(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 001 502 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
30.03.2016 Bulletin 2016/13

(21) Application number: **13885195.1**

(22) Date of filing: **20.05.2013**

(51) Int Cl.:
H01Q 1/38 *(2006.01)*

(86) International application number:
PCT/JP2013/003195

(87) International publication number:
WO 2014/188467 (27.11.2014 Gazette 2014/48)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **Mitsubishi Materials Corporation**
Chiyoda-ku
Tokyo 100-8117 (JP)

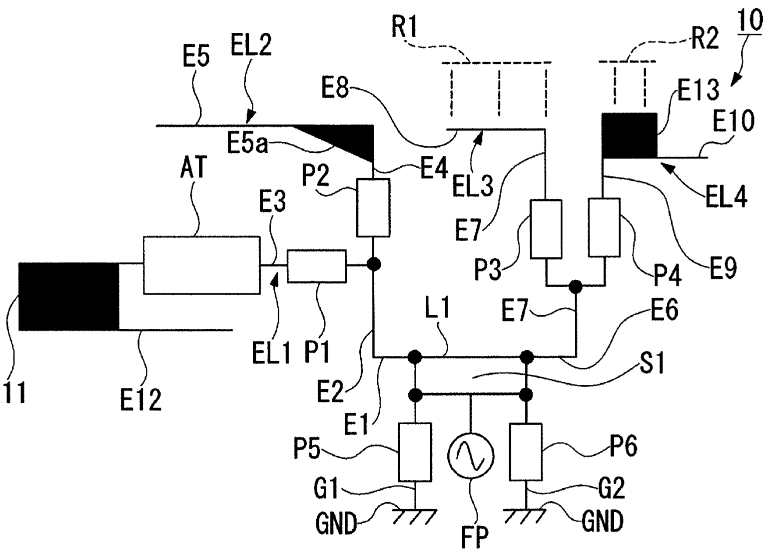
(72) Inventors:
- **YUKIMOTO, Shinsuke**
  Chichibu-gun
  Saitama 368-8502 (JP)
- **SAITO, Ryo**
  Chichibu-gun
  Saitama 368-8502 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) ANTENNA DEVICE USE BOARD AND ANTENNA DEVICE

(57) Provided are an antenna-device substrate and an antenna device that enable flexible adjustment of multiple resonance frequencies and enable reduction in size and thickness. There are provided a substrate main body, first to fourth elements (EL1 to EL4) patterned on the substrate main body by use of metal foils, and a ground plane (GND). The first element (EL1) extends to have a base end on which a power feeding point (FP) is provided and have an antenna element (AT). The second element (EL2) extends to have a base end connected to the first element. The third element extends to have a base end connected to the power feeding point. The fourth element extends to have a base end connected to the third element. The first to fourth elements extend with gaps from the adjacent elements and the ground plane so that stray capacitance between the adjacent elements and stray capacitance with the ground plane can occur.

[Fig. 1]



Description

[Technical Field]

[0001] The present invention relates to an antenna-device substrate and an antenna device which are capable of supporting multiple resonance frequencies.

[Background Art]

[0002] Conventionally, in order to multiple-resonate the resonance frequency of an antenna, antennas provided with a radiation electrode and a dielectric block or an antenna device using a switch and a controlled voltage source have been proposed for communication devices.

[0003] For example, in Patent Literature 1, which is conventional technology using a dielectric block, a composite antenna in which high efficiency is obtained by forming a radiation electrode on a resin molded body and further integrating a dielectric block using an adhesive is proposed.

[0004] In addition, in Patent Literature 2, which is conventional technology using a switch and a controlled voltage source, an antenna device having a first radiation electrode, a second radiation electrode, and a switch interposed between a middle portion of the first radiation electrode and a base end portion of the second radiation electrode and configured to electrically connect or disconnect the second radiation electrode to or from the first radiation electrode is proposed.

[Citation List]

[Patent Literatures]

[0005]

[Patent Literature 1]
Japanese Unexamined Patent Application, First Publication No. 2010-81000
[Patent Literature 2]
Japanese Unexamined Patent Application, First Publication No. 2010-166287

[Summary of Invention]

[Technical Problem]

[0006] However, the following problems remain even in the above-described conventional technology.

[0007] That is, in the technology based on a dielectric block as disclosed in Patent Literature 1, a dielectric block for exciting the radiation electrode is used and designs of a dielectric block, a radiation electrode pattern, etc. are necessary for each device or antenna performance deteriorates according to design conditions or there is inconvenience in that the number of unstable factors increases. In addition, because the radiation electrode is formed on a surface of the resin molded body, it is necessary to design a radiation electrode pattern on the resin molded body, an antenna design and a metal mold design are necessary according to a communication device to be mounted or its use, and a significant increase in cost is caused. Further, because the dielectric block and the resin molded body are integrated using an adhesive, there is inconvenience in that antenna performance is degraded or the number of unstable factors increases according to an adhesive condition (a thickness of an adhesive, an adhesive area, or the like) other than a Q value of the adhesive.

[0008] In addition, there is a problem in that the configuration of the controlled voltage source, a reactance circuit, or the like is necessary in order to switch the resonance frequency using the switch in the case of the antenna device using the switch and the controlled voltage source as disclosed in Patent Literature 2, the antenna configuration is complex according to each device, a degree of freedom of design is inadequate, and antenna adjustment is difficult.

[0009] The present invention has been made in view of the aforementioned problems and an objective of the invention is to provide an antenna-device substrate and an antenna device that enable flexible adjustment of multiple resonance frequencies, can inexpensively and simply secure antenna performance according to each use or device, and enable reduction in size or thickness.

[Solution to Problem]

[0010] The present invention has adopted the following configuration for solving the above-described problems. That is, according to a first present invention, an antenna-device substrate includes an insulating substrate main body; and first to fourth elements patterned using metal foils on the substrate main body and a ground plane, wherein the first element extends to have a base end on which a power feeding point is provided in the vicinity of the ground plane and have a first connector to which a first passive element is contactable and an antenna element of a dielectric antenna in this order, wherein the second element extends to have a base end connected between the power feeding point of the first element and the first connector and have a second connector to which a second passive element is connectable in the middle, wherein the third element extends to have a base end to which the power feeding point is connected and have a third connector to which a third passive element is connectable in the middle, wherein the fourth element extends to have a base end connected between the power feeding point of the third element and the third connector and have a fourth connector to which a fourth passive element is connectable in the middle, and wherein the first to fourth elements extend with gaps from adjacent elements and the ground plane so that stray capacitance between the adjacent elements and stray capacitance with the ground plane are able to occur.

[0011] Because the first to fourth elements extend with the gaps from the adjacent elements and the ground plane so that stray capacitance between the adjacent elements and the stray capacitance with the ground plane can occur in the antenna-device substrate, the substrate can be provided with a multiple resonance (double to quadruple resonance) by effectively employing the stray capacitance between the antenna element of a loading element without self-resonance at a desired resonance frequency and each element. In addition, it is possible to flexibly adjust each resonance frequency and obtain the antenna device in which double to quadruple resonance is possible according to design conditions through selection (a constant change or the like) of the antenna element and the first to fourth passive elements to be connected to the first to fourth connectors. As described above, because it is possible to flexibly adjust each resonance frequency in one substrate for the antenna device according to the antenna configuration, replacement of the resonance frequency is possible and an adjustment position based on a passive element or the like can change according to the use or device. Also, a bandwidth can be adjusted according to settings of a length and width of each element and each stray capacitance.

[0012] In addition, a design is possible within a plane of the substrate main body and thickness reduction is possible as compared with the case in which the conventional dielectric block or resin-molded body or the like is used and size reduction and high performance are also enabled by selecting the antenna element which is the dielectric antenna. In addition, cost according to a metal mold, a design change, or the like is unnecessary and low cost can be implemented.

[0013] The antenna-device substrate according to a second present invention comprises, in the first present invention, a first ground connector having a base end connected to the ground plane and a distal end connected to a base end side of the first element closer than a connection portion of the first element with the second element; a second ground connector having a base end separated from a position at which the first ground connector is connected and connected to the ground plane and a distal end connected to a base end side of the third element closer than a connection portion of the third element with the fourth element; and a connection pattern extending by connecting a distal end side of the first element further than a connection portion of the first element with the first ground connector and a distal end side of the third element further than a connection portion of the third element with the second ground connector, wherein an annular opening pattern portion among the connection pattern, the first element, and the third element is formed in the vicinity of the power feeding point.

[0014] Because the annular opening pattern portion among the connection pattern, the first element, and the third element is formed in the vicinity of the power feeding point in the antenna-device substrate, it is possible to reduce a bad influence from a capacitance occurring between peripheral components by a capacitance occurring within the opening pattern portion and implement high performance for each element. That is, the opening pattern portion can effectively make a flow of a high-frequency current from the power feeding point to elements of the side of the first element (including the second element) and the side of the third element (including the fourth element) with good balance. In particular, when a distance from a peripheral component is short due to size reduction or thickness reduction, it is possible to effectively achieve both size reduction and high performance.

[0015] The antenna-device substrate according to a third present invention is characterized in that, in the first or second present invention, the first element includes a first extension portion extending from the power feeding point in one direction along the ground plane, a second extension portion extending from a distal end of the first extension portion away from the ground plane, and a third extension portion extending from a distal end of the second extension portion in a direction along the ground plane via the first connector and to which the antenna element extending in the same direction is connected, the second element includes a fourth extension portion extending from the distal end of the second extension portion in the same direction as that of the second extension portion via the second connector and a fifth extension portion extending from a distal end of the fourth extension portion to a side of the antenna element in a direction along the third extension portion, the third element includes a sixth extension portion extending from the power feeding point in another direction along the ground plane, a seventh extension portion extending from a distal end of the sixth extension portion away from the ground plane via the third connector, and an eighth extension portion extending from a distal end of the seventh extension portion to the fourth extension portion in a direction along the ground plane, and the fourth element includes a ninth extension portion having a distal end connected to the middle of the seventh extension portion and extending with a gap from the seventh extension portion in the same direction and a tenth extension portion extending from a distal end of the ninth extension portion away from the seventh extension portion.

[0016] That is, because the first element has the first to third extension portions, the second element has the fourth and fifth extension portions, the third element has the sixth to eighth extension portions, and the fourth element has the ninth extension portion and the tenth extension portion on the antenna-device substrate, stray capacitance between the first element and the ground plane, stray capacitance between the antenna element and the fifth extension portion, stray capacitance between the third extension portion and the fifth extension portion, stray capacitance between the fifth extension portion and the eighth extension portion, stray capacitance among the first extension portion, the sixth extension portion, and the eighth extension portion, stray capacitance between the seventh extension portion and the ninth extension portion, and stray capacitance between the tenth extension portion and the ground plane can occur and a high degree of freedom of adjustment at each resonance frequency can be obtained.

[0017] The antenna-device substrate according to a fourth present invention is characterized in that, in the third present invention, a base end side closer than a portion opposite to the antenna element of the fifth extension portion serves as a wide portion formed to be wider than a distal end side.

[0018] That is, because the base end side closer than the portion opposite to the antenna element of the fifth extension portion serves as the wide portion formed to be wider than the distal end side on the antenna-device substrate, it is possible to cause stray capacitance between the fifth extension portion and the third extension portion through the wide portion to effectively occur while securing the wide portion without interference with the antenna element and achieve a broad band and size reduction.

[0019] The antenna-device substrate according to a fifth present invention is characterized in that, in the third or fourth present invention, the first element includes an eleventh extension portion extending from a distal end of the third extension portion to the ground plane and a twelfth extension portion extending from a distal end of the eleventh extension portion to the first extension portion along the ground plane.

[0020] That is, because the first element has an eleventh extension portion extending from the distal end of the third extension portion to the ground plane and the twelfth extension portion extending from the distal end of the eleventh extension portion to the first extension portion along the ground plane on the antenna-device substrate, it is possible to cause stray capacitance between the twelfth extension portion and the third extension portion and stray capacitance between the twelfth extension portion and the ground plane to occur.

[0021] The antenna-device substrate according to a sixth present invention is characterized in that, in any one of the third to fifth present inventions, a thirteenth extension portion extending away from the ground plane is connected to a base end side of the tenth extension portion.

[0022] That is, because the thirteenth extension portion extending away from the ground plane is connected to the base end side of the tenth extension portion on the antenna-device substrate, it is possible to cause stray capacitance between the thirteenth extension portion and the seventh extension portion to occur and distribute a high-frequency current away from the ground plane through the thirteenth extension portion. In addition, because a space between the tenth extension portion and the thirteenth extension portion is empty, it is possible to secure a space or the like for fixing a screw of the substrate main body in the empty space.

[0023] The antenna-device substrate according to a seventh present invention is characterized in that, in any one of the third to sixth present inventions, the eighth extension portion includes a first rear-surface pattern portion patterned on a rear surface of the substrate main body connected to a front surface side via a through-hole and the first rear-surface pattern portion is widely formed toward the ground plane.

[0024] That is, because the eighth extension portion has the first rear-surface pattern portion patterned on the rear surface of the substrate main body connected to the front surface side via the through-hole and the first rear-surface pattern portion is widely formed toward the ground plane on the antenna-device substrate, it is possible to cause stray capacitance with the fourth extension portion to effectively occur without interfering with the fourth extension portion. In addition, because the first rear-surface pattern portion is widely formed toward the ground plane, impedance is also lower than in the fourth extension portion and an influence of interference can be reduced according to stray capacitance with the first extension portion and the eighth extension portion.

[0025] The antenna-device substrate according to an eighth present invention is characterized in that, in the sixth present invention, the thirteenth extension portion includes a second rear-surface pattern portion patterned on a rear surface of the substrate main body connected to a front surface side via a through-hole and the second rear-surface pattern portion is widely formed toward the ground plane.

[0026] That is, because the thirteenth extension portion has the second rear-surface pattern portion patterned on the rear surface of the substrate main body connected to the front surface side via the through-hole and the second rear-surface pattern portion is widely formed toward the ground plane on the antenna-device substrate, it is possible to cause stray capacitance with the eighth extension portion or the ground plane by the pattern arrangement with the tenth extension portion to effectively occur.

[0027] Therefore, it is possible to further achieve both high performance and size reduction of an antenna without widening an antenna occupancy area according to adaptation of the first rear-surface pattern portion or the second rear-surface pattern portion.

[0028] The antenna-device substrate according to a ninth present invention is characterized in that, in the second present invention, a passive element for impedance adjustment is connected to each of the first ground connector and the second ground connector.

[0029] That is, because the passive element for impedance adjustment is connected to each of the first ground connector and the second ground connector on the antenna-device substrate, it is possible to perform impedance adjustment of each frequency band through a setting of the opening pattern portion and settings of two passive elements for impedance adjustment.

[0030] According to a tenth present invention, an antenna device comprises: the antenna-device substrate according to any one of the first to ninth present inventions, wherein the first passive element, the second passive element, the third passive element, and the fourth passive element are connected to the first, second, third, and fourth connectors corresponding thereto.

[0031] That is, because the first passive element, the second passive element, the third passive element, and the fourth passive element are connected to the first, second, third, and fourth connectors corresponding thereto on the antenna device, it is possible to achieve double to quadruple resonance by merely appropriately selecting the first to fourth passive elements and communication at two to four resonance frequencies corresponding to each use or device.

[0032] According to an eleventh present invention, an antenna device comprises: the antenna-device substrate according to any one of the first to ninth present inventions, wherein the first passive element is connected to the first connector and wherein any one or two of the second passive element, the third passive element, and the fourth passive element are connected to the second, third, and fourth connectors corresponding thereto.

[0033] That is, because the first passive element is connected to the first connector and any one or two of the second passive element, the third passive element, and the fourth passive element are connected to the second, third, and fourth connectors corresponding thereto on the antenna device, double resonance in two types or triple resonance in three types is possible in a state in which any one or two of the second passive element, the third passive element, and the fourth passive element are not used.

[Advantageous Effects of Invention]

[0034] The present invention accomplishes the following effects.

[0035] That is, because the first to fourth elements extend with gaps from the adjacent elements and the ground plane so that stray capacitance between adjacent elements and stray capacitance with the ground plane can occur according to the antenna-device substrate and the antenna device having the same according to the present invention, it is possible to perform multiple resonance (double to quadruple resonance). In addition, it is possible to flexibly adjust each resonance frequency and obtain the antenna device in which double to quadruple resonance is possible according to a design condition through selection of the first to fourth passive elements to be connected to the first to fourth connectors and enable size reduction and high performance.

[0036] Therefore, the antenna-device substrate and the antenna device having the same according to the present invention can be easily provided with a multiple resonance characteristic corresponding to various uses or devices and save space.

[Brief Description of Drawings]

[0037]

Fig. 1 is a wiring diagram illustrating an antenna device in an embodiment of an antenna-device substrate and an antenna device according to the present invention.

Fig. 2 is a wiring diagram illustrating stray capacitance occurring on the antenna device in this embodiment.

Fig. 3 is a top view and a rear view illustrating the antenna-device substrate in this embodiment.

Fig. 4 is a top view illustrating the antenna device in this embodiment.

Fig. 5 is a perspective view (a), a top view (b), a front view (c), and a bottom view (d) illustrating an antenna element in this embodiment.

Fig. 6 is an explanatory diagram illustrating a function of an opening pattern portion in this embodiment.

Fig. 7 is a graph illustrating a voltage standing wave ratio (VSWR) characteristic in quadruple resonance in examples of an antenna-device substrate and an antenna device according to the present invention.

Fig. 8 is graphs illustrating radiation patterns of a 920 MHz band, a 1400 MHz band, and a 1920 MHz band in an example according to the present invention.

[Description of Embodiments]

[0038] Hereinafter, an embodiment of an antenna device according to the present invention will be described with reference to Figs. 1 to 6.

[0039] The antenna-device substrate 1 in this embodiment includes an insulating substrate main body 2, a first element EL1, a second element EL2, a third element EL3, and a fourth element EL4 patterned by use of metal foils such as copper foils on the substrate main body 2 and a ground plane GND as illustrated in Figs. 1 to 4.

[0040] Also, a mounting region of a radio frequency (RF) circuit or the like is provided in the ground plane GND. In addition, the ground plane GND is formed in a similar pattern corresponding to a front surface on a rear surface as well as the front surface of the substrate main body 2.

[0041] The first element EL1 extends to have a base end on which a power feeding point FP is provided in the vicinity of the ground plane GND and have a first connector C1 to which a first passive element P1 is contactable and an antenna element AT of a dielectric antenna in this order in the middle. Also, in this embodiment, as illustrated in Figs. 3 and 4, the first passive element P1 is mounted on each of two first connectors C1 and two first passive elements P1 are connected in series.

[0042] The second element EL2 extends to have a base end connected between the power feeding point FP of the first element EL1 and the first connector C1 and have a second connector C2 to which a second passive element P2 is connectable in the middle.

[0043] The third element EL3 extends to have a base end to which the power feeding point FP is connected and have a third connector C3 to which a third passive element P3 is connectable in the middle. Also, in this embodiment, as illustrated in Figs. 3 and 4, the third passive element P3 is mounted on each of two third connectors C3 and two third passive elements P3 are connected in series.

[0044] The fourth element EL4 extends to have a base end connected between the power feeding point FP of the third element EL3 and the third connector C3 and have a fourth connector C4 to which a fourth passive element P4 is connectable in the middle. Also, in this embodiment, as illustrated in Figs. 3 and 4, the fourth passive element P4 is mounted on each of two fourth connectors C4 and two fourth passive elements P4 are connected in series.

[0045] The first passive element P1, the third passive element P3, and the fourth passive element P4 are used by combining two passive elements, but two passive elements having the same characteristic may be used or two passive elements having different characteristics may be used. In addition, one passive element or a combination of three or more passive elements may be used instead of a combination of two passive elements.

[0046] The first element EL1 has a first extension portion E1 extending from the power feeding point FP in one direction along the ground plane GND, a second extension portion E2 extending from a distal end of the first extension portion E1 away from the ground plane GND, and a third extension portion E3 extending from a distal end of the second extension portion E2 in a direction along the ground plane GND via the first connector C1 and to which the antenna element AT extending in the same direction is connected. Also, the direction along the ground plane GND is a direction along an edge side of an opposite ground plane GND.

[0047] Also, the first extension portion E1 extends away from the ground plane GND after extending from the power feeding point FP in one direction along the ground plane GND, further extends in one direction along the ground plane GND, and extends in one direction along the ground plane GND as a whole while being bent in a crank shape.

[0048] In addition, the first element EL1 has an eleventh extension portion E11 extending from a distal end of the third extension portion E3 toward the ground plane GND and a twelfth extension portion E12 extending from a distal end of the eleventh extension portion E11 toward the first extension portion E1 along the ground plane GND. That is, the distal end side of the first element EL1 is bent by the eleventh extension portion E11 and the twelfth extension portion E12. Also, the eleventh extension portion E11 has a wide rectangular shape.

[0049] The second element EL2 has a fourth extension portion E4 extending from a distal end of the second extension portion E2 in the same direction as the second extension portion E2 via the second connector C2 and a fifth extension portion E5 extending from a distal end of the fourth extension portion E4 to a side of the antenna element AT in a direction along the third extension portion E3.

[0050] In addition, a base end side closer than a portion opposite to the antenna element AT of the fifth extension portion E5 serves as a wide portion E5a formed to be wider than a distal end side.

[0051] The third element EL3 has a sixth extension portion E6 extending from the power feeding point FP in another direction along the ground plane GND, a seventh extension portion E7 extending from a distal end of the sixth extension portion E6 away from the ground plane GND via the third connector C3, and an eighth extension portion E8 extending from a distal end of the seventh extension portion E7 toward the fourth extension portion E4 in a direction along the ground plane GND. Also, the sixth extension portion E6 extends away from the ground plane GND after extending from the power feeding point FP in the other direction along the ground plane GND, further extends in the other direction along the ground plane GND, and extends in the other direction along the ground plane GND as a whole while being bent in the crank shape.

[0052] That is, base end portions (the first extension portion E1 and the sixth extension portion E6) of the first element EL1 and the third element EL3 are extended in opposite direction each other from the power feeding point FP.

[0053] The eighth extension portion E8 has a first rear-surface pattern portion R1 patterned on a rear surface of the substrate main body 2 connected to a front surface side via a through-hole H, and the first rear-surface pattern portion R1 is widely formed toward the ground plane GND. Also, the first rear-surface pattern portion R1 is connected to the eighth extension portion E8 of the front surface side through the through-hole H on an end portion side of the substrate main body 2.

[0054] The fourth element EL4 has a ninth extension portion E9 having a distal end connected to the middle of the seventh extension portion E7 and extending with a gap from the seventh extension portion E7 in the same direction and a tenth extension portion E10 extending from a distal end of the ninth extension portion E9 away from the seventh extension portion E7.

[0055] In addition, the thirteenth extension portion E13 extending away from the ground plane GND is connected to a base end side of the tenth extension portion E10.

[0056] The thirteenth extension portion E13 has a second rear-surface pattern portion R2 patterned on a rear surface of the substrate main body 2 connected to the front surface side via the through-hole H, and the second rear-surface pattern portion R2 is widely formed toward the ground plane GND. Also, the second rear-surface pattern portion R2 is connected to the thirteenth extension portion E13 of the front surface side through the through-hole H on an end portion side of the substrate main body 2.

[0057] In addition, the antenna-device substrate 1 includes a first ground connector G1 having a base end connected to the ground plane GND and a distal end connected to a base end side of the first element EL1 closer than a connection portion of the first element EL1 with the second element EL2; a second ground connector G2 having a base end separated from a position at which the first ground connector G1 is connected and connected to the ground plane GND and a distal end connected to a base end side of the third element EL3 closer than a connection portion of the third element EL3 with the fourth element EL4; and a connection pattern L1 extending by connecting a distal end side of the first element EL1 further than a connection portion of the first element EL1 with the first ground connector G1 and a distal end side of the third element EL3 further than a connection portion of the third element EL3 with the second ground connector G2.

[0058] In addition, an annular opening pattern portion S1 among the connection pattern L1, the first element EL 1, and the third element EL3 is formed in the vicinity of the power feeding point FP. That is, the opening pattern portion S1 having an approximately rectangular shape that extends along the ground plane GND is configured by parts of the first extension portion E1 and the sixth extension portions E6 bent in the crank shape and the connection pattern L1.

[0059] A fifth passive element P5 which is a passive element for impedance adjustment is connected to the first ground connector G1 and a sixth passive element P6 which is a passive element for impedance adjustment is connected to the second ground connector G2. Also, in this embodiment, the ground plane GND and the first element EL1 are directly connected by only the fifth passive element P5 and the fifth passive element P5 itself functions as the first ground connector G1. In addition, the ground plane GND and the third element EL3 are directly connected by only the sixth passive element P6, and the sixth passive element P6 itself functions as the second ground connector G2.

[0060] The substrate main body 2 is a general printed circuit board. In this embodiment, a main body of the printed circuit board formed of a rectangular glass epoxy resin or the like is adopted. Also, dimensions of the substrate main body 2 of this embodiment are a longitudinal direction: 110 mm, a lateral direction: 52 mm, and a thickness: 1.0 mm. In addition, dimensions of the antenna region (including a part of the ground plane GND below the fourth element EL4) on the substrate main body 2 are a longitudinal direction of the substrate main body 2: 11 mm and a lateral direction of the substrate main body 2: 35 mm.

[0061] The power feeding point FP is connected to the power feeding point of a high-frequency circuit (not illustrated) via a power feeding means such as a coaxial cable. As the power feeding means, various structures such as a coaxial cable, a connector such as a receptacle, a connection structure having a contact point of a plate spring shape, a connection structure having a contact point of a pin probe shape or a pin shape, a connection structure using a soldering land, etc. can be adopted.

[0062] For example, when the coaxial cable is adopted as the power feeding means, a ground line of the coaxial cable is connected to a base end side of the ground plane GND and a core wire of the coaxial cable is connected to the power feeding point FP.

[0063] The antenna element AT is a loading element without self-resonance at a desired resonance frequency, and, for example, is a chip antenna in which a conductor pattern 102 is formed, for example, of Ag, on the surface of a dielectric block 101 such as a ceramic as illustrated in Fig. 5. For the antenna element AT, according to a setting such as a resonance frequency, elements different in a length, a width, a conductor pattern 102, etc. thereof may be selected or the same element may be selected. Also, the dimensions of the antenna element AT of this embodiment are a width: 10.5 mm, a depth: 3.0 mm, and a height: 0.8 mm.

[0064] For example, inductors, condensers, or resistors are adopted for the first passive element P1 to the sixth passive element P6.

[0065] On the antenna-device substrate 1 of this embodiment, the elements from the first element EL1 to the fourth element EL4 extend with gaps from the adjacent elements and the ground plane GND so that stray capacitance between adjacent elements and stray capacitance with the ground plane GND can occur.

[0066] That is, as illustrated in Fig. 2, stray capacitance Ca between the twelfth extension portion E12 and the ground plane GND, stray capacitance Cb between the antenna element AT (third extension portion E3) and the twelfth extension portion E12, stray capacitance Cc between the antenna element AT and the fifth extension portion E5, stray capacitance Cf between the third extension portion E3 and the fifth extension portion E5, stray capacitance Cg between the fifth extension portion E5 and the eighth extension portion E8, stray capacitance Ch between the opening pattern portion S1 (the first extension portion E1 and the sixth extension portion E6) and the eighth extension portion E8, stray capacitance Ci between the eighth extension portion E8 and the thirteenth extension portion E13, stray capacitance Cj between the seventh extension portion E7 and the ninth extension portion E9, and stray capacitance Ck between the tenth extension portion E10 and the ground plane GND can occur. In addition, a capacitance Cd is also generated by the opening pattern portion S1.

[0067] As illustrated in Fig. 4, the antenna device 10 of this embodiment includes the antenna-device substrate 1, and the first passive element P1, the second passive element P2, the third passive element P3, and the fourth passive element P4 are connected to the first connector C1, the second connector C2, the third connector C3, and the fourth connector C4 corresponding thereto, respectively.

[0068] Next, a resonance frequency of the antenna device 10 of this embodiment will be described with reference to Fig. 7.

[0069] The antenna device 10 of this embodiment, as illustrated in Fig. 7, has multiple resonance frequencies at four frequencies, i.e., a first resonance frequency f1, a second resonance frequency f2, a third resonance frequency f3, and a fourth resonance frequency f4.

[0070] The first resonance frequency f1 is that of a low frequency band (for example, a 920 MHz band) among the four resonance frequencies, and is determined by the antenna element AT and a length of the first element EL1 (the first extension portion E1, the second extension portion E2, the eleventh extension portion E11, and the twelfth extension portion E12).

[0071] In addition, the bandwidth widening of the first resonance frequency f1 is determined by lengths and widths of the twelfth extension portion E12, the eleventh extension portion E11, and the third extension portion E3.

[0072] In addition, impedance at the first resonance frequency f1 is determined by the stray capacitances Ca to Cd.

[0073] Further, the final adjustment of the first resonance frequency f1 can be flexibly adjusted using the first passive element P1.

[0074] Therefore, the first resonance frequency f1 is mainly adjusted by a part surrounded by a broken line A1 in Fig. 2.

[0075] As described above, for the first resonance frequency f1, the resonance frequency, the bandwidth, and the impedance can be flexibly adjusted according to settings of the length and width of the first element EL1, the first passive element P1, the antenna element AT, and each stray capacitance described above.

[0076] Next, the third resonance frequency f3 is determined by lengths of the first extension portion E1, the second extension portion E2, the fourth extension portion E4, and the fifth extension portion E5.

[0077] In addition, the bandwidth widening of the third resonance frequency f3 is determined by lengths and widths of the first extension portion E1, the second extension portion E2, the fourth extension portion E4, and the fifth extension portion E5.

[0078] In addition, the impedance at the third resonance frequency f3 is determined by the stray capacitances Cd, Cc, Cf, and Cg.

[0079] Further, the final adjustment of the third resonance frequency f3 can be flexibly adjusted using the second passive element P2.

[0080] Therefore, the third resonance frequency f3 is mainly adjusted by a part surrounded by a dash-dot line A3 in Fig. 2.

[0081] As described above, for the third resonance frequency f3, the resonance frequency, the bandwidth, and the impedance can be flexibly adjusted according to settings of the length and width of the first extension portion E1, the second extension portion E2, and the second element EL2, the second passive element P2, and each stray capacitance described above.

[0082] Next, the fourth resonance frequency f4 is determined by lengths of the eighth extension portion E8 and the seventh extension portion E7.

[0083] In addition, the bandwidth widening of the fourth resonance frequency f4 is determined by lengths and widths of the eighth extension portion E8 and the seventh extension portion E7.

[0084] In addition, the impedance at the fourth resonance frequency f4 is determined by the stray capacitances Cd, Cg, Ch, and Ci.

[0085] Further, the final adjustment of the fourth resonance frequency f4 can be flexibly adjusted using the third passive element P3.

[0086] Therefore, the fourth resonance frequency f4 is mainly adjusted by a part surrounded by a dash-double-dot line A4 in Fig. 2.

[0087] As described above, for the fourth resonance frequency f4, the resonance frequency, the bandwidth, and the impedance can be flexibly adjusted according to settings of the length and width of the third element EL3 (the seventh extension portion E7 and the eighth extension portion E8), the third passive element P3, and each stray capacitance described above.

[0088] Next, the second resonance frequency f2 is determined by lengths of the seventh extension portion E7, the thirteenth extension portion E13, the tenth extension portion E10, and the ninth extension portion E9.

[0089] In addition, the bandwidth widening of the second resonance frequency f2 is determined by lengths and widths of the seventh extension portion E7, the thirteenth extension portion E13, the tenth extension portion E10, and the ninth extension portion E9.

[0090] In addition, the impedance at the second resonance frequency f2 is determined by the stray capacitances Cd, Ci, Cj, and Ck.

[0091] Further, the final adjustment of the second resonance frequency f2 can be flexibly adjusted using the fourth passive element P4.

[0092] Therefore, the second resonance frequency f2 is mainly adjusted by a part surrounded by a broken line A2 in Fig. 2.

[0093] As described above, for the second resonance frequency f2, the resonance frequency, the bandwidth, and the impedance can be flexibly adjusted according to settings of lengths and widths of the seventh extension portion E7, the thirteenth extension portion E13, the tenth extension portion E10, and the ninth extension portion E9, the fourth passive element P4, and each stray capacitance described above.

[0094] Also, for each resonance frequency described above, it is possible to flexibly perform the final impedance adjustment using the fifth passive element P5 and the sixth passive element P6 which are passive elements for impedance adjustment.

[0095] Next, the effect of the opening pattern portion S1 will be described.

[0096] The opening pattern portion S1 is provided in the vicinity of the power feeding point FP in this embodiment, and a high-frequency current can effectively flow from the power feeding point FP to the left and right elements according to the opening pattern portion S1.

[0097] That is, when there is no opening pattern portion S1, the flow to the antenna elements (the third element EL3 and the fourth element EL4) of the right side of the drawing in the flow of the high-frequency current from the power feeding point FP is smooth, but a capacitance with the element from the power feeding point FP occurs in the flow to the left side as illustrated in (b) of Fig. 6. Even in the case of wiring illustrated in (c) of Fig. 6, the flow to the left side is similarly smooth, but the capacitance with the element from the power feeding point FP occurs in the flow to the right side.

[0098] As a result, two antenna elements are provided in each of the left and right directions and a degree of influence is also different, leading to performance degradation.

[0099] In addition, when there is no opening pattern portion S1 and a connection is achieved in the center as illustrated in (d) of Fig. 6, similar capacitances occur in both the left and right and significant performance degradation occurs.

[0100] Further, as illustrated in (e) of Fig. 6, in the case of a pattern in which a part of the opening pattern portion S1 becomes a wide pattern without an opening and a connection is achieved in large area in the center, a high-frequency current of each element is not problematic, but performance degradation increases because the area is large by mounting a component around the antenna.

[0101] In particular, with size reduction or thickness reduction, a distance from a peripheral component become short and significant performance degradation further occurs.

[0102] Therefore, as illustrated in (a) of Fig. 6, by providing the opening pattern portion S1 as in the present invention, a bad influence from a capacitance occurring between peripheral components is reduced by a capacitance within the opening pattern portion S1, a high-frequency current flowing through each antenna element can efficiently flow, and it is possible to implement both size reduction and high performance.

[0103] Next, a first rear-surface pattern portion R1 and a second rear-surface pattern portion R2 will be described.

[0104] First, in the first rear-surface pattern portion R1, stray capacitance for the fourth extension portion E4 and the opening pattern portion S1 occurs in the surface.

[0105] Because the stray capacitance occurs in the fourth extension portion E4 when the first rear-surface pattern portion R1 is designed, the stray capacitance is not effectively used according to a thickness of the substrate main body 2 in an extension direction of the fourth extension portion E4 and the fourth extension portion E4 may be interfered with.

[0106] In regard to this, impedance in any direction toward the opening pattern portion S1 is lower than that of the fourth extension portion E4 and an influence of interference is small according to a capacitance of the side of the opening pattern portion S1. Thus, for the first rear-surface pattern portion R1, a design in which a width corresponding to the eighth extension portion E8 is set as a maximum width and the first rear-surface pattern portion R1 extends from an end portion side of the substrate main body 2 in an extension direction of the fourth extension portion E4 is effective.

[0107] In addition, in the second rear-surface pattern portion R2, stray capacitance with the eighth extension portion E8 or the ground plane GND by the pattern arrangement with the tenth extension portion E10 occurs for the thirteenth extension portion E13. Thus, for the second rear-surface pattern portion R2, as in the first rear-surface pattern portion R1, a design in which a width corresponding to the thirteenth extension portion E13 is set as a maximum width and the second rear-surface pattern portion R2 extends from an end portion side of the substrate main body 2 in a direction toward the tenth extension portion E10 is effective.

[0108] Next, the tenth extension portion E10 and the thirteenth extension portion E13 will be described.

[0109] The thirteenth extension portion E13 is combined with the tenth extension portion E10 and has an orthogonal pattern arrangement. When this thirteen extension portion E13 is patterned in only the horizontal direction (the extension direction of the tenth extension portion E10), a degree of freedom of the design is low because it is necessary to design the stray capacitance with the eighth extension portion E8 in consideration of the stray capacitance with the ground plane GND. Thus, further size reduction is difficult.

[0110] Therefore, by disposing the tenth extension portion E10 which uses the stray capacitance with the ground plane GND and designing the thirteenth extension portion E13 in a distribution pattern which uses the stray capacitance with the eighth extension portion E8, a high-frequency current, which flows through each antenna element, is also distributed and each stray capacitance can be effectively designed. In addition, there is an advantage in that the ground plane GND can be disposed up to the vicinity of the tenth extension portion E10 and other parts (a button/switch, a microphone, a flexible printed circuit (FPC), etc.) for use in the device can be mounted, leading to size reduction of the device.

[0111] Next, the fifth extension portion E5 will be described.

[0112] The fifth extension portion E5 has a pattern arrangement using stray capacitance with the antenna element AT, but it is necessary to reduce an antenna region when the entire size reduction is considered and the arrangements of the fifth extension portion E5 and the antenna element AT are important.

[0113] It is ideal to widely design a width of the fifth extension portion E5 because it leads to a wider bandwidth, but compatibility with size reduction may be difficult due to an antenna region. Therefore, it is desirable to finely design the width of the fifth extension portion E5 and design the fifth extension portion E5 at a position close to the end portion of the substrate main body 2.

[0114] Further, it is preferable to designate the wide portion E5a by widening a pattern width of the side of the fifth extension portion E5 of a part in which stray capacitance Cf between the third extension portion E3 and the fifth extension portion E5 occurs and form an efficient pattern arrangement. The wide portion E5a has a chamfered shape (a triangular shape or a trapezoidal shape) rather than a square shape in consideration of an influence of the stray capacitance Cc between the antenna element AT and the fifth extension portion E5, so that it is possible to control a high-frequency current flowing through the fifth extension portion E5 while effectively using the stray capacitance.

[0115] Because the elements from the first element EL1 to the fourth element EL4 extend with gaps from the adjacent elements and the ground plane GND so that stray capacitance between adjacent elements and stray capacitance with the ground plane GND can occur in the antenna-device substrate 1 of this embodiment, the substrate 1 can be provided with a multiple resonance (double to quadruple resonance) by effectively employing the stray capacitance between the antenna element AT of a loading element without self-resonance at a desired resonance frequency and each element.

[0116] In addition, it is possible to flexibly adjust each resonance frequency and obtain the antenna device 10 in which double to quadruple resonance is possible according to design conditions through selection (a constant change or the like) of the antenna element AT and the first to fourth passive elements P1 to P4 to be connected to the first to fourth connectors C1 to C4. As described above, because it is possible to flexibly adjust each resonance frequency in one antenna-device substrate 1 according to the antenna configuration, the replacement of the resonance frequency is possible and an adjustment position based on a passive element or the like can change according to the use or device.

[0117] In addition, a design is possible within a plane of the substrate main body 2 and thickness reduction is possible as compared with the case in which the conventional dielectric block or resin molded body or the like is used and size reduction and high performance are also enabled by selecting the antenna element AT which is the dielectric antenna. In addition, cost according to a mold, a design change, or the like is unnecessary and low cost can be implemented.

[0118] Further, because the annular opening pattern portion S1 among the connection pattern L1, the first element EL1, and the third element EL3 is formed in the vicinity of the power feeding point FP, it is possible to reduce a bad influence from a capacitance occurring between peripheral components by the capacitance Cd occurring within the opening pattern portion S1 and implement high performance for each element.

[0119] In addition, because a base end side closer than a portion opposite to the antenna element AT of the fifth extension portion E5 serves as the wide portion E5a formed to be wider than a distal end side, it is possible to cause stray capacitance between the fifth extension portion E5 and the third extension portion E3 to effectively occur through the wide portion E5a while securing the wide portion E5a without interference with the antenna element AT and achieve a broad band and size reduction.

[0120] In addition, because the thirteenth extension portion E13 extending away from the ground plane GND is connected to the base end side of the tenth extension portion E10, it is possible to cause stray capacitance Ci between the thirteenth extension portion E13 and the seventh extension portion E7 to occur and distribute a high-frequency current away from the ground plane GND through the thirteenth extension portion E13. In addition, because a space between the tenth extension portion E10 and the thirteenth extension portion E13 is empty, it is possible to secure a space or the like for fixing a screw of the substrate main body 2 in the empty space.

[0121] In addition, because the eighth extension portion E8 has the first rear-surface pattern portion R1 connected to the front surface side via the through-hole H and patterned on a rear surface of the substrate main body 2, and the first rear-surface pattern portion R1 is widely formed toward the ground plane GND, it is possible to cause stray capacitance with the fourth extension portion E4 to effectively occur without interfering with the fourth extension portion E4. In addition, because the first rear-surface pattern portion R1 is widely formed toward the ground plane GND, impedance is also lower than with the fourth extension portion E4 and an influence of interference can also be reduced according to the stray capacitance Ch with the opening pattern portion S1 (the first extension portion E1 and the eighth extension portion E8).

[0122] In addition, because the thirteenth extension portion E13 has the second rear-surface pattern portion R2 connected to the front surface side via the through-hole H and patterned on the rear surface of the substrate main body 2, and the second rear-surface pattern portion R2 is widely formed toward the ground plane GND, it is possible to cause stray capacitance with the eighth extension portion E8 or stray capacitance with the ground plane GND by the pattern arrangement with the tenth extension portion E10 to effectively occur. Therefore, it is possible to further achieve both high performance and size reduction of an antenna without widening an antenna occupancy area by adopting the first rear-surface pattern portion R1 or the second rear-surface pattern portion R2.

[0123] In addition, because passive elements (the fifth passive element P5 and the sixth passive element P6) for impedance adjustment are connected to the first ground connector G1 and the second ground connector G2 respectively, it is possible to perform impedance adjustment of each frequency band through a setting of the opening pattern portion S1 and settings of two passive elements for impedance adjustment.

[0124] Accordingly, because the first passive element P1, the second passive element P2, the third passive element P3, and the fourth passive element P4 are connected to the first connector C1, the second connector C2, the third connector C3, and the fourth connector C4 corresponding thereto in the antenna device 10 of this embodiment, it is possible to achieve double to quadruple resonances by merely appropriately selecting the first to fourth passive elements P1 to P4 and communication at two to four resonance frequencies corresponding to each use or device.

[Examples]

[0125] Next, for an example produced based on an antenna-device substrate and an antenna device of this embodiment, a result of measuring a VSWR characteristic (voltage standing wave ratio) and a radiation pattern in quadruple resonance at each resonance frequency will be described with reference to Figs. 7 and 8.

[0126] Also, as the passive elements, two first passive elements P1: an inductor of 3.3 nH and an inductor of 10 nH (an inductor of 13 nH in total), a second passive element P2: 8.2 nH, a third passive element P3: an inductor of 4.7 nH and an inductor of 5.6 nH (an inductor of 10 nH in total), and two fourth passive elements P4: an inductor of 5.6 nH and an inductor of 12 nH (an inductor of 18 nH in total) were used. In addition, a condenser of 0.5 pF was used as the fifth passive element P5 and an inductor of 8.2 nH was used as the sixth passive element P6.

[0127] As a result, a good VSWR characteristic was obtained as illustrated in Fig. 7 at resonance frequencies from the first resonance frequency f1 to the fourth resonance frequency f4 in the example of the present invention.

[0128] In addition, for measurement of a radiation pattern, a direction toward the ground plane GND in which the second extension portion E2 extended was designated as an X direction, a direction opposite to the extension direction of the third extension portion E3 was designated as a Y direction, and a direction perpendicular to the front surface of the substrate main body 2 was designated as a Z direction. At this time, vertical polarization, horizontal polarization, and power gain for the ZX plane were measured.

[0129]

(a) of Fig. 8 illustrates a radiation pattern (ZX plane) at a first resonance frequency f1 of a 920 MHz band and an average power gain is -5.1 dBi.
(b) of Fig. 8 illustrates a radiation pattern (ZX plane) at a second resonance frequency f2 of a 1400 MHz band and an average power gain is -1.9 dBi.
(c) of Fig. 8 illustrates a radiation pattern (ZX plane) at a fourth resonance frequency f4 of a 1920 MHz band and an average power gain is -0.8 dBi.

[0130] Also, the present invention is not limited to the above-described embodiments and examples, but various changes may be made without departing from the subject matter of the present invention.

[0131] For example, in the above-described embodiment, an antenna element is provided in the first element, but the antenna element may also be provided in another element. In this case, it is possible to shorten the length of the element according to the antenna element and the present invention is preferable when an antenna occupancy area is narrowed or the like. For example, the antenna element may be connected to the fifth extension portion, the eighth extension portion, the thirteenth extension portion, and the tenth extension portion.

[0132] In addition, it is possible to flexibly change and replace a frequency band to be used for an antenna element (an element other than the first element) outside a lowest frequency band using the antenna element.

[0133] Further, a maximum of quadruple resonance is implemented in the present invention, but it is possible to cope with double or triple resonance according to presence and absence of each passive element for frequency bands other than a lowest frequency band using the antenna element.

[0134] That is, it is possible to arbitrarily perform double or triple resonance by connecting any one or two of the second passive element, the third passive element, and the fourth passive element to the second connector, the third connector, and the fourth connector corresponding thereto.

[Reference Signs List]

[0135]

1 Antenna-device substrate
2 Substrate main body
10 Antenna device
AT Antenna element
C1 First connector
C2 Second connector
C3 Third connector
C4 Fourth connector
E1 First extension portion
E2 Second extension portion
E3 Third extension portion
E4 Fourth extension portion
E5 Fifth extension portion
E6 Sixth extension portion
E7 Seventh extension portion
E8 Eighth extension portion
E9 Ninth extension portion
E10 Tenth extension portion
E11 Eleventh extension portion
E12 Twelfth extension portion
E13 Thirteenth extension portion
EL1 First element
EL2 Second element
EL3 Third element

EL4 Fourth element
G1 First ground connector
G2 Second ground connector
GND Ground plane
H Through-hole
L1 Connection pattern
P1 First passive element
P2 Second passive element
P3 Third passive element
P4 Fourth passive element
P5 Fifth passive element (passive element for impedance adjustment)
P6 Sixth passive element (passive element for impedance adjustment)
FP Power feeding point
R1 First rear-surface pattern portion
R2 Second rear-surface pattern portion
S1 Opening pattern portion

Claims

1. An antenna-device substrate comprising:

an insulating substrate main body; and
first to fourth elements patterned by use of metal foils on the substrate main body and a ground plane,
wherein the first element extends to have a base end on which a power feeding point is provided in the vicinity of the ground plane and have a first connector to which a first passive element is contactable and an antenna element of a dielectric antenna in this order,
wherein the second element extends to have a base end connected between the power feeding point of the first element and the first connector and have a second connector to which a second passive element is connectable in the middle,
wherein the third element extends to have a base end to which the power feeding point is connected and have a third connector to which a third passive element is connectable in the middle,
wherein the fourth element extends to have a base end connected between the power feeding point of the third element and the third connector and have a fourth connector to which a fourth passive element is connectable in the middle, and
wherein the first to fourth elements extend with gaps from adjacent elements and the ground plane so that stray capacitance between the adjacent elements and stray capacitance with the ground plane are able to occur.

2. The antenna-device substrate according to claim 1, comprising:

a first ground connector having a base end connected to the ground plane and a distal end connected to a base end side of the first element closer than a connection portion of the first element with the second element;
a second ground connector having a base end separated from a position at which the first ground connector is connected and connected to the ground plane and a distal end connected to a base end side of the third element closer than a connection portion of the third element with the fourth element; and
a connection pattern extending by connecting a distal end side of the first element further than a connection portion of the first element with the first ground connector and a distal end side of the third element further than a connection portion of the third element with the second ground connector,
wherein an annular opening pattern portion among the connection pattern, the first element, and the third element is formed in the vicinity of the power feeding point.

3. The antenna-device substrate according to claim 1, wherein the first element has a first extension portion extending from the power feeding point in one direction along the ground plane, a second extension portion extending from a distal end of the first extension portion away from the ground plane, and a third extension portion extending from a distal end of the second extension portion in a direction along the ground plane via the first connector and to which the antenna element extending in the same direction is connected,
wherein the second element has a fourth extension portion extending from the distal end of the second extension portion in the same direction as the second extension portion via the second connector and a fifth extension portion extending from a distal end of the fourth extension portion to a side of the antenna element in a direction along the third extension portion,
wherein the third element has a sixth extension portion extending from the power feeding point in another direction along the ground plane, a seventh extension portion extending from a distal end of the sixth extension portion away from the ground plane via the third connector, and an eighth extension portion extending from a distal end of the seventh extension portion to the fourth extension portion in a direction along the ground plane, and
wherein the fourth element has a ninth extension portion having a distal end connected to the middle of the seventh extension portion and extending with a gap from the seventh extension portion in the same direction and a tenth extension portion extending from a distal end of the ninth extension portion away

from the seventh extension portion.

4. The antenna-device substrate according to claim 3, wherein a base end side closer than a portion opposite to the antenna element of the fifth extension portion serves as a wide portion formed to be wider than a distal end side.

5. The antenna-device substrate according to claim 3, wherein the first element has an eleventh extension portion extending from a distal end of the third extension portion to the ground plane and a twelfth extension portion extending from a distal end of the eleventh extension portion to the first extension portion along the ground plane.

6. The antenna-device substrate according to claim 3, wherein a thirteenth extension portion extending away from the ground plane is connected to a base end side of the tenth extension portion.

7. The antenna-device substrate according to claim 3, wherein the eighth extension portion has a first rear-surface pattern portion connected to a front surface side via a through-hole and patterned on a rear surface of the substrate main body and
wherein the first rear-surface pattern portion is widely formed toward the ground plane.

8. The antenna-device substrate according to claim 6, wherein the thirteenth extension portion has a second rear-surface pattern portion connected to a front surface side via a through-hole and patterned on a rear surface of the substrate main body and
wherein the second rear-surface pattern portion is widely formed toward the ground plane.

9. The antenna-device substrate according to claim 2, wherein a passive element for impedance adjustment is connected to each of the first ground connector and the second ground connector.

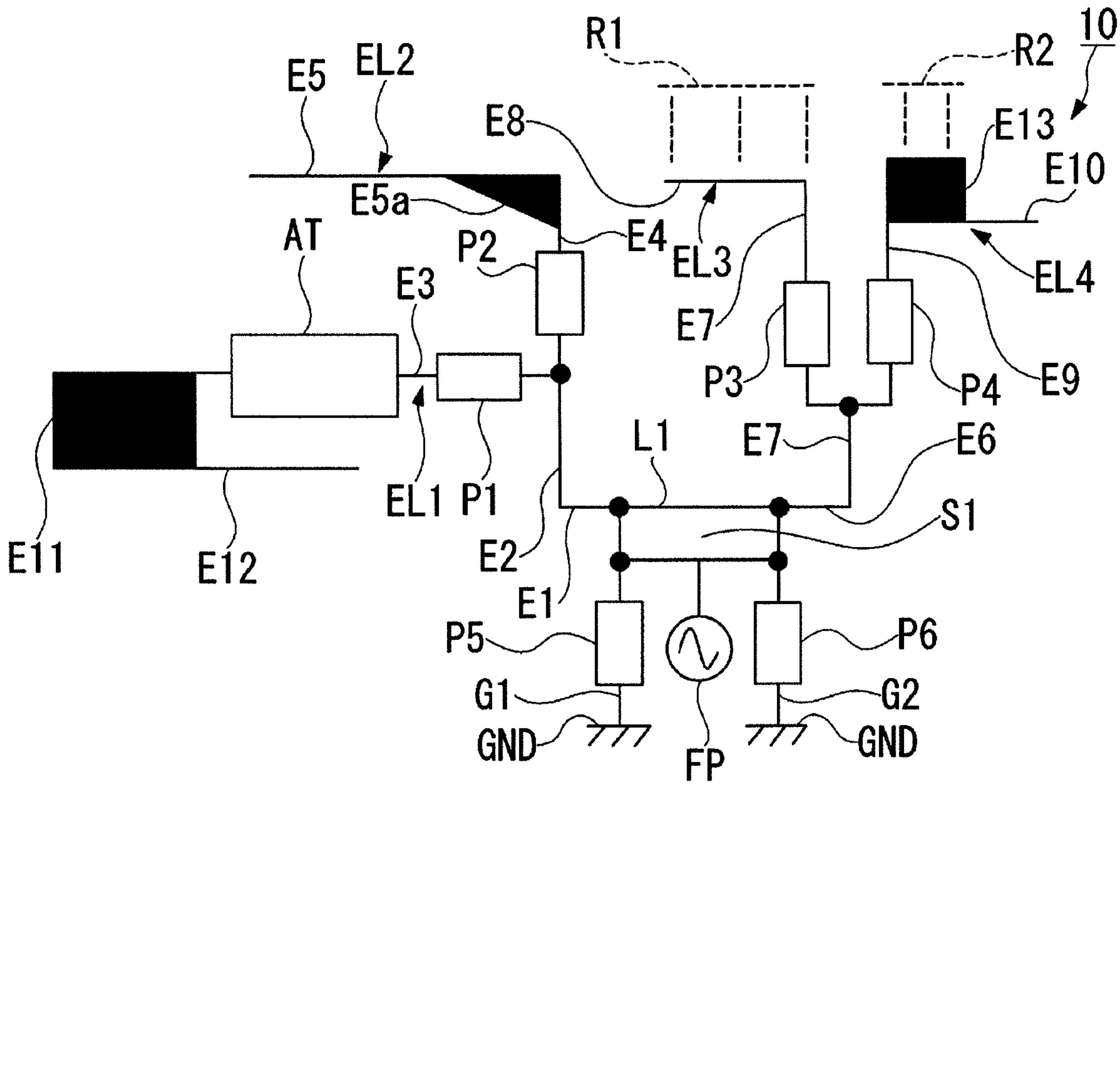
10. An antenna device comprising:

    the antenna-device substrate according to claim 1,
    wherein the first passive element, the second passive element, the third passive element, and the fourth passive element are connected to the first, second, third, and fourth connectors corresponding thereto.

11. An antenna device comprising:

    the antenna-device substrate according to claim 1,
    wherein the first passive element is connected to the first connector and
    wherein any one or two of the second passive element, the third passive element, and the fourth passive element are connected to the second, third, and fourth connectors corresponding thereto.

[Fig. 1]


R1
R2
10
E5
EL2
E8
E13
E10
E5a
E4
EL3
EL4
AT
P2
E3
E7
P3
P4
E9
L1
E7
E6
S1
E11
E12
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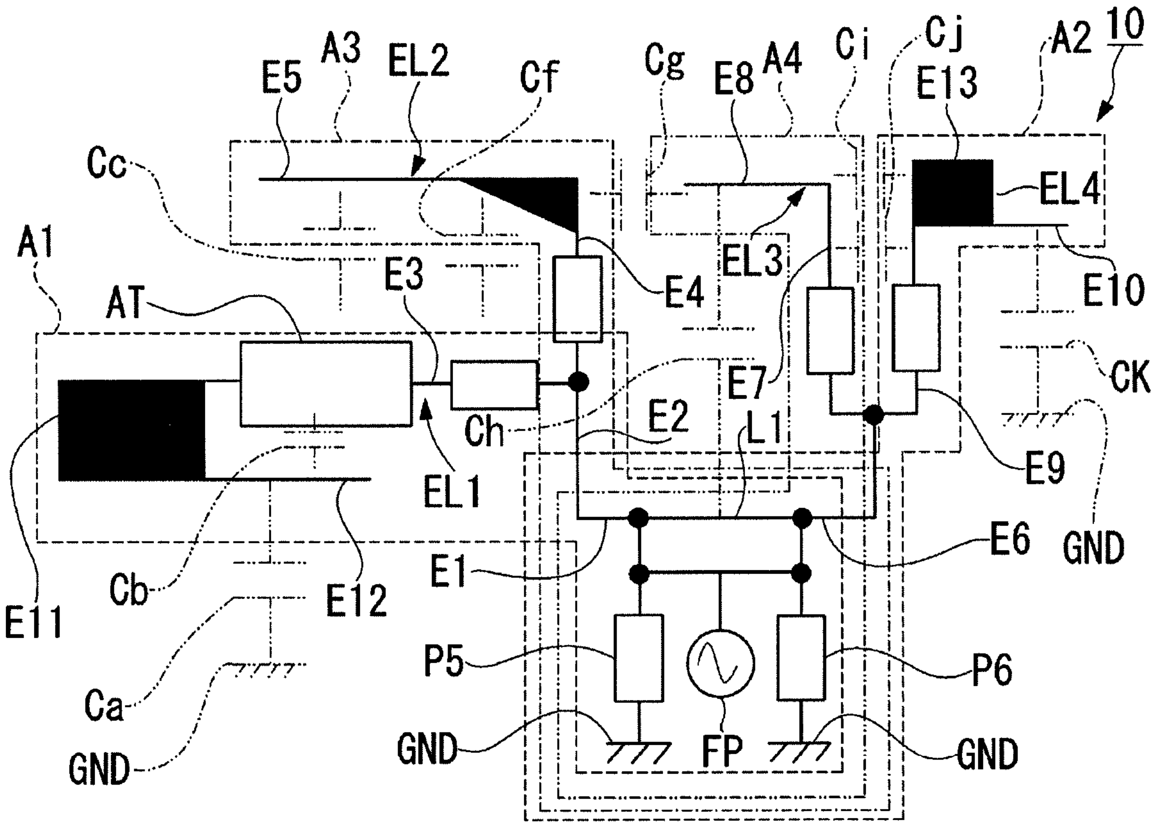
P1
E2
E1
P5
P6
G1
G2
GND
GND
FP

[Fig. 2]


E5
A3
EL2
Cf
Cg
E8
A4
Ci
Cj
A2
10
E13
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A1
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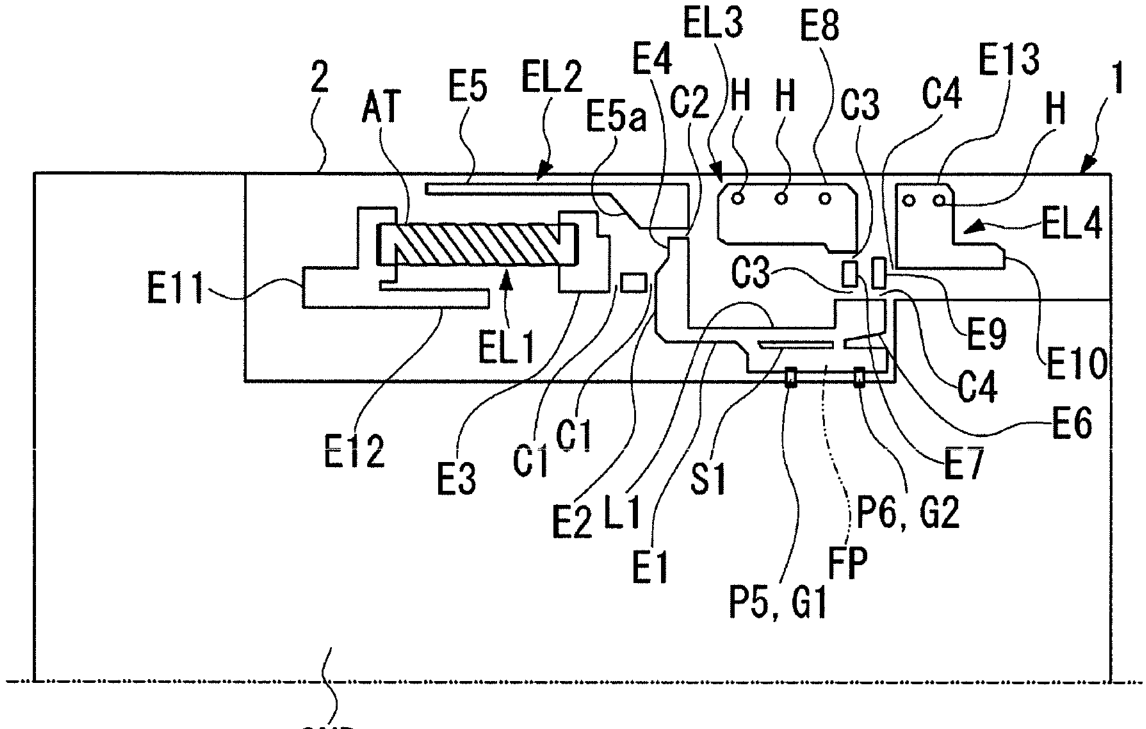
E4
EL3
E10
E7
CK
Ch
E2
L1
EL1
E9
E1
E6
GND
E11
Cb
E12
P5
P6
Ca
FP
GND

[Fig. 3]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EL2
E4
EL3
E8
E5a
C2
H
H
C3
C4
E13
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E11
C3
E9
E10
EL1
C4
E6
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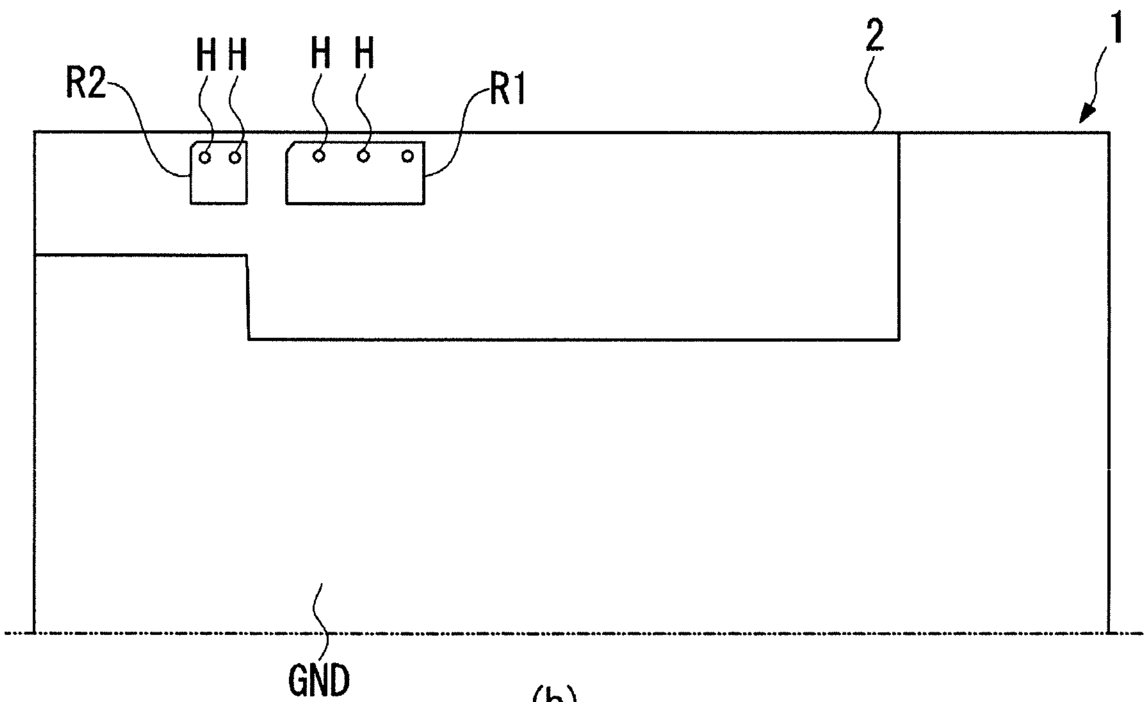
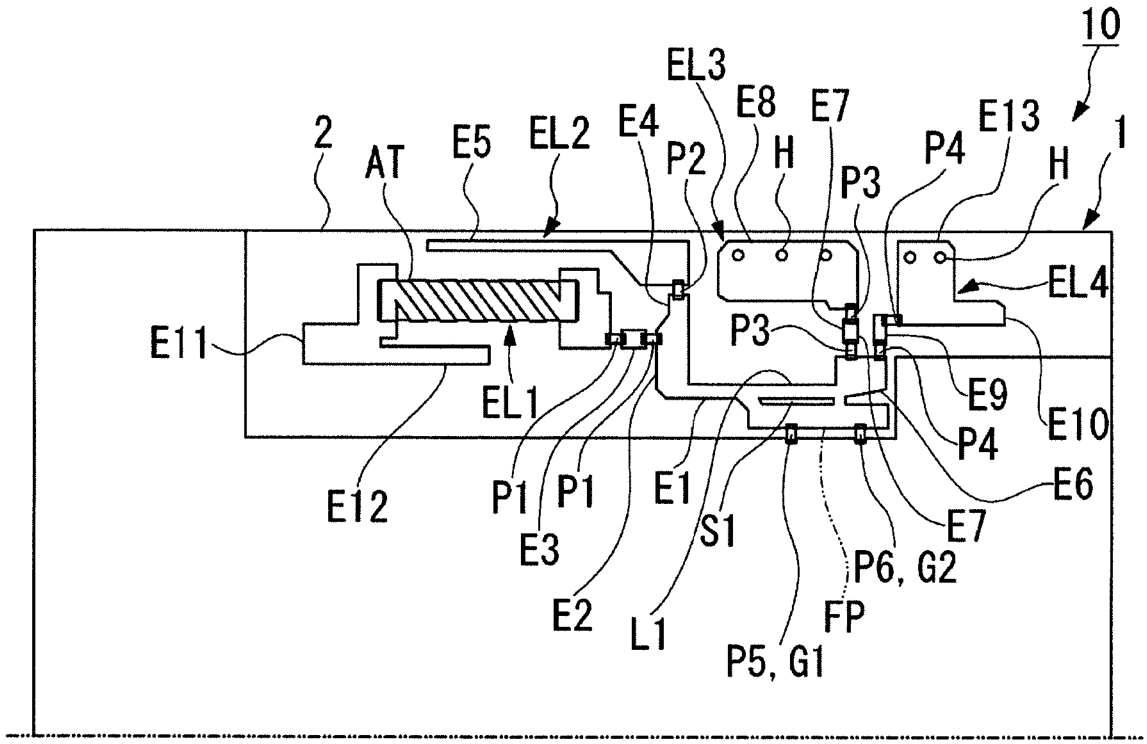
P5, G1
GND

(a)


R2
H H
H H
R1
2
1
GND

(b)

[Fig. 4]


10
2
AT
E5
EL2
E4
P2
EL3
E8
H
E7
P3
P4
E13
H
1
EL4
E11
P3
E9
E10
P4
E6
E7
P6, G2
FP
P5, G1
L1
S1
E1
E2
E3
P1
P1
EL1
E12

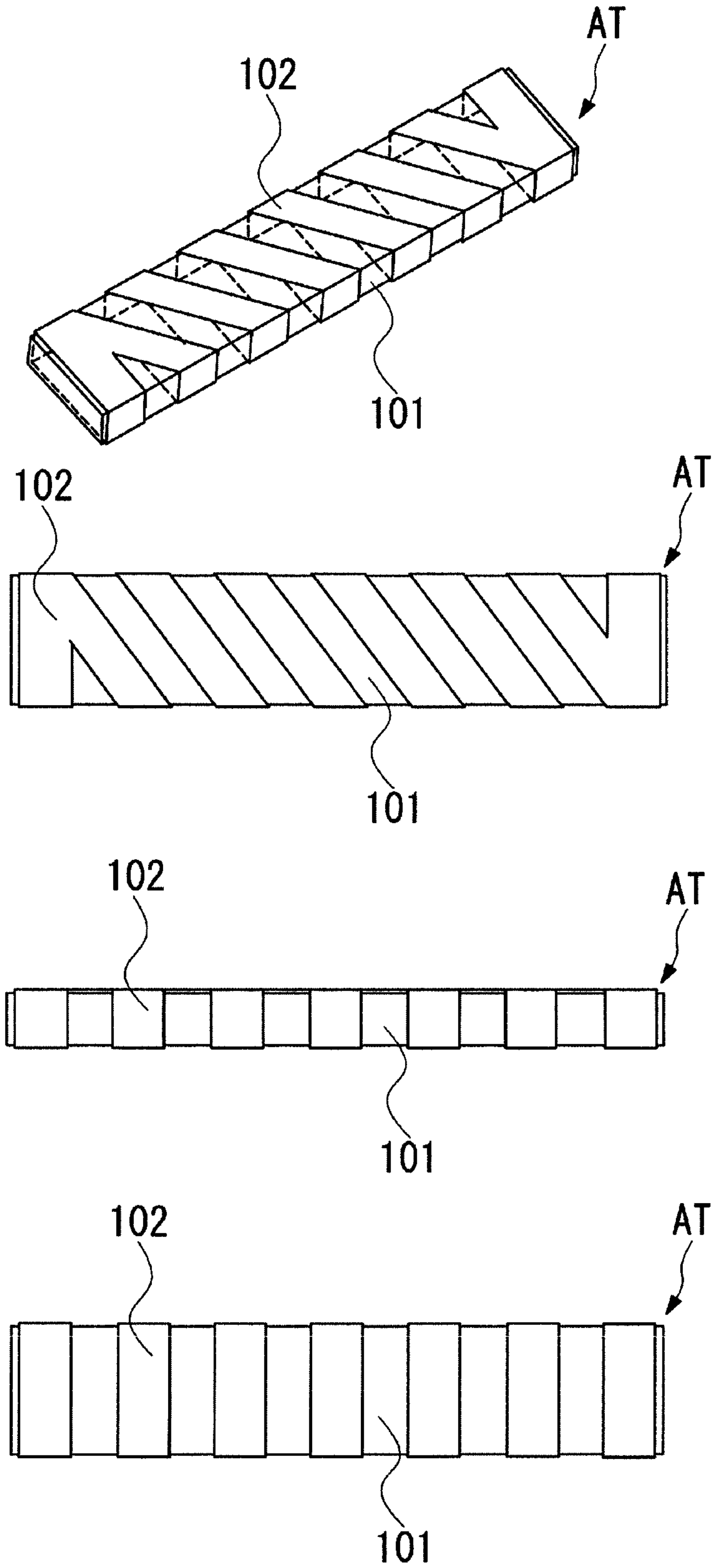
[Fig. 5]

(a)

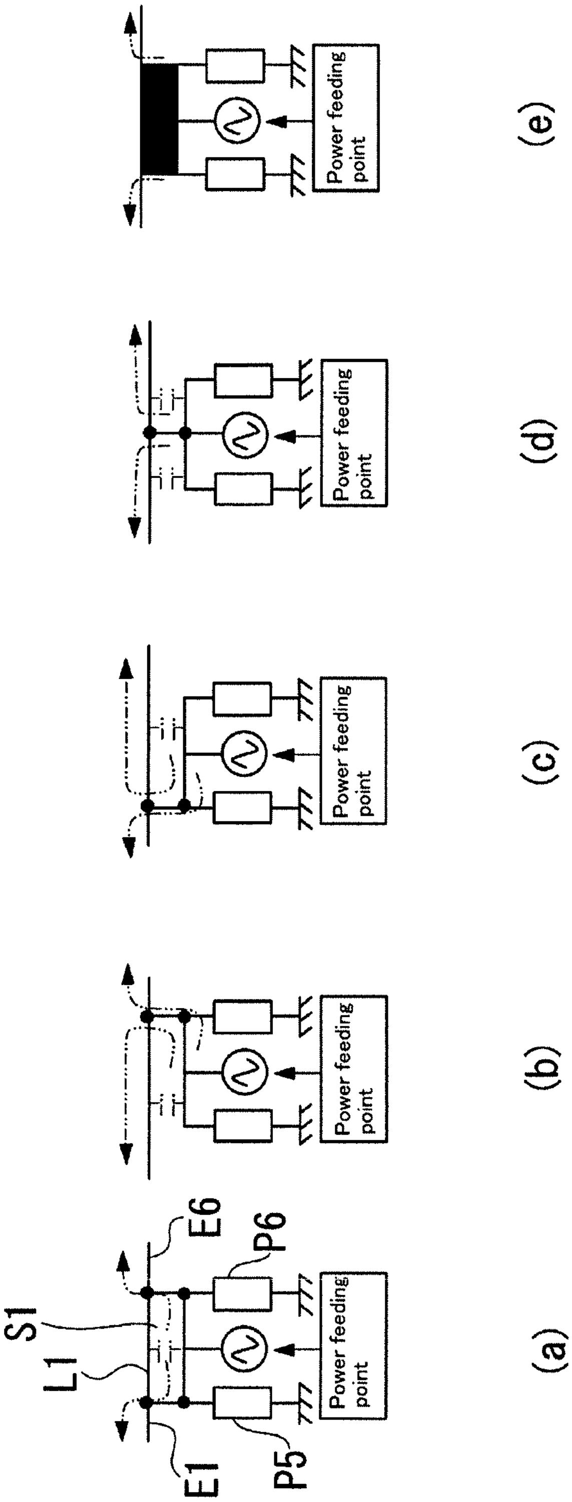
(b)

(c)

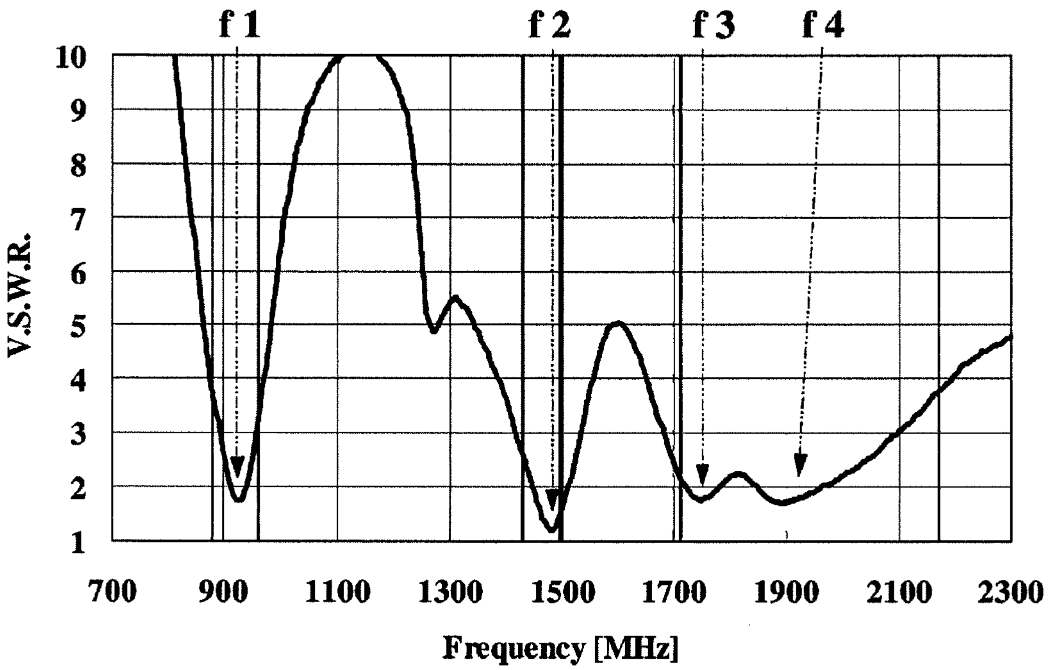
(d)



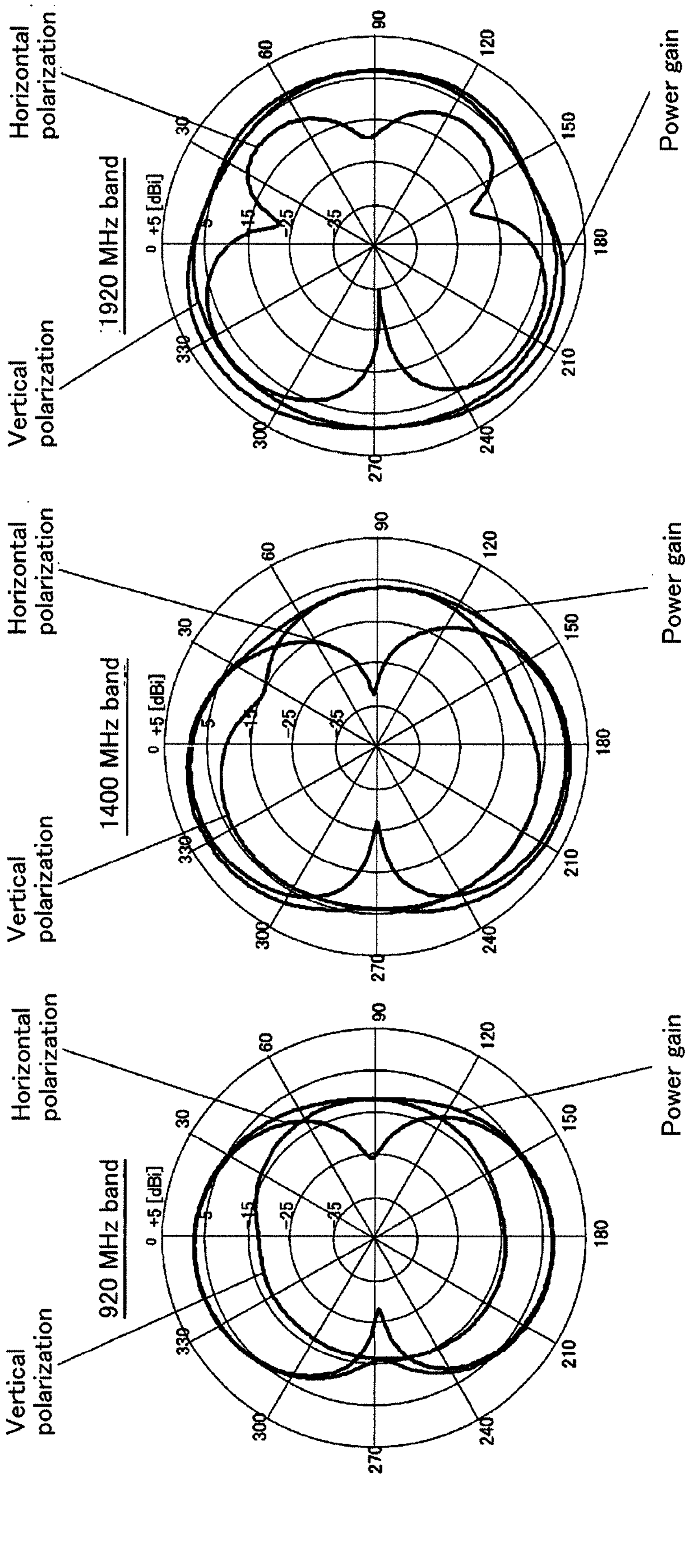
[Fig. 6]


S1
L1
E1
E6
P5
P6
Power feeding point
Power feeding point
Power feeding point
Power feeding point
Power feeding point
(a)
(b)
(c)
(d)
(e)

[Fig. 7]


f 1
f 2
f 3
f 4
10
9
8
7
6
5
4
3
2
1
V.S.W.R.
700
900
1100
1300
1500
1700
1900
2100
2300
Frequency [MHz]

[Fig. 8]


920 MHz band
1400 MHz band
1920 MHz band
Horizontal polarization
Vertical polarization
Power gain
+5 [dBi]
0
5
-15
-25
-35
90
60
30
120
150
180
210
240
270
300
330
(a)
(b)
(c)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/003195

A. CLASSIFICATION OF SUBJECT MATTER
H01Q5/01(2006.01)i, *H01Q1/38*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q5/01, H01Q1/38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2012-142775 A (Mitsubishi Materials Corp.), 26 July 2012 (26.07.2012), entire text; all drawings & WO 2012/090415 A1	1,10,11 2-9
Y	JP 2010-103841 A (Murata Mfg. Co., Ltd.), 06 May 2010 (06.05.2010), paragraph [0036]; fig. 8 (Family: none)	1,10,11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search
24 July, 2013 (24.07.13)

Date of mailing of the international search report
06 August, 2013 (06.08.13)

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