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Tanaka

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(54) **RESONANT DEVICE, FILTER, AND MODULE**

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H01F 27/28 (2006.01)
(Continued)

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CPC ***H03H 7/0115*** (2013.01); ***H01F 27/2804*** (2013.01); ***H01G 4/012*** (2013.01);
(Continued)

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(Continued)

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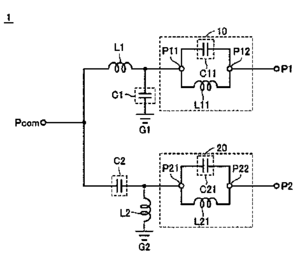
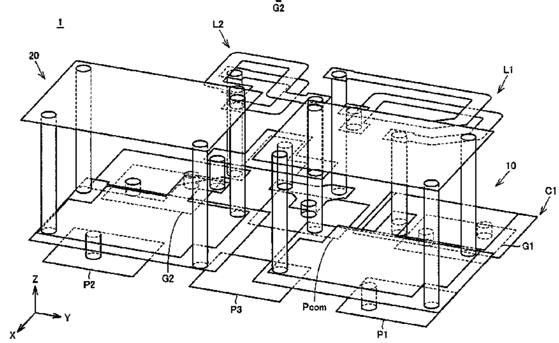
(57) **ABSTRACT**

In a resonant device, a first via electrode and a second via electrode connect a first plane electrode and a third plane electrode. A third via electrode and a fourth via electrode connect the first plane electrode and a second plane electrode. When the first plane electrode is seen in plan view in a normal direction of the first plane electrode, a first imaginary line connecting the first via electrode and the second via electrode intersects with a second imaginary line connecting the third via electrode and the fourth via electrode.

20 Claims, 10 Drawing Sheets





(51) **Int. Cl.**

H01G 4/012	(2006.01)
H01G 4/30	(2006.01)
H01P 1/203	(2006.01)
H03H 7/03	(2006.01)
H03H 7/46	(2006.01)

(52) **U.S. Cl.**
CPC ***H01G 4/30*** (2013.01); ***H01P 1/20345*** (2013.01); ***H03H 7/03*** (2013.01); ***H03H 7/463*** (2013.01)

(58) **Field of Classification Search**
USPC 333/126, 175, 185, 204, 205
See application file for complete search history.

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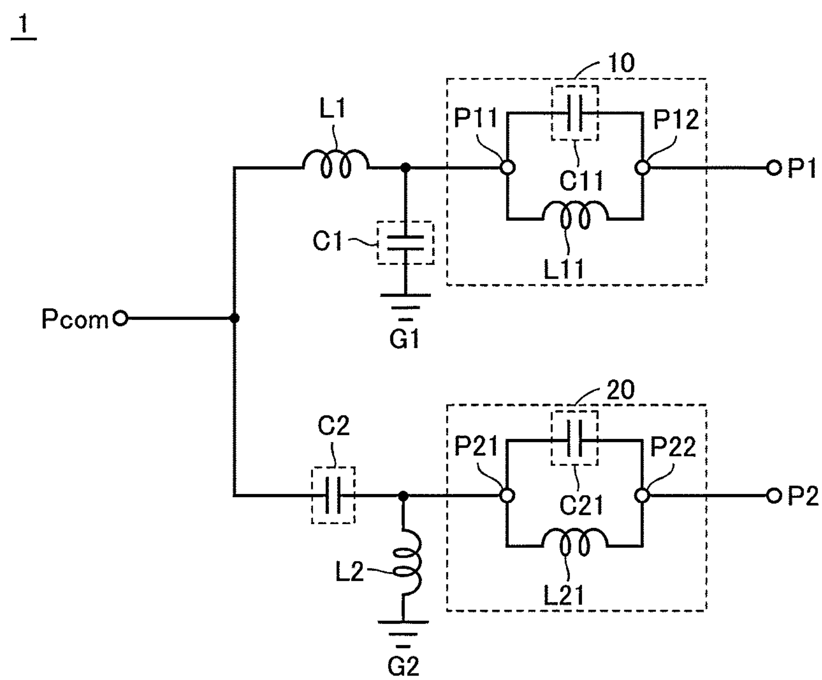
FIG.1



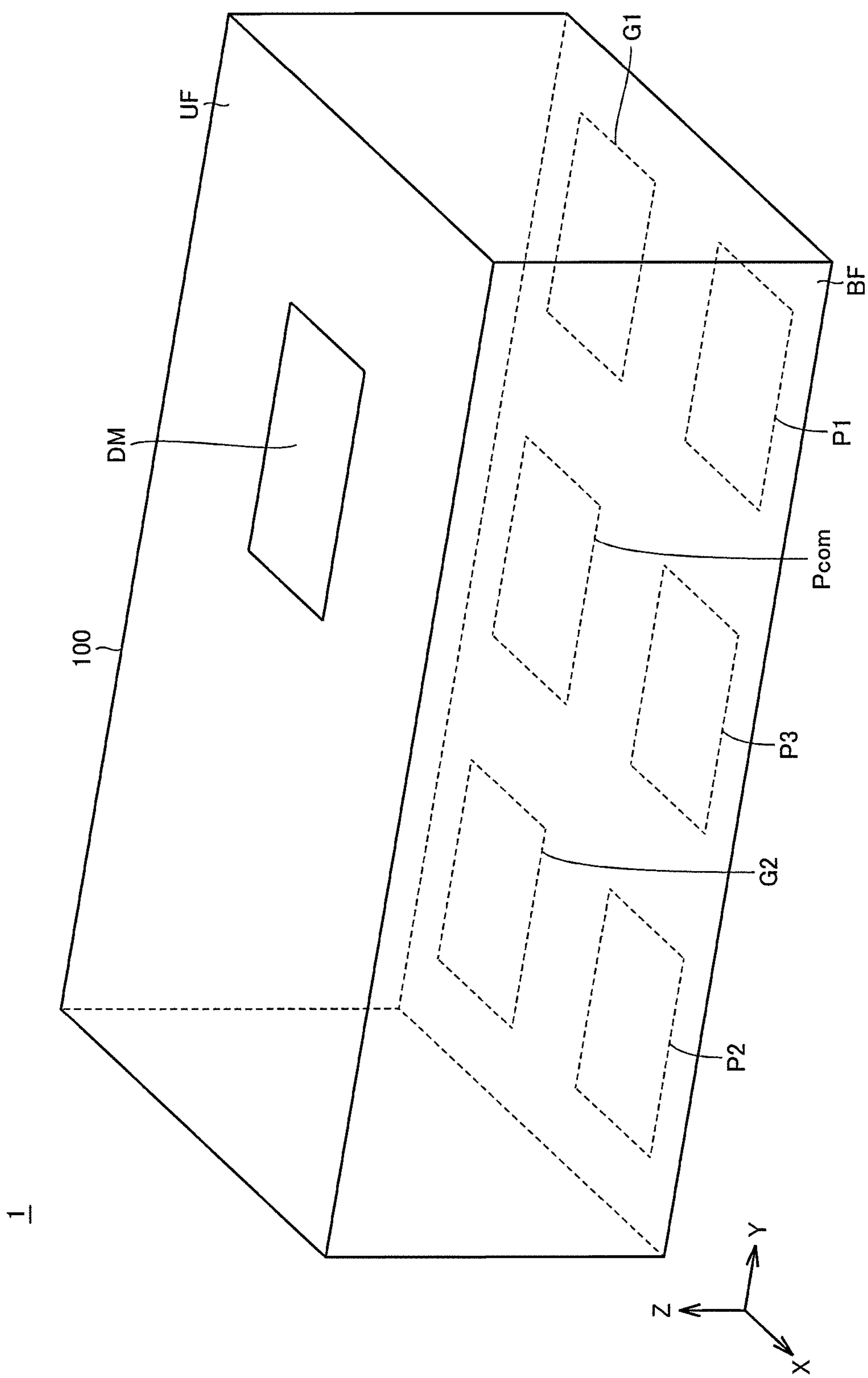


FIG.2

FIG.3

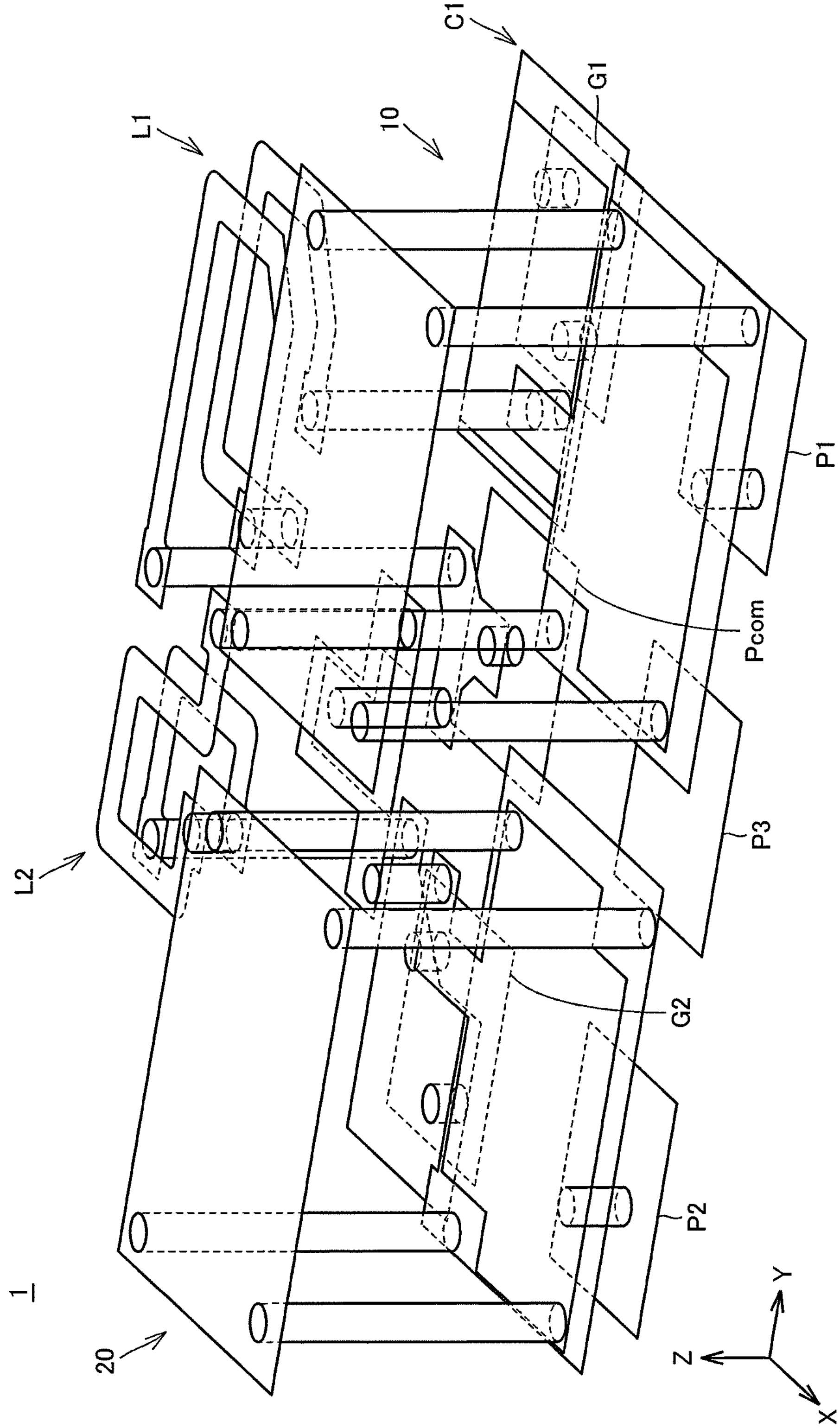
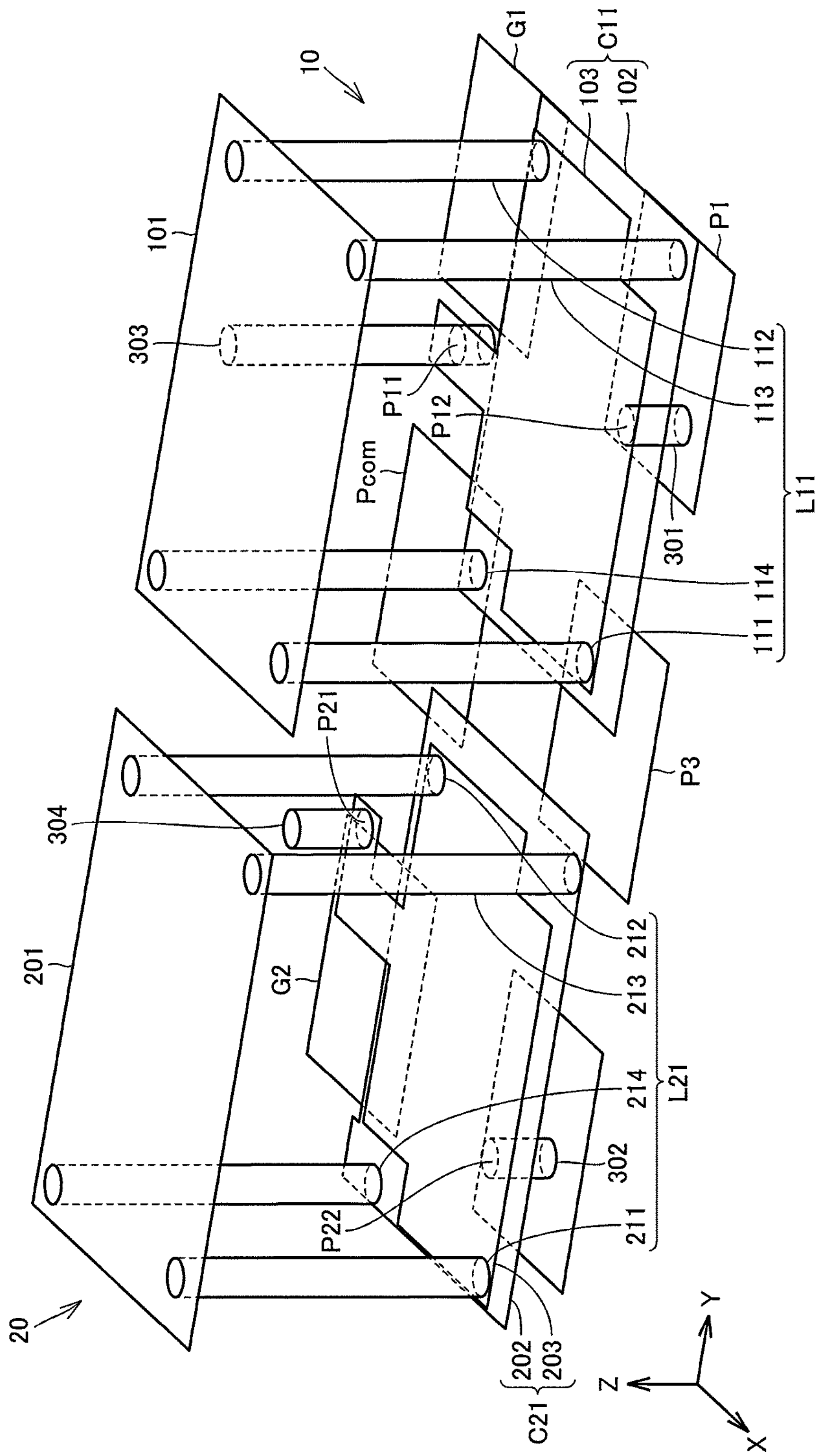


FIG.4


10
G1
103
102
C11
101
P1
303
112
113
P11
P12
Pcom
301
L11
114
111
P21
P3
304
212
213
201
G2
214
L21
302
P22
211
20
202
203
C21
Z
Y
X

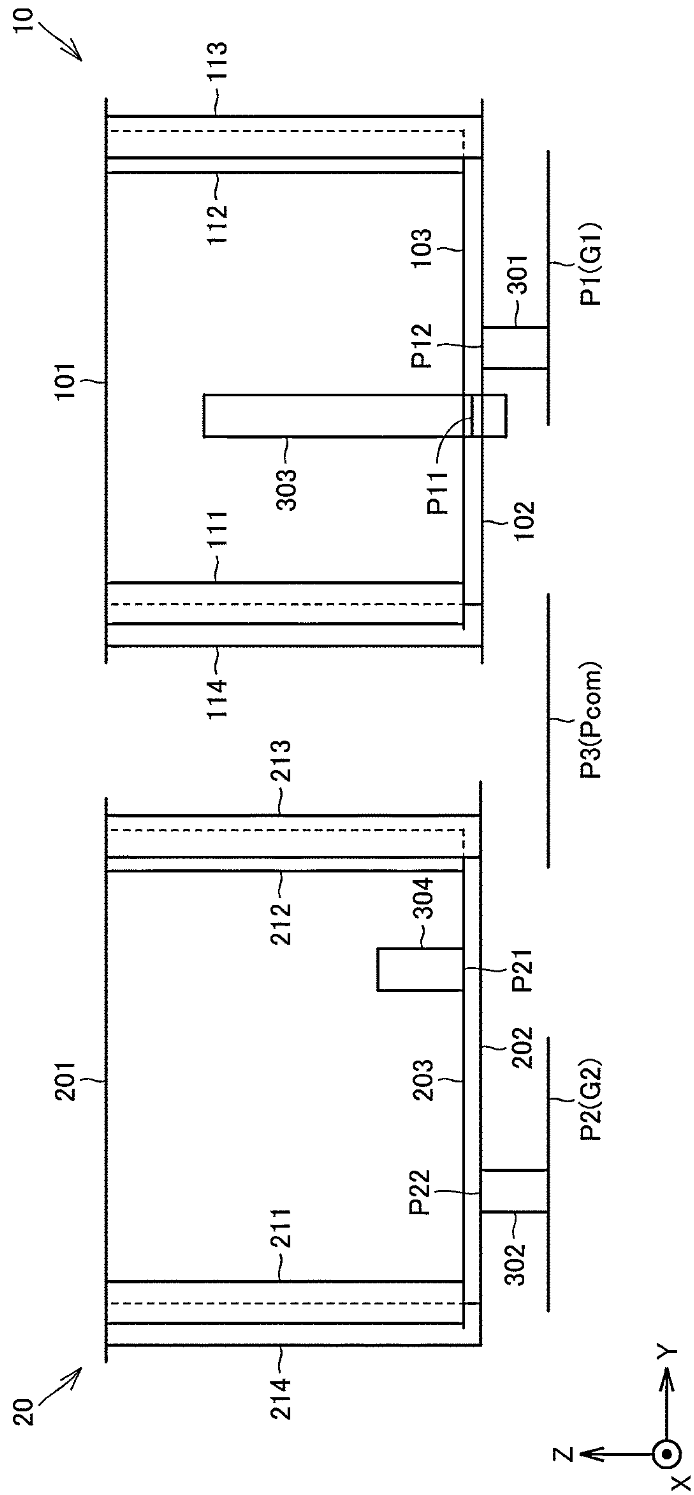
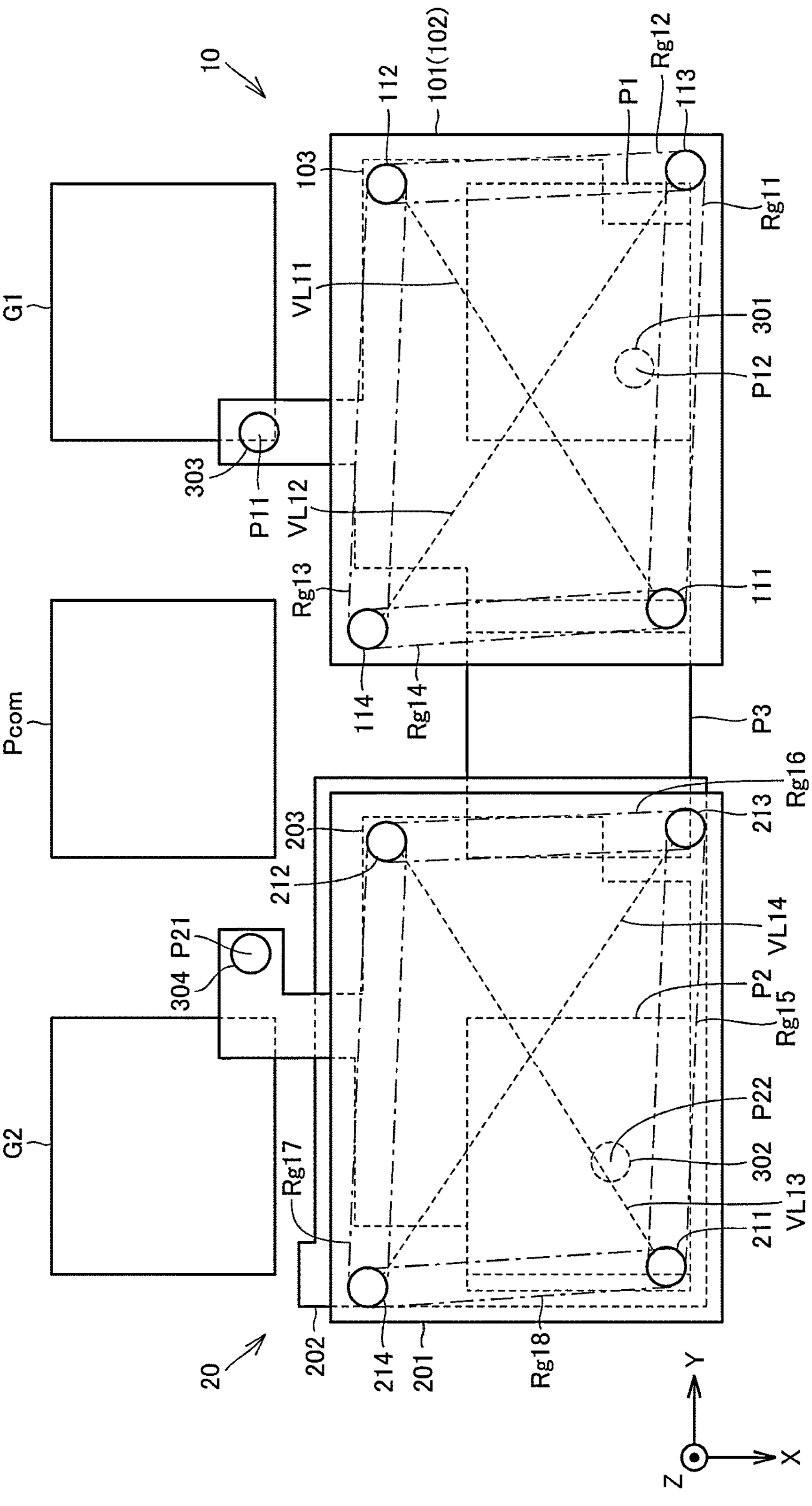

10
113
112
103
301
P1(G1)
P12
101
303
P11
102
111
114
P3(Pcom)
213
212
304
P21
202
201
203
P2(G2)
P22
211
302
214
20
Y
Z
X

FIG.5

FIG.6


10
101(102)
103
111
112
113
114
Rg11
Rg12
Rg13
Rg14
P1
VL11
VL12
301
P12
303
P11
G1
Pcom
P3
20
201
202
203
211
212
213
214
Rg15
Rg16
Rg17
Rg18
VL13
VL14
P2
P21
304
P22
302
G2
Y
X
Z

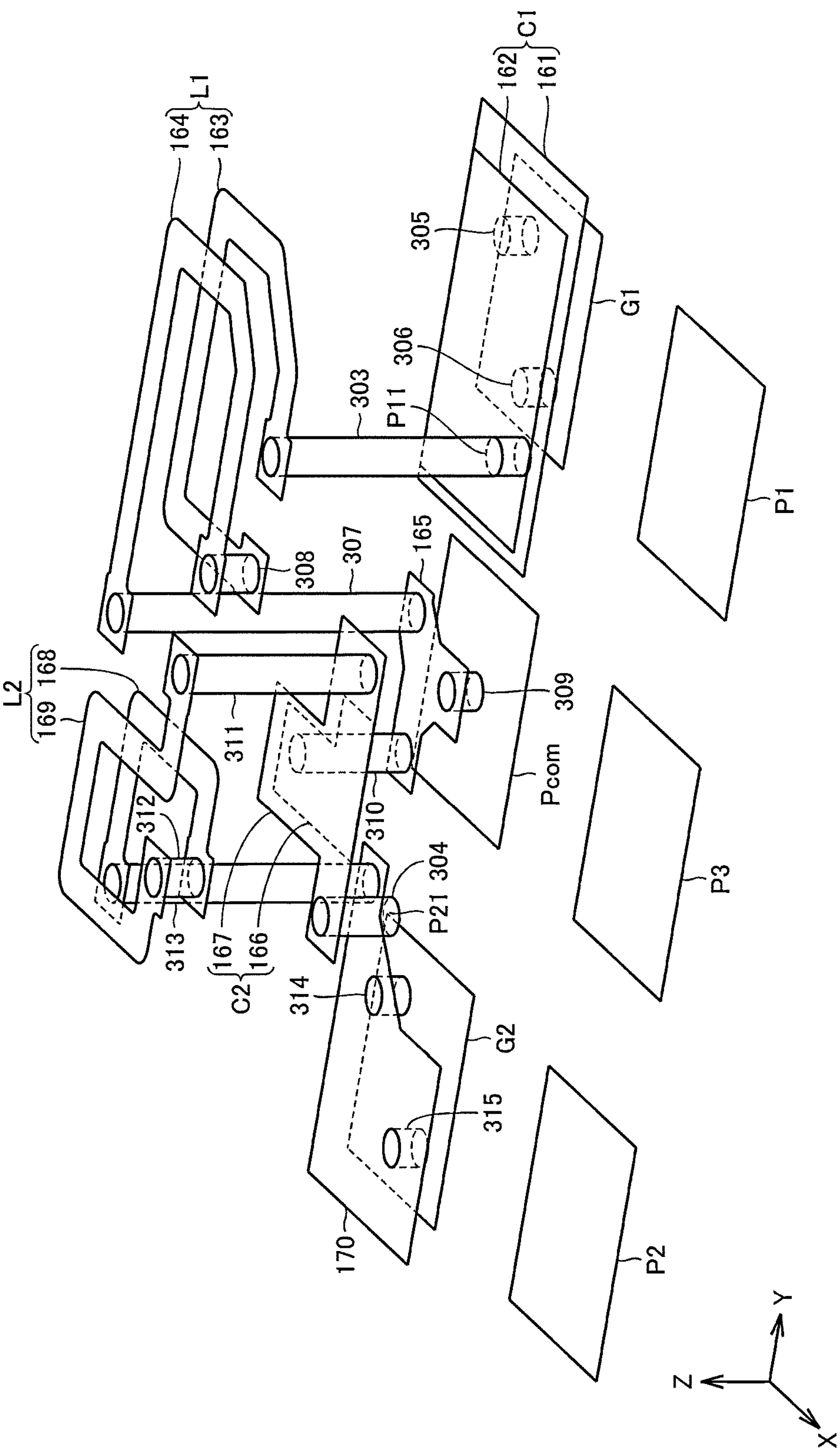

C1
162
161
L1
164
163
305
306
303
P11
G1
P1
308
307
165
309
L2
168
169
311
Pcom
P3
310
312
304
P21
313
167
166
C2
314
G2
315
170
P2
Y
Z
X

FIG.7

FIG.8

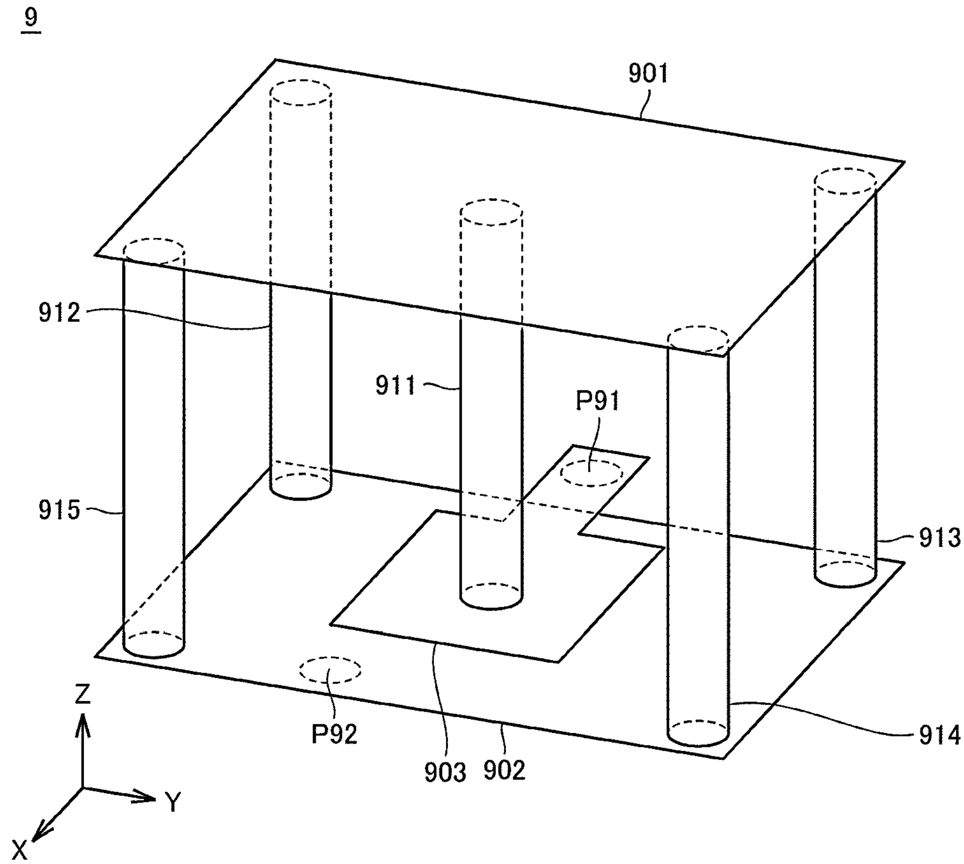


FIG.9

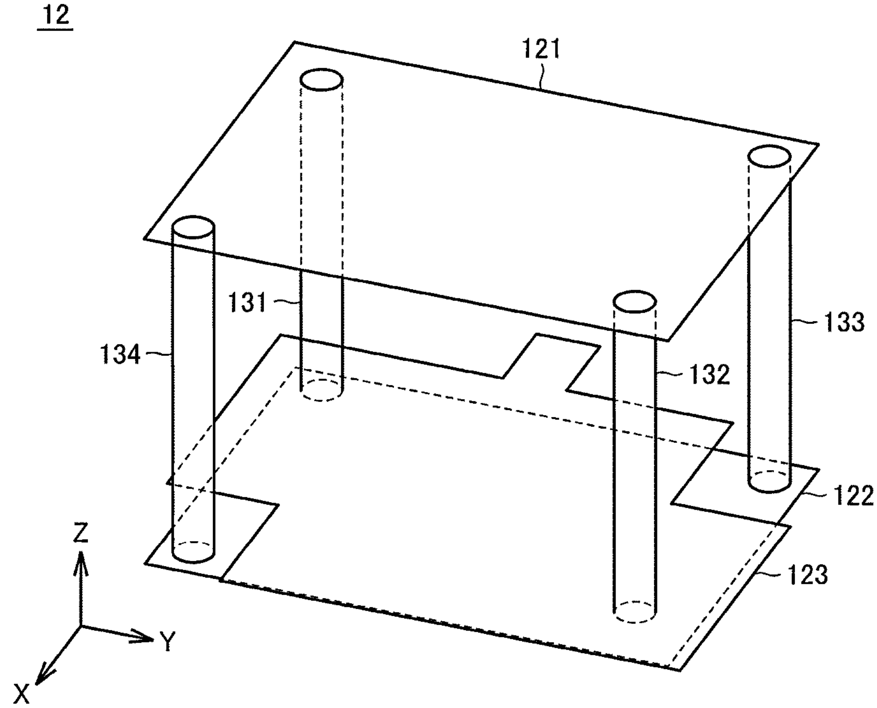

12
121
131
134
133
132
122
123
Z
Y
X

FIG.10

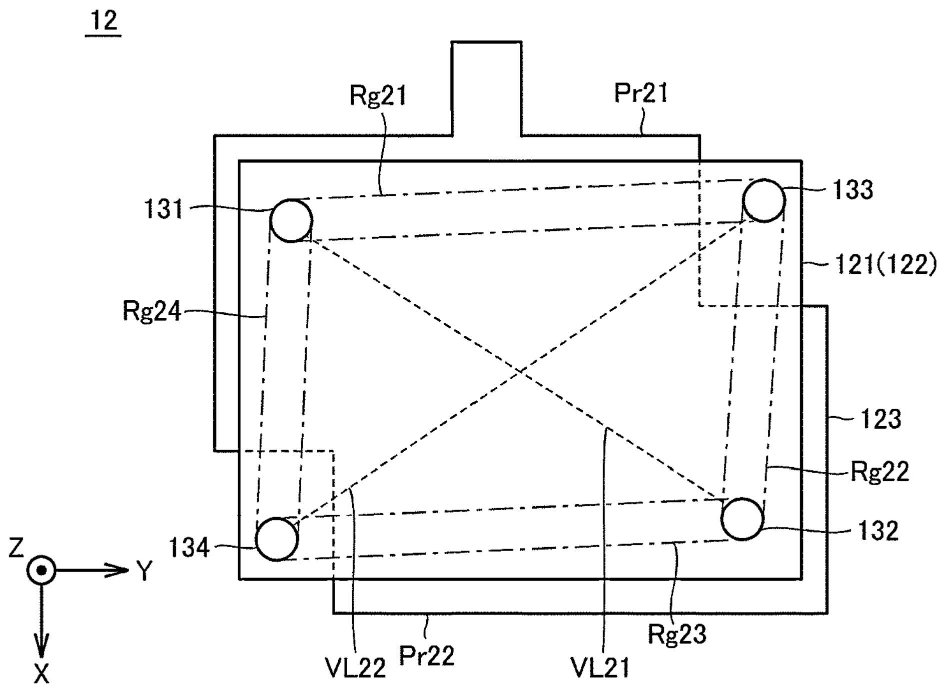

12
Rg21
Pr21
131
133
121(122)
Rg24
123
Rg22
134
132
Z
Y
X
VL22
Pr22
VL21
Rg23

FIG.11

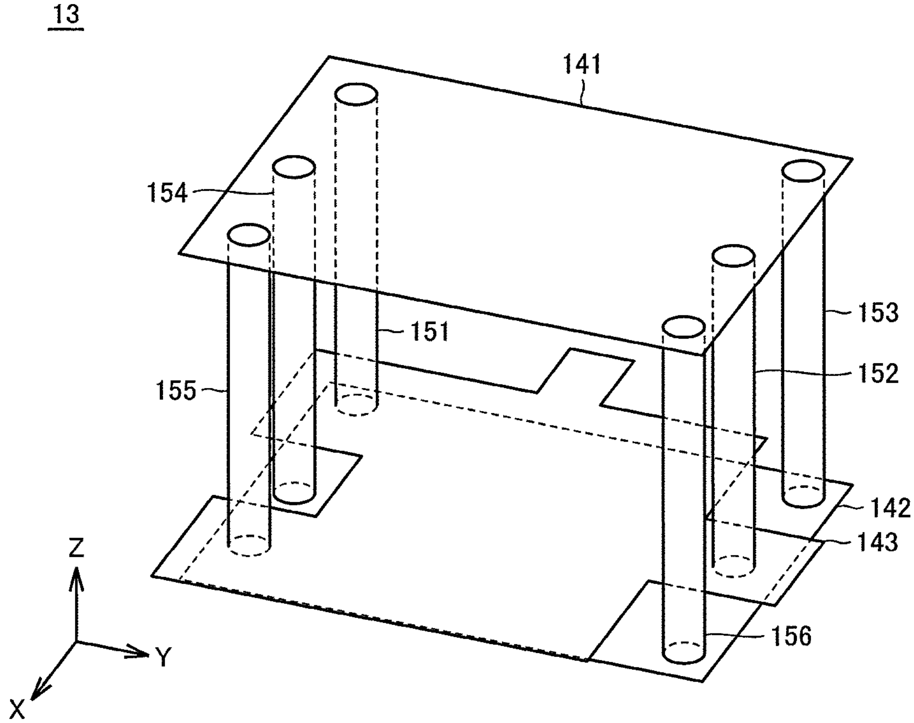
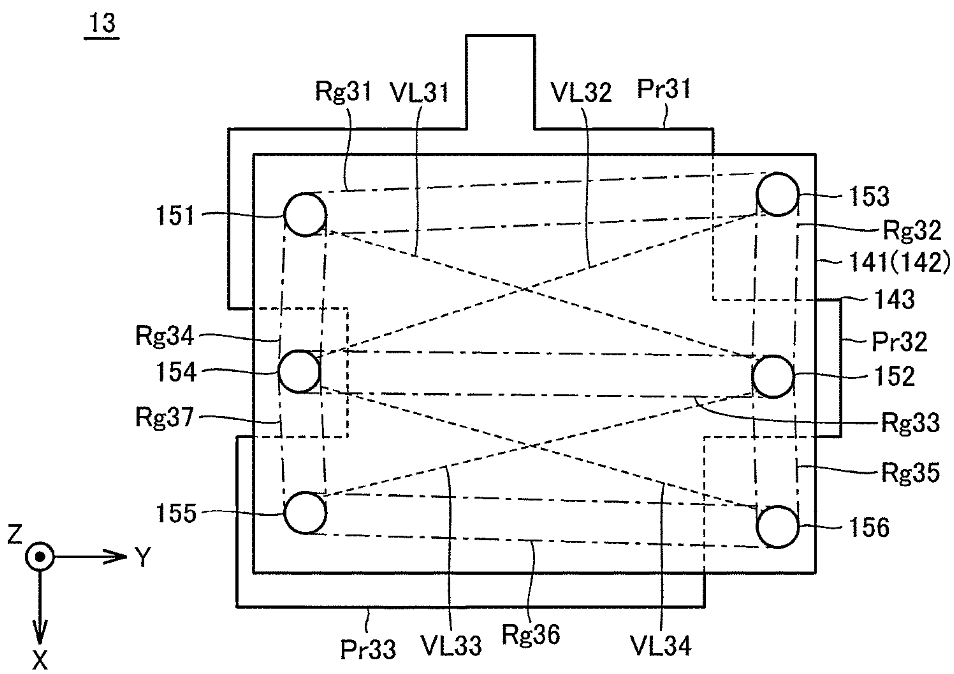

13
141
154
151
153
152
155
142
143
156
Z
Y
X

FIG.12


13
Rg31
VL31
VL32
Pr31
151
153
Rg32
141(142)
143
Rg34
Pr32
154
152
Rg37
Rg33
Rg35
155
156
Z
Y
X
Pr33
VL33
Rg36
VL34

RESONANT DEVICE, FILTER, AND MODULE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to Japanese Patent Application No. 2020-163254 filed on Sep. 29, 2020 and is a Continuation Application of PCT Application No. PCT/JP2021/032070 filed on Sep. 1, 2021. The entire contents of each application are hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a resonant device, a filter including the resonant device, and a module including the filter.

2. Description of the Related Art

Conventionally, resonant devices have been known. For example, International Publication No. 2020/105257 discloses a resonant device with a plurality of via electrodes formed inside a dielectric. The plurality of via electrodes constitute an inductor, and thus, a percentage of the dielectric in the resonant device increases. As a result, intensity of the resonant device can be increased.

SUMMARY OF THE INVENTION

In the resonant device disclosed in International Publication No. 2020/105257, one of two plane electrodes constituting a capacitor is connected to one via electrode, and thus, current flowing in the capacitor concentrates on the one via electrode. As a result, insertion loss of the resonant device may become worse.

Preferred embodiments of the present invention improve insertion loss of resonant devices.

A resonant device according to a preferred embodiment of the present invention includes a multilayer body, a first plane electrode, a second plane electrode, a third plane electrode, a first via electrode, a second via electrode, a third via electrode, and a fourth via electrode. The first plane electrode, the second plane electrode, and the third plane electrode are provided to the multilayer body. The third plane electrode is located between the first plane electrode and the second plane electrode in a normal direction of the first plane electrode. The first via electrode and the second via electrode connect the first plane electrode and the third plane electrode. The third via electrode and the fourth via electrode connect the first plane electrode and the second plane electrode. When the first plane electrode is seen in plan view in the normal direction of the first plane electrode, a first imaginary line connecting the first via electrode and the second via electrode intersects with a second imaginary line connecting the third via electrode and the fourth via electrode.

According to a resonant device of a preferred embodiment of the present invention, when the first plane electrode is seen in plan view in the normal direction of the first plane electrode, the first imaginary line connecting the first via electrode and the second via electrode intersects with the

second imaginary line connecting the third via electrode and the fourth via electrode. Thus, insertion loss of the resonant device can be improved.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an equivalent circuit diagram of a diplexer as one example of a filter according to Preferred Embodiment 1 of the present invention.

FIG. **2** is an external perspective view of the diplexer of FIG. **1**.

FIG. **3** is a perspective view of a plurality of electrodes located inside a multilayer body of FIG. **2**.

FIG. **4** is a perspective view of a plurality of electrodes of resonant devices of FIG. **3**.

FIG. **5** is a plan view of the resonant devices of FIG. **4** when seen in an X-axis direction.

FIG. **6** is a plan view of the resonant devices of FIG. **4** when seen in a Z-axis direction.

FIG. **7** is a perspective view of a plurality of electrodes of inductors and capacitors of FIG. **3**.

FIG. **8** is a perspective view of a plurality of electrodes of a resonant device according to a comparative example.

FIG. **9** is a perspective view of a plurality of electrodes of a resonant device according to Preferred Embodiment 2 of the present invention.

FIG. **10** is a plan view of the resonant device of FIG. **9** when seen in the Z-axis direction.

FIG. **11** is a perspective view of a plurality of electrodes of a resonant device according to Preferred Embodiment 3 of the present invention.

FIG. **12** is a plan view of the resonant device of FIG. **11** when seen in the Z-axis direction.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments are described in detail with reference to the drawings. Note that the same reference characters are given to the same or corresponding elements in the drawings, and description thereof is not repeated in general.

Preferred Embodiment 1

FIG. **1** is an equivalent circuit diagram of a diplexer **1** as one example of a filter according to Preferred Embodiment 1. As illustrated in FIG. **1**, the diplexer **1** includes a common terminal Pcom, terminals P**1** and P**2**, inductors L**1** and L**2**, capacitors C**1** and C**2**, and resonant devices **10** and **20**. A resonant frequency of the resonant device **20** is different from a resonant frequency of the resonant device **10**.

The resonant device **10** includes terminals P**11** and P**12**, an inductor L**11**, and a capacitor C**11**. The inductor L**11** and the capacitor C**11** are connected in parallel between the terminals P**11** and P**12**. The resonant device **10** includes an LC parallel resonant circuit.

The inductor L**1** is connected between the common terminal Pcom and the terminal P**11**. The capacitor C**1** is connected between a ground terminal G**1**, which is a ground point, and the terminal P**11**. The terminal P**1** is connected to the terminal P**12**.

The resonant device **20** includes terminals P**21** and P**22**, an inductor L**21**, and a capacitor C**21**. The inductor L**21** and the capacitor C**21** are connected in parallel between the terminals P**21** and P**22**. The resonant device **20** includes an LC parallel resonant circuit.

The capacitor C**2** is connected between the common terminal Pcom and the terminal P**21**. The inductor L**2** is connected between a ground terminal G**2**, which is a ground point, and the terminal P**21**. The terminal P**2** is connected to the terminal P**22**.

FIG. **2** is an external perspective view of the diplexer **1** of FIG. **1**. An X-axis, a Y-axis, and a Z-axis illustrated in FIG. **2** are orthogonal to each other, which is also the same in FIGS. **3** to **12**. A plurality of dielectric layers are laminated in the Z-axis direction in a multilayer body **100**. Inside the multilayer body **100**, a plurality of electrodes defining the equivalent circuit illustrated in FIG. **1** are provided. That is, the diplexer **1** is included in a module where a plurality of electrodes are provided in the plurality of laminated dielectric layers.

As illustrated in FIG. **2**, a direction distinguishing mark DM is located on an upper surface UF of the diplexer **1**. The common terminal Pcom, the terminals P**1**, P**2**, and P**3**, and the ground terminals G**1** and G**2** are located on a bottom surface BF of the diplexer **1**. The common terminal Pcom, the terminals P**1** to P**3**, and the ground terminals G**1** and G**2** are, for example, land grid array (LGA) terminals where plane electrodes are regularly positioned on the bottom surface BF. The bottom surface BF of the diplexer **1** is connected to a circuit board (not illustrated).

FIG. **3** is a perspective view of a plurality of electrodes inside the multilayer body **100** of FIG. **2**. In order to facilitate the understanding of an electrode structure including the plurality of electrodes, the plurality of electrodes illustrated in FIG. **3** will be described below while being divided into the plurality of electrodes of the resonant devices **10** and **20** and the plurality of electrodes of the inductors L**1** and L**2** and the capacitors C**1** and C**2**.

FIG. **4** is a perspective view of the plurality of electrodes of the resonant devices **10** and **20** of FIG. **3**. FIG. **5** is a plan view of the resonant devices **10** and **20** of FIG. **4** when seen in the X-axis direction. FIG. **6** is a plan view of the resonant devices **10** and **20** of FIG. **4** when seen in the Z-axis direction.

As illustrated in FIGS. **4** to **6**, the resonant device **10** includes a plane electrode **101** (first plane electrode), a plane electrode **102** (second plane electrode), a plane electrode **103** (third plane electrode), a via electrode **111** (first via electrode), a via electrode **112** (second via electrode), a via electrode **113** (third via electrode), and a via electrode **114** (fourth via electrode).

The plane electrode **103** is located between the plane electrodes **101** and **102** in a normal direction (Z-axis direction) of the plane electrode **101**. The via electrodes **111** and **112** extend in the Z-axis direction and connect the plane electrodes **101** and **103**. The via electrodes **113** and **114** extend in the Z-axis direction and connect the plane electrodes **101** and **102**.

The plane electrode **103** is connected to a via electrode **303**. The terminal P**11** is located at a connection between the plane electrode **103** and the via electrode **303**. A via electrode **301** connects the plane electrode **102** and the terminal P**1**. The terminal P**12** is located at a connection between the plane electrode **102** and the via electrode **301**.

Each of the via electrodes **111** and **112** is shorter than each of the via electrodes **113** and **114**. A distance between the plane electrodes **103** and **102** is shorter than a distance between the plane electrodes **103** and **101**.

The via electrodes **111** to **114** define the inductor L**11**. The plane electrodes **102** and **103** are opposed to each other in the Z-axis direction and define the capacitor C**11**.

The resonant device **20** includes a plane electrode **201** (first plane electrode), a plane electrode **202** (second plane electrode), a plane electrode **203** (third plane electrode), a via electrode **211** (first via electrode), a via electrode **212** (second via electrode), a via electrode **213** (third via electrode), and a via electrode **214** (fourth via electrode).

The plane electrode **203** is located between the plane electrodes **201** and **202** in a normal direction of the plane electrode **201**. The via electrodes **211** and **212** extend in the Z-axis direction and connect the plane electrodes **201** and **203**. The via electrodes **213** and **214** extend in the Z-axis direction and connect the plane electrodes **201** and **202**.

The plane electrode **203** is connected to a via electrode **304**. The terminal P**21** is located at a connection between the plane electrode **203** and the via electrode **304**. A via electrode **302** connects the plane electrode **202** and the terminal P**2**. The terminal P**22** is located at a connection between the plane electrode **202** and the via electrode **302**.

Each of the via electrodes **211** and **212** is shorter than each of the via electrodes **213** and **214**. A distance between the plane electrodes **203** and **202** is shorter than a distance between the plane electrodes **203** and **201**.

The via electrodes **211** to **214** constitute the inductor L**21**. The plane electrodes **202** and **203** are opposed to each other in the Z-axis direction and define the capacitor C**21**.

As illustrated in FIG. **6**, when the plane electrode **101** is seen in plan view in the Z-axis direction, the via electrode **111**, a range Rg**11** between the via electrodes **111** and **113**, the via electrode **113**, a range Rg**12** between the via electrodes **113** and **112**, the via electrode **112**, a range Rg**13** between the via electrodes **112** and **114**, the via electrode **114**, and a range Rg**14** between the via electrodes **114** and **111** define a loop-shaped range. In the loop-shaped range, the via electrodes **111** and **112** connecting the plane electrodes **101** and **103** are disposed alternately with the via electrodes **113** and **114** connecting the plane electrodes **101** and **102**. An imaginary line VL**11** (first imaginary line) connecting the via electrodes **111** and **112** intersects with an imaginary line VL**12** (second imaginary line) connecting the via electrodes **113** and **114**.

A direction in which current flows in the via electrode **111** and a direction in which current flows in the via electrode **112** are the same as each other. A direction in which current flows in the via electrode **113** and a direction in which current flows in the via electrode **114** are the same as each other. The direction in which current flows in the via electrode **111** and the direction in which current flows in the via electrode **113** are opposite from each other.

A portion of the plane electrode **103** is not overlapped with the plane electrodes **101** and **102**. The terminal P**11** is located at the portion of the plane electrode **103** not overlapping with the plane electrodes **101** and **102**.

When the plane electrode **201** is seen in plan view in the Z-axis direction, the via electrode **211**, a range Rg**15** between the via electrodes **211** and **213**, the via electrode **213**, a range Rg**16** between the via electrodes **213** and **212**, the via electrode **212**, a range Rg**17** between the via electrodes **212** and **214**, the via electrode **214**, and a range Rg**18** between the via electrodes **214** and **211** form a loop-shaped range. In the loop-shaped range, the via electrodes **211** and **212** connecting the plane electrodes **201** and **203** are disposed alternately with the via electrodes **213** and **214** connecting the plane electrodes **201** and **202**. An imaginary line VL**13** (first imaginary line) connecting the via electrodes **211** and **212** intersects with an imaginary line VL**14** (second imaginary line) connecting the via electrodes **213** and **214**.

A direction in which current flows in the via electrode **211** and a direction in which current flows in the via electrode **212** are the same as each other. A direction in which current flows in the via electrode **213** and a direction in which current flows in the via electrode **214** are the same as each other. The direction in which current flows in the via electrode **211** and the direction in which current flows in the via electrode **213** are opposite from each other.

A portion of the plane electrode **203** is not overlapped with the plane electrodes **201** and **202**. The terminal P**21** is located at the portion of the plane electrode **203** not overlapping with the plane electrodes **201** and **202**.

FIG. **7** is a perspective view of the plurality of electrodes of the inductors L**1** and L**2** and the capacitors C**1** and C**2** of FIG. **3**. As illustrated in FIG. **7**, a plane electrode **161** is connected to the ground terminal G**1** by via electrodes **305** and **306**. A plane electrode **162** is opposed to the plane electrode **161** in the Z-axis direction. The plane electrodes **161** and **162** define the capacitor C**1**.

Line electrodes **163** and **164** wind around an axis extending in the Z-axis direction. The line electrode **163** is connected to the plane electrode **162** by the via electrode **303**. The line electrode **163** is connected to the line electrode **164** by a via electrode **308**. The line electrode **164** is connected to a plane electrode **165** by a via electrode **307**. The line electrodes **163** and **164** define the inductor L**1**.

The plane electrode **165** is connected to the common terminal Pcom by a via electrode **309**. The plane electrode **165** is connected to a plane electrode **166** by a via electrode **310**. The plane electrode **166** is opposed to a plane electrode **167** in the Z-axis direction. The plane electrodes **166** and **167** define the capacitor C**2**.

Line electrodes **168** and **169** wind around an axis extending in the Z-axis direction. The line electrode **168** is connected to the plane electrode **130** by a via electrode **313**. The line electrode **168** is connected to the line electrode **169** by a via electrode **312**. The line electrode **169** is connected to the plane electrode **167** by a via electrode **311**. The line electrodes **168** and **169** define the inductor L**2**. A plane electrode **170** is connected to the ground terminal G**2** by via electrodes **314** and **315**.

FIG. **8** is a perspective view of a plurality of electrodes of a resonant device **9** according to a comparative example. As illustrated in FIG. **8**, the resonant device **9** includes plane electrodes **901**, **902**, and **903** and via electrodes **911**, **912**, **913**, **914**, and **915**.

The plane electrode **903** is located between the plane electrodes **901** and **902** in a normal direction of the plane electrode **901**. The via electrode **911** extends in the Z-axis direction and connects the plane electrodes **901** and **903**. The via electrodes **912** to **915** extend in the Z-axis direction and connect the plane electrodes **901** and **902**. The via electrodes **912** and **913** are positioned along the Y-axis direction. The via electrodes **913** and **914** are positioned along the X-axis direction. The via electrodes **914** and **915** are positioned along the Y-axis direction. The via electrodes **915** and **912** are positioned along the X-axis direction.

The via electrode **911** is shorter than each of the via electrodes **912** to **915**. A distance between the plane electrodes **903** and **902** is shorter than a distance between the plane electrodes **903** and **901**.

The via electrodes **911** to **915** define an inductor. The plane electrodes **902** and **903** are opposed to each other in the Z-axis direction and constitute a capacitor.

The plane electrode **903** includes a portion located between the via electrodes **912** and **913**. A terminal P**91** is located at the portion. A terminal P**92** is located in or on the plane electrode **902**.

In the resonant device **9**, the plane electrodes **901** and **903** are connected by the via electrode **911**. Therefore, current flowing in the capacitor including the plane electrodes **901** and **903** concentrates on the via electrode **911**. As a result, insertion loss of the resonant device **9** may become worse.

In this respect, in the resonant device according to the present preferred embodiment, when the first plane electrode is seen in plan view in the normal direction of the first plane electrode, the plurality of via electrodes connecting the first plane electrode and the third plane electrode and the plurality of via electrodes connecting the first plane electrode and the second plane electrode are disposed alternately in the loop-shaped range, and the first imaginary line and the second imaginary line intersect with each other. Since the first plane electrode and the third plane electrode are connected to each other by the plurality of via electrodes, current flowing in the capacitor including the second plane electrode and the third plane electrode is distributed to the plurality of via electrodes connecting the first plane electrode and the third plane electrode. As a result, insertion loss of the resonant device can be improved compared with the insertion loss of the resonant device according to the comparative example.

Moreover, the flowing direction of the current in the plurality of via electrodes connecting the first plane electrode and the third plane electrode is opposite from the flowing direction of the current in the plurality of via electrodes connecting the first plane electrode and the second plane electrode. Thus, directions of magnetic fields generated from the two via electrodes adjacent to each other in the loop-shaped range also become opposite from each other. Since mutually independent magnetic fields are generated from the plurality of via electrodes disposed in the loop-shaped range, coupling between the resonant device and other circuit devices can be reduced or prevented.

As described above, the resonant device according to Preferred Embodiment 1 can improve the insertion loss of the resonant device.

Preferred Embodiment 2

Preferred Embodiment 2 describes the configuration in which a width of the third plane electrode is increased and manufacturing variations in characteristics of the resonant device and a risk of short circuiting between the first plane electrode and the second plane electrode are reduced.

FIG. **9** is a perspective view of a plurality of electrodes of a resonant device **12** according to Preferred Embodiment 2. As illustrated in FIG. **9**, the resonant device **12** includes a plane electrode **121** (first plane electrode), a plane electrode **122** (second plane electrode), a plane electrode **123** (third plane electrode), a via electrode **131** (first via electrode), a via electrode **132** (second via electrode), a via electrode **133** (third via electrode), and a via electrode **134** (fourth via electrode).

The plane electrode **123** is located between the plane electrodes **121** and **122** in a normal direction (Z-axis direction) of the plane electrode **121**. The via electrodes **131** and **132** extend in the Z-axis direction and connect the plane electrodes **121** and **123**. The via electrodes **133** and **134** extend in the Z-axis direction and connect the plane electrodes **121** and **122**.

Each of the via electrodes **131** and **132** is shorter than each of the via electrodes **133** and **134**. A distance between the plane electrodes **123** and **122** is shorter than a distance between the plane electrodes **123** and **121**.

The via electrodes **131** to **134** define an inductor. The plane electrodes **122** and **123** are opposed to each other in the Z-axis direction and define a capacitor.

FIG. **10** is a plan view of the resonant device **12** of FIG. **9** when seen in the Z-axis direction. As illustrated in FIG. **10**, when the plane electrode **123** is seen in plan view in the Z-axis direction, the via electrode **131**, a range Rg**21** between the via electrodes **131** and **133**, the via electrode **133**, a range Rg**22** between the via electrodes **133** and **132**, the via electrode **132**, a range Rg**23** between the via electrodes **132** and **134**, the via electrode **134**, and a range Rg**24** between the via electrodes **134** and **131** form a loop-shaped range. In the loop-shaped range, the via electrodes **131** and **132** connecting the plane electrodes **121** and **123** are positioned alternately with the via electrodes **133** and **134** connecting the plane electrodes **121** and **122**. An imaginary line VL**21** (first imaginary line) connecting the via electrodes **131** and **132** intersects with an imaginary line VL**22** (second imaginary line) connecting the via electrodes **133** and **134**.

A direction in which current flows in the via electrode **131** and a direction in which current flows in the via electrode **132** are the same as each other. A direction in which current flows in the via electrode **133** and a direction in which current flows in the via electrode **134** are the same as each other. The direction in which current flows in the via electrode **131** and the direction in which current flows in the via electrode **133** are opposite from each other.

The plane electrode **123** includes a portion Pr**21** (first portion) to which the via electrode **131** is connected, and a portion Pr**22** (second portion) to which the via electrode **132** is connected. A portion of the portion Pr**21** and a portion of Pr**22** are not overlapped with the plane electrodes **121** and **122**.

Even when misalignment of a relative positional relationship is caused between the plane electrodes **122** and **123** due to manufacturing variations, since the plane electrode **123** has the portion (margin) not overlapped with the plane electrode **122**, an area of a portion of the plane electrode **123** overlapping with the plane electrode **122** is prevented from being decreased. Since manufacturing variations in capacitance of the capacitor constituted by the plane electrodes **122** and **123** is reduced or prevented, manufacturing variations in characteristics of the resonant device **12** are reduced or prevented.

Further, since a width of the plane electrode **123** is comparatively large, the capacitance of the capacitor including the plane electrodes **122** and **123** can be made comparatively large. Thus, it is less necessary to bring the plane electrodes **122** and **123** closer to each other in order to increase the capacitance of the capacitor. Since a certain amount of space can be secured between the plane electrodes **122** and **123**, a risk of short circuiting between the plane electrodes **121** and **122** by the via electrodes **121** and **122** penetrating the plane electrode **123** during the manufacture of the resonant device **12** can be reduced.

As described above, the resonant device according to Preferred Embodiment 2 and a modification can improve the insertion loss of the resonant device. Moreover, the resonant device according to Preferred Embodiment 2 can reduce manufacturing variations in characteristics of the resonant device, and a risk of short circuiting of the two plane electrodes.

Preferred Embodiment 3

In Preferred Embodiments 1 and 2, the case where each of the number of the via electrodes connecting the first plane electrode and the third plane electrode and the number of the via electrodes connecting the first plane electrode and the second plane electrode is two is described. Each number of the via electrodes may be three or more, for example. In Preferred Embodiment 3, a case where the number of the via electrodes is three is described.

FIG. **11** is a perspective view of a plurality of electrodes of a resonant device **13** according to Preferred Embodiment 3. As illustrated in FIG. **11**, the resonant device **13** includes a plane electrode **141** (first plane electrode), a plane electrode **142** (second plane electrode), a plane electrode **143** (third plane electrode), a via electrode **151** (first via electrode), a via electrode **152** (second via electrode), a via electrode **153** (third via electrode), a via electrode **154** (fourth via electrode), a via electrode **155** (fifth via electrode), and a via electrode **156** (sixth via electrode).

The plane electrode **143** is located between the plane electrodes **141** and **142** in a normal direction (Z-axis direction) of the plane electrode **141**. The via electrodes **151**, **152**, and **155** extend in the Z-axis direction and connect the plane electrodes **121** and **123**. The via electrodes **153**, **154**, and **156** extend in the Z-axis direction and connect the plane electrodes **141** and **142**.

Each of the via electrodes **151**, **152**, and **155** is shorter than each of the via electrodes **153**, **154**, and **156**. A distance between the plane electrodes **143** and **142** is shorter than a distance between the plane electrodes **143** and **141**.

The via electrodes **151** to **156** and an inductor are provided. The plane electrodes **142** and **143** are opposed to each other in the Z-axis direction and constitute a capacitor.

FIG. **12** is a plan view of the resonant device **13** of FIG. **11** when seen in the Z-axis direction. As illustrated in FIG. **12**, when the plane electrode **143** is seen in plan view in the Z-axis direction, the via electrode **151**, a range Rg**31** between the via electrodes **151** and **153**, the via electrode **153**, a range Rg**32** between the via electrodes **153** and **152**, the via electrode **152**, a range Rg**35** between the via electrodes **152** and **156**, the via electrode **156**, a range Rg**36** between the via electrodes **156** and **155**, the via electrode **155**, a range Rg**37** between the via electrodes **155** and **154**, the via electrode **154**, and a range Rg**34** between the via electrodes **154** and **151** form a loop-shaped range. In the loop-shaped range, the via electrodes **151**, **152**, and **155** connecting the plane electrodes **141** and **143** are disposed alternately with the via electrodes **153**, **154**, and **156** connecting the plane electrodes **121** and **122**.

An imaginary line VL**31** (first imaginary line) connecting the via electrodes **151** and **152** intersects with an imaginary line VL**32** (second imaginary line) connecting the via electrodes **153** and **154**. An imaginary line VL**33** (third imaginary line) connecting the via electrodes **152** and **155** intersects with and an imaginary line VL**34** (fourth imaginary line) connecting the via electrodes **154** and **156**.

A direction in which current flows in the via electrode **151**, a direction in which current flows in the via electrode **152**, and a direction in which current flows in the via electrode **155** are the same as each other. A direction in which current flows in the via electrode **153**, a direction in which current flows in the via electrode **154**, and a direction in which current flows in the via electrode **156** are the same as each other. The direction in which current flows in the via electrode **151** and the direction in which current flows in the via electrode **153** are opposite from each other.

Note that, similarly to Preferred Embodiment 1, the via electrode **151**, the range Rg**31**, the via electrode **153**, the range Rg**32**, the via electrode **152**, a range Rg**33** between the via electrodes **152** and **154**, the via electrode **154**, and the range Rg**34** also define a loop-shaped range.

The plane electrode **143** includes a portion Pr**31** (first portion) to which the via electrode **151** is connected, a portion Pr**32** (second portion) to which the via electrode **152** is connected, and a portion Pr**33** (third portion) to which the via electrode **155** is connected. A portion of the portion Pr**31**, a portion of the portion Pr**32**, and a portion of the portion Pr**33** are not overlapped with the plane electrodes **141** and **142**.

Similarly to Preferred Embodiment 2, also the resonant device **13** can reduce or prevent manufacturing variations in characteristics of the resonant device **13**, and a risk of short circuiting of the plane electrodes **141** and **142**.

Further, since each of the number of the via electrodes connecting the plane electrodes **141** and **143** and the number of the via electrodes connecting the plane electrodes **141** and **142** is three, current flowing between the two plane electrodes is distributed more than in Preferred Embodiments 1 and 2. As a result, insertion loss of the resonant device **13** can be further improved compared to Preferred Embodiments 1 and 2.

As described above, the resonant device according to Preferred Embodiment 3 can further improve insertion loss of the resonant device compared to Preferred Embodiments 1 and 2. Further, the resonant device according to Preferred Embodiment 3 can reduce manufacturing variations in characteristics of the resonant device, and a risk of short circuiting of the two plane electrodes.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A resonant device comprising:
a multilayer body;
a first plane electrode provided to the multilayer body;
a second plane electrode provided to the multilayer body;
a third plane electrode provided to the multilayer body and located between the first plane electrode and the second plane electrode in a normal direction of the first plane electrode;
a first via electrode and a second via electrode connecting the first plane electrode and the third plane electrode; and
a third via electrode and a fourth via electrode connecting the first plane electrode and the second plane electrode; wherein
when the first plane electrode is seen in a plan view in the normal direction, a first imaginary line connecting the first via electrode and the second via electrode intersects with a second imaginary line connecting the third via electrode and the fourth via electrode; and
the second plane electrode and the third plane electrode define a capacitor.

2. The resonant device according to claim **1**, wherein
a direction in which current flows in the first via electrode and a direction in which current flows in the second via electrode are the same as each other;
a direction in which current flows in the third via electrode and a direction in which current flows in the fourth via electrode are the same as each other; and
the direction in which current flows in the first via electrode and the direction in which current flows in the third via electrode are opposite from each other.

3. The resonant device according to claim **1**, wherein
a terminal is provided in or on the third plane electrode; and
when the third plane electrode is seen in the plan view in the normal direction, the terminal is not overlapped with the first plane electrode and the second plane electrode.

4. The resonant device according to claim **1**, wherein
the third plane electrode includes a first portion to which the first via electrode is connected, and a second portion to which the second via electrode is connected; and
when the third plane electrode is seen in the plan view in the normal direction, a portion of the first portion and a portion of the second portion are not overlapped with the second plane electrode.

5. The resonant device according to claim **1**, further comprising:
a fifth via electrode connecting the first plane electrode and the third plane electrode; and
a sixth via electrode connecting the first plane electrode and the second plane electrode; wherein
when the first plane electrode is seen in the plan view in the normal direction, a third imaginary line connecting the second via electrode and the fifth via electrode intersects with a fourth imaginary line connecting the fourth via electrode and the sixth via electrode.

6. The resonant device according to claim **5**, wherein
a direction in which current flows in the first via electrode, a direction in which current flows in the second via electrode, and a direction in which current flows in the fifth via electrode are the same as each other;
a direction in which current flows in the third via electrode, a direction in which current flows in the fourth via electrode, and a direction in which current flows in the sixth via electrode are the same as each other; and
the direction in which current flows in the first via electrode and the direction in which current flows in the third via electrode are opposite from each other.

7. The resonant device according to claim **5**, wherein
the first via electrode, the fourth via electrode, and the fifth via electrode are positioned along a first direction perpendicular or substantially perpendicular to an extending direction of the first via electrode; and
the third via electrode, the second via electrode, and the sixth via electrode are positioned along a second direction perpendicular or substantially perpendicular to the extending direction.

8. The resonant device according to claim **5**, wherein
the third plane electrode further includes a third portion to which the fifth via electrode is connected; and
when the third plane electrode is seen in the plan view in the normal direction, a portion of the third portion is not overlapped with the second plane electrode.

9. A filter comprising:
the resonant device according to claim **1**.

10. The filter according to claim **9**, wherein

a direction in which current flows in the first via electrode and a direction in which current flows in the second via electrode are the same as each other;

a direction in which current flows in the third via electrode and a direction in which current flows in the fourth via electrode are the same as each other; and

the direction in which current flows in the first via electrode and the direction in which current flows in the third via electrode are opposite from each other.

11. The filter according to claim **9**, wherein

a terminal is provided in or on the third plane electrode; and

when the third plane electrode is seen in the plan view in the normal direction, the terminal is not overlapped with the first plane electrode and the second plane electrode.

12. The filter according to claim **9**, wherein

the third plane electrode includes a first portion to which the first via electrode is connected, and a second portion to which the second via electrode is connected; and

when the third plane electrode is seen in the plan view in the normal direction, a portion of the first portion and a portion of the second portion are not overlapped with the second plane electrode.

13. The filter according to claim **9**, further comprising:

a fifth via electrode connecting the first plane electrode and the third plane electrode; and

a sixth via electrode connecting the first plane electrode and the second plane electrode; wherein

when the first plane electrode is seen in the plan view in the normal direction, a third imaginary line connecting the second via electrode and the fifth via electrode intersects with a fourth imaginary line connecting the fourth via electrode and the sixth via electrode.

14. The filter according to claim **13**, wherein

a direction in which current flows in the first via electrode, a direction in which current flows in the second via electrode, and a direction in which current flows in the fifth via electrode are the same as each other;

a direction in which current flows in the third via electrode, a direction in which current flows in the fourth via electrode, and a direction in which current flows in the sixth via electrode are the same as each other; and

the direction in which current flows in the first via electrode and the direction in which current flows in the third via electrode are opposite from each other.

15. The filter according to claim **14**, wherein

the first via electrode, the fourth via electrode, and the fifth via electrode are positioned along a first direction perpendicular or substantially perpendicular to an extending direction of the first via electrode; and

the third via electrode, the second via electrode, and the sixth via electrode are positioned along a second direction perpendicular or substantially perpendicular to the extending direction.

16. The filter according to claim **14**, wherein

the third plane electrode further includes a third portion to which the fifth via electrode is connected; and

when the third plane electrode is seen in the plan view in the normal direction, a portion of the third portion is not overlapped with the second plane electrode.

17. A module comprising:

the filter according to claim **9**.

18. The module according to claim **17**, wherein

a direction in which current flows in the first via electrode and a direction in which current flows in the second via electrode are the same as each other;

a direction in which current flows in the third via electrode and a direction in which current flows in the fourth via electrode are the same as each other; and

the direction in which current flows in the first via electrode and the direction in which current flows in the third via electrode are opposite from each other.

19. The module according to claim **17**, wherein

a terminal is provided in or on the third plane electrode; and

when the third plane electrode is seen in the plan view in the normal direction, the terminal is not overlapped with the first plane electrode and the second plane electrode.

20. The module according to claim **17**, wherein

the third plane electrode includes a first portion to which the first via electrode is connected, and a second portion to which the second via electrode is connected; and

when the third plane electrode is seen in the plan view in the normal direction, a portion of the first portion and a portion of the second portion are not overlapped with the second plane electrode.

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