been drawn up for all claims

Place of search | Date of completion of the search | Examiner
--- | --- | ---
Munich | 26 June 2008 | La Casta Muñoa, S

### CATEGORY OF CITED DOCUMENTS

- **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
- **A**: member of the same patent family, corresponding document

**X**: particularly relevant if taken alone

**Y**: particularly relevant if combined with another document of the same category

**A**: technological background

**P**: intermediate document
ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.  

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.  

26-06-2008  

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 5479142 A</td>
<td>26-12-1995</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82
REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader’s convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004007352 A [0004]
- JP 2006244707 A [0029] [0052]

Non-patent literature cited in the description

- T.SCOTT MARTIN; FUCHEN WANG; KAI CHANG. ELECTRONICALLY TUNABLE AND SWITCHABLE FILTERS USING MICROSTRIP RING RESONATOR CIRCUITS. IEEE MTT-S Digest, 1988, 803-806 [0055]