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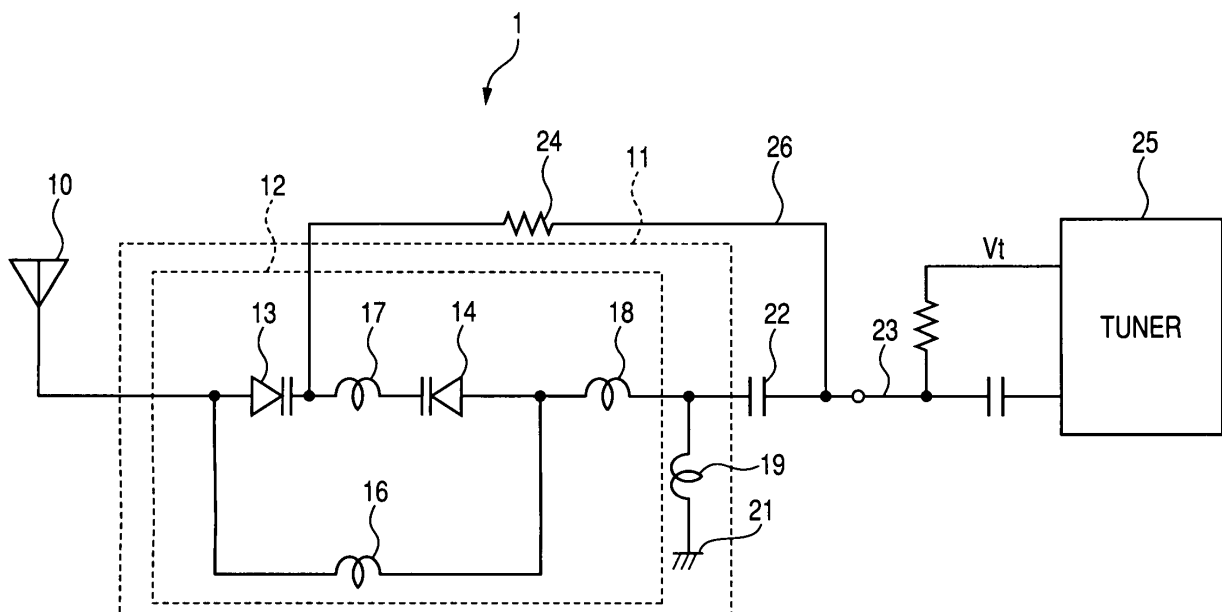
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(54) **Antenna apparatus**

(57) Provided is an antenna apparatus (1) that supplies a power feeding signal to an antenna element (10) via a matching circuit (11). The matching circuit (11) includes a parallel circuit (12) having variable capacitance elements (13, 14), a first inductance element (16) connected in parallel to the variable capacitance elements (13, 14), and a second inductance element (17) connect-

ed in series to the variable capacitance elements (13, 14) and connected in parallel to the first inductance element (16). A resonance point of the parallel circuit (12) is set smaller than a tuning frequency (T) of the antenna element (10). The tuning frequency (T) of the antenna element (10) is varied with variation of capacitance of the variable capacitance elements (13, 14).

FIG. 3



Description

Cross Reference to Related Applications

[0001] The present application contains subject matter related to Japanese Patent Application No. 2008-137717 filed in the Japanese Patent Office on May 27, 2008, the entire contents of which being incorporated herein by reference.

BACKGROUND

1. Technical Field

[0002] The present invention relates to an antenna apparatus that supplies a power feeding signal to an antenna element via a matching circuit, and more particularly to an antenna apparatus that varies a tuning frequency by use of a variable capacitance element.

2. Related Art

[0003] Generally, antenna apparatuses for television receivers built in mobile instruments such as a cellular phone have been known, which includes a matching circuit having a resonant circuit interconnecting a variable capacitance element and an inductance element in parallel; and an antenna element connecting the matching circuit in series (for example, refer to Japanese Unexamined Patent Application Publication No. 2004-320611). The antenna apparatus is configured to increase a tuning band by interconnecting the variable capacitance element and the inductance element in parallel and vary a tuning frequency by varying a tuning voltage applied to the variable capacitance element.

[0004] However, in the known antenna apparatuses, the resonant circuit is configured such that the inductance element is connected in parallel to the variable capacitance element. Hence, when a desired tuning frequency is set, a resistance component in the resonant circuit increases at a band lower than the tuning frequency. This causes a problem that increases passage loss.

SUMMARY

[0005] It is desirable to provide an antenna apparatus capable of reducing passage loss at a low band and increasing a tuning band by interconnecting a variable capacitance element and an inductance element in parallel.

[0006] According to an aspect of the invention, an antenna apparatus supplies a power feeding signal to an antenna element via a matching circuit. The matching circuit includes a parallel circuit having variable capacitance elements, a first inductance element connected in parallel to the variable capacitance elements, and a second inductance element connected in series to the variable capacitance elements and connected in parallel to the first inductance element. A resonance point of the

parallel circuit is set smaller than a tuning frequency of the antenna element. The tuning frequency of the antenna element is varied with variation of capacitance of the variable capacitance elements.

[0007] With such a configuration, since the second inductance element is connected in series to the variable capacitance elements and in parallel to the first inductance element, a resistance component in the parallel circuit at the lower band than the tuning frequency is reduced when the tuning frequency is set desirably as compared with the known resonant circuit in which the variable capacitance element and the first inductance element are connected in parallel. Thus, it is possible to reduce passage loss at the low band of the tuning frequency, as compared with the known resonant circuit, as the resistance component in the parallel circuit is reduced.

[0008] In the antenna apparatus according to the aspect of the invention, it is preferred that the parallel circuit include a third inductance element connected in series thereto.

[0009] With such a configuration, it is possible to more appropriately set a tuning frequency of the antenna element by connecting the third inductance element to the parallel circuit in series.

[0010] In the antenna apparatus according to the aspect of the invention, it is preferred that the antenna element include a film substrate and a radiation conductor formed in a film shape on a surface of the film substrate.

[0011] With such a configuration, it is possible to reduce passage loss at the low band of the tuning frequency when the tuning frequency is set desirably in the antenna element having a film shape including the film substrate and the radiation conductor formed in a film shape.

[0012] In the antenna apparatus according to the aspect of the invention, it is preferred that a signal received by the antenna element be a digital terrestrial television broadcast signal.

[0013] With such a configuration, it is possible to reduce passage loss of a digital terrestrial television broadcast signal at the low band of the tuning frequency when the tuning frequency is set desirably.

[0014] According to the aspect of the invention, it is possible to provide an antenna apparatus capable of reducing passage loss at a low band and increasing a tuning band by interconnecting the variable capacitance element and the inductance element in parallel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a perspective diagram illustrating a mounted condition of an antenna apparatus according to an embodiment of the present invention.

Fig. 2 is a perspective diagram of the antenna apparatus according to the embodiment of the inven-

tion.

Fig. 3 is an equivalent circuit diagram of the antenna apparatus according to the embodiment of the invention.

Fig. 4 is a diagram illustrating frequency characteristics of the antenna apparatus according to the embodiment of the invention, when an impedance of the resonant circuit at the time of setting the tuning frequency to 470 MHz is regarded as a resistance component.

Fig. 5 is a diagram illustrating frequency characteristics of the antenna apparatus according to the embodiment of the invention, when an impedance of the resonant circuit at the time of setting the tuning frequency to 610 MHz is regarded as a resistance component.

Fig. 6 is a diagram illustrating frequency characteristics of the antenna apparatus according to the embodiment of the invention, when an impedance of the resonant circuit at the time of setting the tuning frequency to 770 MHz is regarded as a resistance component.

Fig. 7 is a diagram illustrating frequency characteristics of the antenna apparatus according to the embodiment of the invention, when an impedance of the resonant circuit at the time of setting the tuning frequency to 470 MHz is regarded as a reactance component.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0016] Hereinafter, an embodiment of the present invention will be described in detail with reference to the accompanying drawings. Fig. 1 is a perspective diagram illustrating a mounted condition of an antenna apparatus according to an embodiment of the invention. Fig. 2 is a perspective diagram of the antenna apparatus according to the embodiment of the invention.

[0017] As shown in Fig. 1, the antenna apparatus 1 is a chip antenna used as a receiver antenna for digital terrestrial television broadcast. The antenna apparatus 1 is mounted on the corner of a circuit board 2 built in a mobile phone. A signal of the digital terrestrial television broadcast has, for example, a frequency band from 470 MHz to 770 MHz in Japan. The antenna apparatus 1 performs a tuning in the frequency band.

[0018] As shown in Fig. 2, the antenna apparatus 1 mainly includes: a base substance 5 formed of a dielectric substance in a prismatic shape; a radiation conductor 6 formed by winding a conductor pattern having a spiral shape around a circumferential surface of the base substance 5; and an electronic component group 7 arranged on the upper surface of the base substance 5.

Furthermore, the antenna element 10 of the antenna apparatus 1 includes the base substance 5 and the radiation conductor 6. One end of the radiation conductor 6 wound in a spiral shape is formed as a power supply section A. The other end thereof is formed as an open end B. The electronic component group 7 includes a plurality of variable capacitance elements, a plurality of inductance elements, a resistance element, a capacitor, and the like. The plurality of variable capacitance element is a so-called varactor diode, and capacitance thereof is configured to be varied by applying an inverse voltage.

[0019] Next, a circuit configuration of the antenna apparatus will be described with reference to Fig. 3. Fig. 3 is an equivalent circuit diagram of the antenna apparatus according to the embodiment of the invention.

[0020] As shown in Fig. 3, the antenna apparatus 1 includes an antenna element 10 for receiving a broadcast signal, and a matching circuit 11 for matching impedances of the antenna element 10 and a television tuner circuit 25 to be described later. The matching circuit 11 includes a resonant circuit 12 for tuning to a desirable frequency and varying a tuning frequency T by varying a resonance point.

[0021] The resonant circuit 12 includes a first variable capacitance element 13, a second variable capacitance element 14, a first inductance element 16, a second inductance element 17, and a third inductance element 18. A power feeding point of the antenna element 10 is connected to an anode of the first variable capacitance element 13. One end of the second inductance element 17 is connected to a cathode of the first variable capacitance element 13. A cathode of the second variable capacitance element 14 is connected to the other end of the second inductance element 17. One end of the third inductance element 18 is connected to an anode of the second variable capacitance element 14.

[0022] The first inductance element 16 is connected in parallel to the first variable capacitance element 13, the second inductance element 17, and the second variable capacitance element 14 between the anodes of the first variable capacitance element 13 and the second variable capacitance element 14.

[0023] The matching circuit 11 includes the resonant circuit 12 and a fourth inductance element 19. The fourth inductance element 19 is installed between a ground 21 and the other end of the third inductance element 18.

[0024] The antenna apparatus 1 is connected to a television tuner circuit 25 via a transmission line 23 for a highfrequency signal (RF signal). A tuning line 26 is connected to the transmission line 23. One end of the tuning line 26 is connected between the cathode of the first variable capacitance element 13 and one end of the second inductance element 17. The other end thereof is connected to the transmission line 23 via a bias resistance 24. A DC-cut capacitor 22 is installed between the matching circuit 11 and the transmission line 23. The first variable capacitance element 13 and second variable capacitance element 14 are configured to vary the tuning fre-

quency T of the antenna element 10 by applying a DC tuning voltage V_t which is turned into an inverse voltage via the bias resistance 24.

[0025] The circuit board 2 has a not-shown bias circuit formed thereon. The circuit board 2 is configured to generate the tuning voltage V_t by inputting a power supply voltage or a PWM (pulse width modulation) signal as a bias control signal to the bias circuit. When the tuning voltage V_t is set to a large value, capacitance values of the first variable capacitance element 13 and second variable capacitance element 14 decreases, thereby increasing the tuning frequency T of the antenna element 10. When the tuning voltage V_t is set to a small value, capacitance values of the first variable capacitance element 13 and second variable capacitance element 14 increases, thereby decreasing the tuning frequency T of the antenna element 10.

[0026] Next, a result of impedance simulation when the resonant circuit 12 shown in Fig. 3 is used as a circuit model will be described. Figs. 4 to 6 show simulation results when the tuning frequency T is set to 470 MHz, 610 MHz, and 770 MHz. The dotted line W1 shows a simulation result based on a circuit model (comparative example) in which the inductance element 17 is excluded from the resonant circuit 12 shown in Fig. 3. The solid line W2 is a simulation result when the resonant circuit 12 shown in Fig. 3 is used as a circuit model (according to the invention). The simulation results show frequency characteristics when the impedance of the resonant circuit 12 is regarded as a resistance component.

Passage loss will be described with reference to

[0027] Fig. 4. When the tuning frequency T of the antenna apparatus 1 is set to 470 MHz as shown in Fig. 4, it can be seen from the comparison between the solid line W1 and the solid line W2 that a resistance P2 of the embodiment of the invention (W2) is lower than a resistance P1 of the comparative example (W1) at the tuning frequency T. In addition, a resonance point of the embodiment of the invention (W2) is lower than a resonance point of the comparative example (W1), and the resistances of those are varied to rapidly increase as the dotted line W1 and the solid line W2 approach to the resonance points.

Therefore, the resistance of the embodiment of the invention (W2) is greatly lower than the resistance of the comparative example (W1) at the low band of the tuning frequency T. According to the embodiment of the invention, the passage loss can be greatly reduced at the low band of the tuning frequency T when the tuning frequency T of the antenna apparatus 1 is set to 470 MHz.

[0028] When the tuning frequency T of the antenna element 10 is set to 610 MHz and 770 MHz, an effect of reduction in passage loss at the low band of the tuning frequency T becomes larger as shown in Figs. 5 and 6.

[0029] Fig. 7 shows frequency characteristics when an impedance of the resonant circuit 12 at the time of setting

the tuning frequency T to 470 MHz is regarded as a reactance component. As shown in Fig. 7, a reactance component of the embodiment of the invention (W2) is more deteriorated than a reactance component of the comparative example (W1), but the reactance component of the embodiment of the invention is in an allowable range.

[0030] As described above, the antenna apparatus 1 according to the embodiment includes the first inductance element 16 connected in series to the first variable capacitance element 13 and the second variable capacitance element 14 and connected in parallel to the second inductance element 17. Hence, a resistance component in the resonant circuit 12 at the lower band than the tuning frequency T is reduced when the tuning frequency T is set desirably as compared with the known resonant circuit. Thus, it is possible to reduce passage loss at the low band of the tuning frequency T, as compared with the known resonant circuit, as the resistance component in the resonant circuit 12 is reduced.

[0031] In the embodiment, the antenna element 10 is formed by winding the radiation conductor 6 in a spiral shape around the base substance 5 which has a prismatic shape. However, the antenna element may include the film substrate and the radiation conductor having a film shape formed on a surface of the film substrate.

[0032] Furthermore, The above described embodiment is set forth by way of example and is not for the purpose of limiting the present invention. Scope of the invention is expressed by not only the above-mentioned embodiment but also the appended claims, and the invention may be understood to include all possible modifications within the scope and equivalents of the appended claims.

[0033] As described above, the invention has an advantage that is able to increase the tuning band by interconnecting the variable capacitance element and the inductance element in parallel and to reduce the passage loss at the low band. Particularly, the invention is useful for the antenna apparatus capable of varying the tuning frequency by use of the variable capacitance element.

[0034] It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims of the equivalents thereof.

Claims

1. An antenna apparatus (1) that supplies a power feeding signal to an antenna element (10) via a matching circuit (11), wherein the matching circuit (11) includes a parallel circuit (12) having variable capacitance elements (13, 14), a first inductance element (16) connected in parallel to the variable capacitance elements (13,

14), and a second inductance element (17) connected in series to the variable capacitance elements (13, 14) and connected in parallel to the first inductance element (16),

wherein a resonance point of the parallel circuit (12) is set smaller than a tuning frequency (T) of the antenna element (10), and

wherein the tuning frequency (T) of the antenna element (10) is varied with variation of capacitance of the variable capacitance elements (13, 14).

2. The antenna apparatus (1) according to claim 1, wherein the parallel circuit (12) includes a third inductance element (18) connected in series thereto.

3. The antenna apparatus (1) according to claim 1 or 2, wherein the antenna element (10) includes a film substrate (5) and a radiation conductor (6) formed in a film shape on a surface of the film substrate (5).

4. The antenna apparatus (1) according to any one of claims 1 to 3, wherein a signal received by the antenna element (10) is a digital terrestrial television broadcast signal.

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FIG. 1

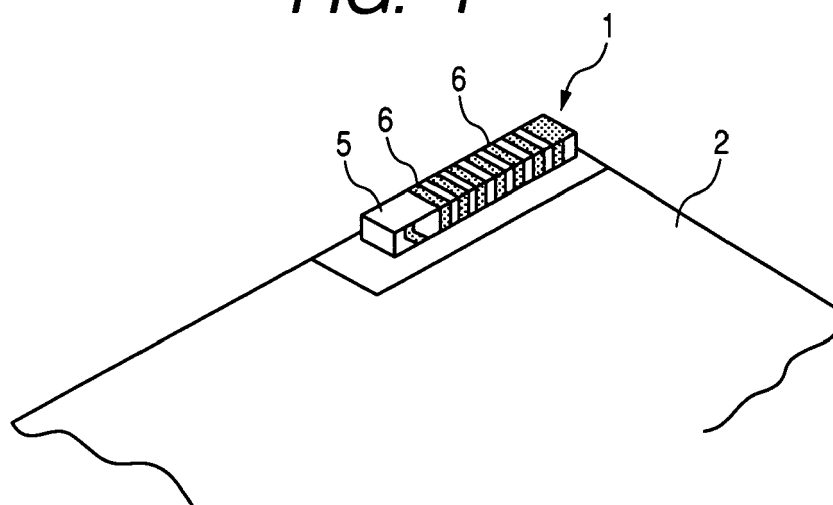


FIG. 2

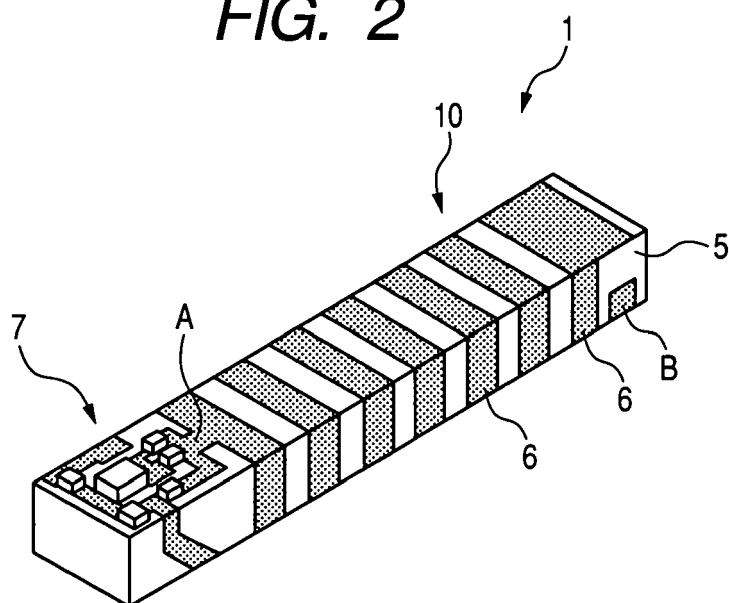


FIG. 4

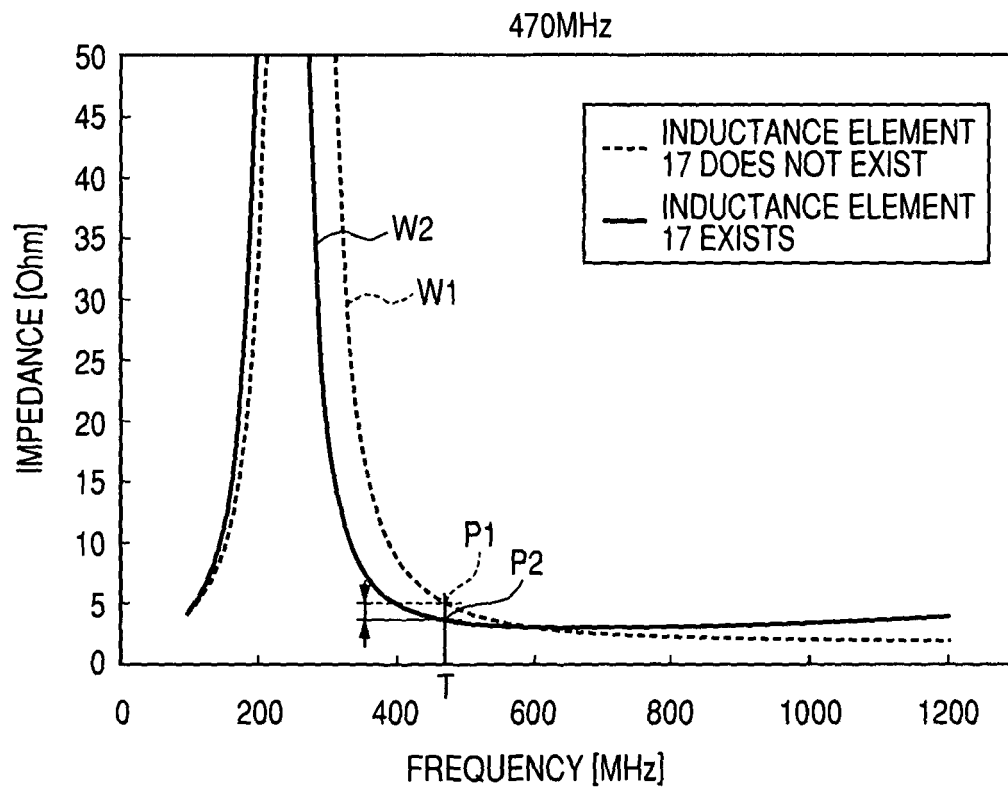


FIG. 5

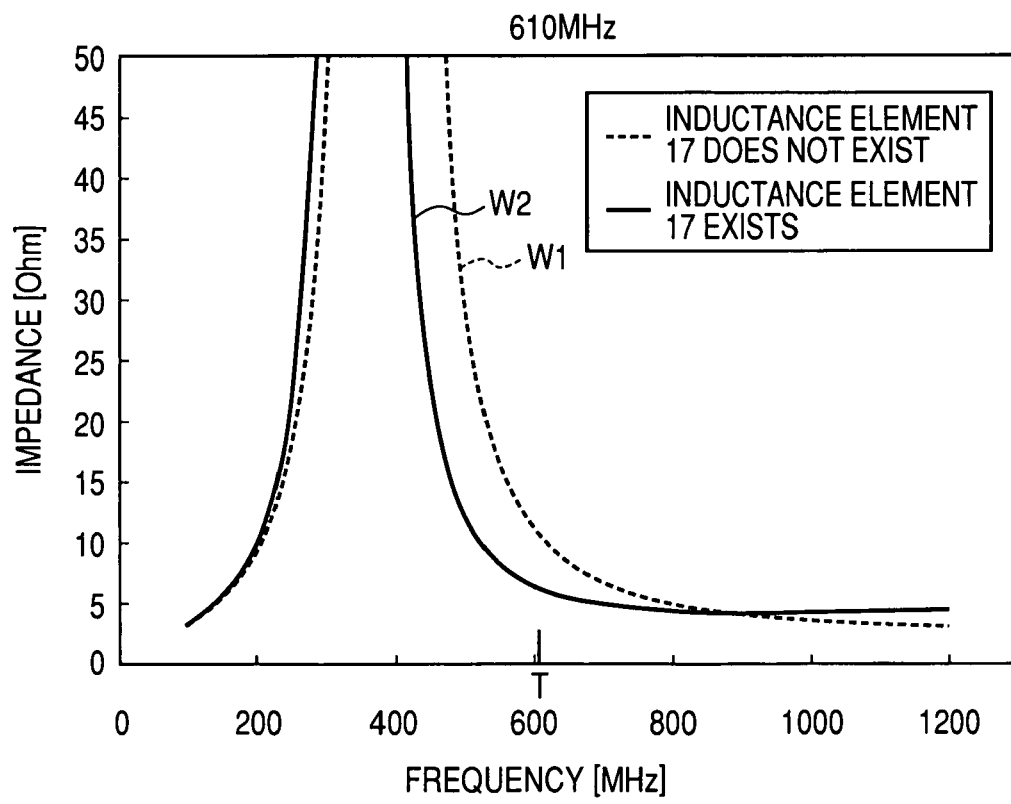


FIG. 6

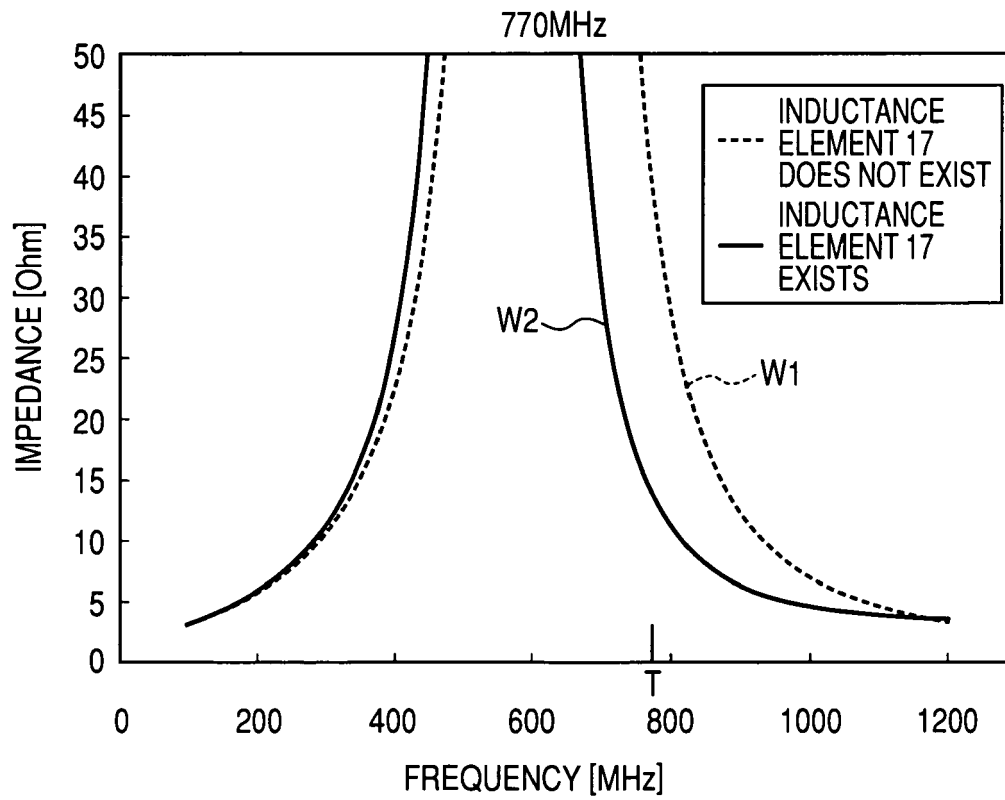
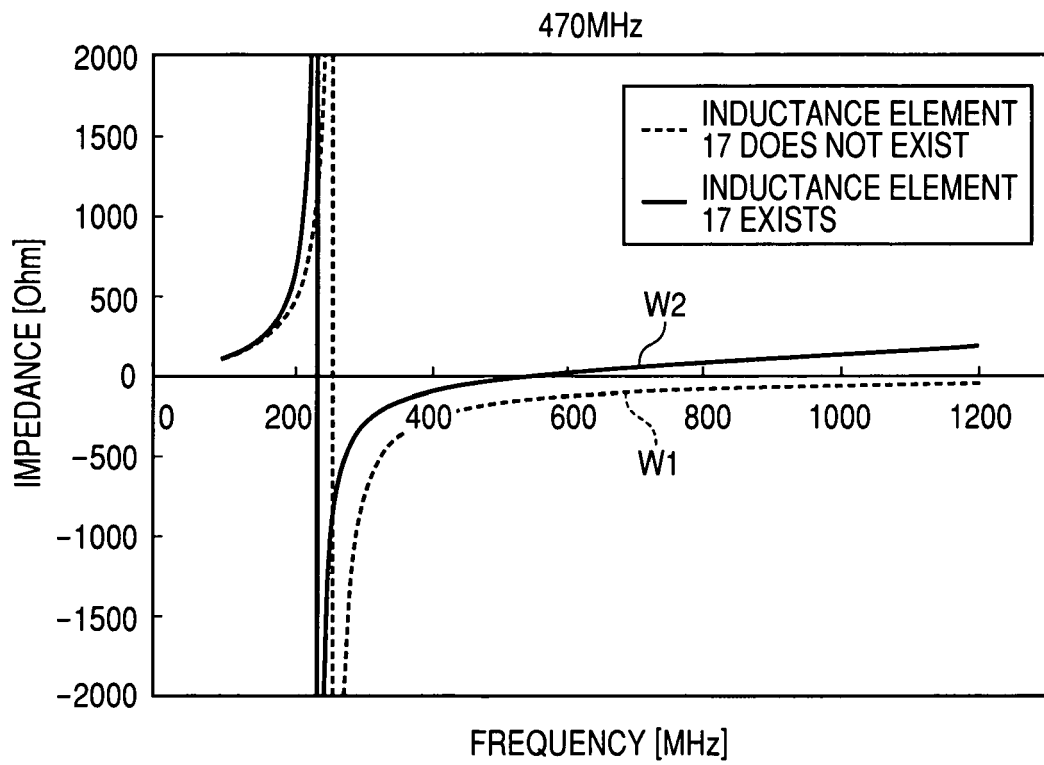


FIG. 7





EUROPEAN SEARCH REPORT

Application Number
EP 09 00 7011

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Place of search Munich		Date of completion of the search 26 August 2009	Examiner Köppe, Maro
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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