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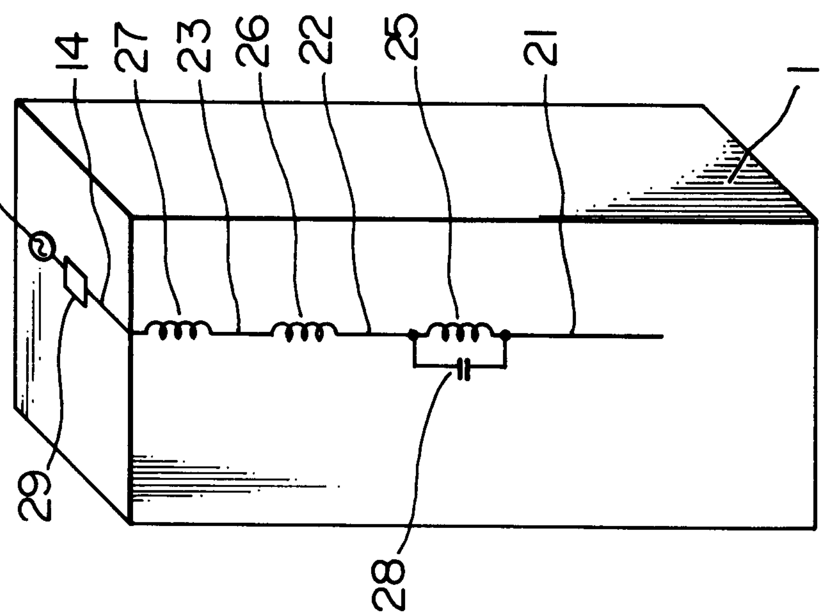
(54) **Antenna apparatus.**

(57) In an antenna apparatus, a plurality of divisions of antenna elements (21-24) are formed on a radio apparatus cabinet (41) or on a substrate packaged on the surface of the radio apparatus cabinet (1), the divisions are interconnected together by coils (25-27), and a capacitor (28) is connected in parallel with at least one of the coils. The antenna apparatus is compact and tunable to a plurality of frequencies and has a high antenna gain.

FIG. 5



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BACKGROUND OF THE INVENTION

The present invention relates to an antenna apparatus for use in radio apparatus.

To describe a conventional first type antenna apparatus, there has been available a built-in loop antenna 2 comprised in a radio apparatus cabinet 1 or an inverted-1 type antenna 4 fixedly mounted inside a radio apparatus cabinet 1 as shown in Figs. 1A and 1B. A feeding point 3 supplies electrical power.

Because of the incorporation in the cabinet, the conventional first type antenna has however a physical dimension which is much shorter than the wavelength and therefore has a small radiation resistance component to exhibit a single-tuned characteristic of very narrow band.

Accordingly, the conventional antenna can cope with a simplex-transmission radio apparatus such as a pocket bell or a wireless microphone; but a single built-in antenna cannot cope with a duplex-transmission radio apparatus such as a portable telephone or a cordless telephone in which different frequencies are used for transmission and reception. Accordingly, for use with the duplex-transmission radio apparatus, an antenna 5 for a transmission frequency (f_T) and an antenna 6 for a reception frequency (f_R) must be incorporated separately as shown in Fig. 2.

This explains that a plurality of antennas must be incorporated in the cabinet of a portable radio apparatus required to be reduced in size, giving rise to drastic inconvenience that the RF unit also needs input and output circuits dedicated to transmission and reception.

To describe a conventional second type antenna, there has in general been available a whip antenna having a length of about 1/4 wavelength as shown in Fig. 3 or a helical antenna 14 as shown in Fig. 4 meeting requirements of shortened antenna. Denoted by 12 is a feeding point and by 13 a radio apparatus cabinet.

In principle, however, the conventional second type antenna is a single-tuned type antenna which has only one resonance frequency. Especially, the 1/4 wavelength antenna has a necessarily long length for a particular frequency band in use to impair ease of use of the antenna; and the helical antenna contrived to eliminate the above disadvantage, on the other hand, can be reduced in antenna length but its band becomes narrower in proportion to a reduction in antenna length, having difficulties in covering the band of the duplex transmission type radio apparatus which utilizes different frequencies for transmission and reception. To cope with this problem, a helical antenna tunable to two different frequencies has been contrived, which is complicated in structure and suffers from low antenna gain.

SUMMARY OF THE INVENTION

The present invention contemplates elimination of the above drawbacks of the conventional antenna apparatus and its object is to provide a compact antenna apparatus which is tunable to a plurality of frequencies and which has a high antenna gain.

According to the invention, to accomplish the above object, a plurality of divisions of antenna elements are formed on a radio apparatus cabinet or on a substrate packaged along the surface of the radio apparatus cabinet, and the divisions of antenna elements are interconnected together by a plurality of inductance elements to cancel a capacitive component of a built-in antenna.

Preferably, a capacitance element is connected in parallel with at least one of the plurality of interconnected inductance elements to form a resonance circuit, thus realizing a built-in antenna which utilizes a characteristic of the resonance circuit so as to be tunable to at least two frequencies.

Therefore, according to the invention, the built-in antenna is formed on the radio apparatus cabinet or the substrate packaged along the cabinet and the interconnection of the plurality of inductance elements makes the built-in antenna tunable to different frequencies. Further, by virtue of the action of the parallel resonance circuit, even a single built-in antenna can behave as an antenna which can be used commonly with at least two different frequencies for transmission and reception.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are schematic perspective views illustrating conventional antenna apparatus;

Figs. 2, 3 and 4 are schematic perspective views illustrating other conventional antenna apparatus;

Fig. 5 is a schematic perspective view showing a first embodiment of an antenna apparatus according to the invention;

Figs. 6A and 6B are schematic perspective views for explaining the operation of the antenna apparatus of a first embodiment;

Fig. 7 is a schematic perspective view showing a second embodiment of the antenna apparatus according to the invention;

Fig. 8 is a schematic perspective view showing a third embodiment of the antenna apparatus of the invention;

Fig. 9 is a schematic perspective view showing a fourth embodiment of the antenna apparatus of the invention;

Fig. 10 is a perspective view showing the external appearance of the Fig. 9 antenna apparatus;

Figs. 11A and 11B are schematic perspective views for explaining the operation of the antenna apparatus of the fourth embodiment;

Fig. 12 is a schemataic perspective view showing a fifth embodiment of the antenna apparatus of the invention;

Fig. 13 is a perspective view showing a sixth embodiment of the antenna apparatus of the invention; and

Fig. 14 is an equivalent circuit diagram of the sixth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 5 shows the construction of a first embodiment of the invention. In Fig. 5, a built-in antenna has a plurality of divisions of antenna elements 21 to 24 formed, through graphic process, on a cabinet 1 of a radio apparatus.

The divisions of antenna elements are interconnected by a plurality of inductance elements 25 to 27 which may be formed of inductive lumped constant elements or inductive distributed constant elements. A coapacitance element 28 is connected in parallel with the inductance element 25. Denoted by 29 is a matching circuit for matching the antenna impedance with the input/output impedance of the radio apparatus, and by 3 is a feeding point.

A duplex-transmission type portable radio apparatus has a transmission frequency f_T and a receiving frequency f_R and $f_T < f_R$ is assumed. A resonance circuit comprised of the interconnected inductance element 25 and capacitance element 28 has constant values which are selected such that the resonance circuit can resonante with a higher one f_R of the two of transmission and receiving frequencies in use. Therefore, the resonance circuit has such a characteristic that this resonance circuit assumes a high impedance for the receiving frequency f_R but behaves as an inductance component for the transmission frequency f_T which is lower than f_R.

Accordingly, the present antenna equivalently operates as an antenna as shown in Fig. 6A for the frequency f_T and as an antenna as shown in Fig. 6B for the frequency f_R.

More specifically, the antenna elements 21, 22, 23 and 24 and the interconnected inductance elements 25, 26 and 27 which are set up as shown in Fig. 6A can resonate with f_T and the antenna elements 22, 23 and 24 and the interconnected inductance elements 26 and 27 which are set up as shown in Fig. 6B can resonate with f_R, indicating that even a single built-in antenna can operate to resonate with the two different frequencies for transmision and reception. For example, where the inductance element 27 is 27 nH, the inductance element 26 is 18 nH, the inductance element 25 is 15 nH and the capacitance element 28 is 11.7 pF, there result a transmission frequency f_T of 254 MH_z and a receiving frequency f_R of 380 MH_z pursuant to a formula $f = \frac{1}{2\pi\sqrt{LC}}$ for determining the resonance frequency.

Figs. 7 and 8 show second and third embodiments of the invention, respectively. In Fig. 7, the antenna has a bent structure and in Fig. 8 the antenna has a folded type structure. In the above structure, the surface of the radio apparatus cabinet 1 is used highly efficiently as an antenna forming surface to promote compactness of the radio apparatus cabinet 1.

While in the foregoing embodiments, the antenna elements are formed, through graphic process, on the radio apparatus cabinet, they may alternatively be formed on the surface of a substrate packaged along the surface of the radio apparatus cabinet.

Further, as embodied previously, the capacitance element is described as being connected in parallel with one inductance element but capacitance elements may be connected in parallel with the plurality of inductance elements, respectively, and constant values may be set such that the respective resonance circuits have different resonance frequencies, thus making it possible to perform transmission/reception through a multifrequency band of three or more frequencies.

As is clear from the foregoing description of the first, second and third embodiments, the preset invention can attain the following beneficial effects.

(1) The built-in antenna can be formed on the radio apparatus cabinet or on the substrate packaged on the cabinet.

(2) The interconnection of the plurality of inductance elements can afford to provide a built-in antenna of low loss and high sensitivity.

(3) In contrast to the conventional built-in antenna of narrow band and which has the single-tuned characteristic, a built-in antenna for common use with multi-frequencies in the duplex-transmission type portable radio apparatus for transmission/reception can be realized by providing the resonance circuit which can resonate with the frequency band used.

Consequently, the built-in antenna for common use with two or multi-frequencies, which cannot be realized with the conventional antennas, can be materialized without impairing the high sensitivity characteristic.

Fig. 9 shows the construction of a fourth embodiment of the invention and Fig. 10 shows the external appearance of the antenna apparatus of the fourth embodiment.

Referring to Figs. 9 and 10, a linear antenna shorter than the wavelength is divided into a plurality of antenna elements 31 to 34. Divisions of the antenna elements are interconnected by inductance elements 35 to 37 having inductive inductance which may be formed of lumped constant elements or distributed constant elements. A capacitance element 38 is connected in parallel with the inductance element 35. A matching circuit 39 is adapted to match the antenna impedance with that of the radio apparatus. Denoted by 40 is a feeding point, by 41 a radio apparatus cabinet, and by 42 is an antenna.

A duplex-transmission type radio apparatus has a transmission frequency f_T and a receiving frequency f_R and $f_T < f_R$ is assumed. A resonance circuit comprised of the interconnected inductance element 35 and capacitance element 38 has constant values which are selected such that the resonance circuit can resonate with a higher one f_R of the two of transmission and receiving frequencies in use. Therefore, the resonance circuit has such a characteristic that this resonance circuit assumes a high impedance for the receiving frequency f_R but behaves as an inductance component for the transmission frequency f_T which is lower than f_R.

Accordingly, the present antenna equivalently operates as an antenna as shown in Fig. 11A for the frequency f_T used and as an antenna as shown in Fig. 11B for the frequency f_R used.

More specifically, the antenna elements 31, 32, 33 and 34 and the interconnected inductance elements 35, 36 and 37 can resonate with f_T and the antenna elements 32, 33 and 34 and the interconnected inductance elements 36 and 37 can resonate with f_R, indiacting that even a compact antenna shorter than the wavelength can exhibit such a characteristic that the antenna can resonate with two frequencies.

Fig. 12 shows a fifth embodiment of the invention. In this embodiment, the number of capacitance elements for parallel connection is increased such that three capacitance elements 38, 42 and 43 are connected in parallel with inductance elements 35, 36 and 37, materializing an antenna which can resonate with four frequencies. Thus, according to the present embodiment, a single antenna can be used commonly for four different transmission/reception frequencies utilized inside a radio apparatus cabinet 41 and the employment of a plurality of antennas can be dispensed with. In proportion to the number of divisions of the antenna elements, the number of frequencies with which the antenna can resonate can be increased.

As is clear from the foregoing description of the fourth and fifth embodiments, the present invention can attain the following beneficial effects.

(1) The interconnection of the plurality of inductance elements can afford to provide a compact antenna of low loss.

(2) In contrast to the conventional compact and shortened antenna which is of narrow band and exhibits a single-tuned characteristic, the number of different frequencies with which the antenna can resonate can be increased by, in principle, the number of the divisions of the antenna elements by utilizing the plurality of resonance circuits.

The above advantages (1) and (2) can eliminate drawbacks inevitably concomitant with reducing the size of the antenna and are effective to provide an antenna indispensable for realization of a compact portable radio apparatus. The application can further be extended to, for example, a car antenna which is required to be a single antenna having ability to receive a plurality of waves such as AM, FM and TV waves.

A sixth embodiment of the invention will now be described by referring to the drawing, in particular, Fig. 13 thereof.

In Fig. 13, an antenna 51 has a printed wiring board 52 in the form of a film on which substantially ⊐ letter shaped antenna elements 53 and 54 are formed face to face in staggered fashion and linear antenna elements 55 and 56 are formed using print pattern technique. The elements 55 and 53, the elements 53 and 54 and the elements 54 and 56 are respectively connected together by coils 57 which are packaged on the surface to prolong the length of the antenna. This antenna 51 is provided on the surface of a cabinet 59 of a radio apparatus 58 and connected to transmitting and receiving circuits of the radio apparatus 58.

Fig. 14 is a circuit diagram showing an equivalent circuit of the antenna 51. In Fig. 14, the same components as those in Fig. 12 are designated by the same reference numerals. Transmission and reception of an electric wave E is effected by means of the antenna elements 53 to 57 and the coils 57.

The antenna 51 of the invention constructed as above can be reduced in antenna length by virtue of the surface packaged type coils 57 as in the case of the conventional, helical whip antenna and besides can be reduced in size by virtue of the substantially ⊐ letter shape antenna elements 53 to 56 formed face to face in staggered fashion. Further, in the antenna 51 of the present invention, the printed wiring board 52 on which the antenna elements 53 to 56 are formed has the form of a film which can be shaped freely and upon mounting to the cabinet 59, can be bent and rounded to drastically improve the degree of freedom of packaging the film to the radio apparatus 58 and permit size reduction, weight reduction and freedom of shape design of the radio apparatus.

In the present embodiment, two ⊐ letter shape antenna elements are used to construct the antenna but the number of the antenna elements used is not limited to two and may be set suitably in accordance with frequencies used.

As is clear from the foregoing description of the sixth embodiment, the antenna of the invention can be reduced in size so as to be tailored to its application to the portable type mobile radio apparatus which is required to be compact and light; and the printed wiring board on which the antenna elements are formed is in the form of a film which can be shaped freely and upon mounting to the cabinet, can be bent or rounded to drastically improve the degree of freedom of packaging the film to the radio apparatus.

Claims

1. An antenna apparatus comprising:

a plurality of divisions of antenna elements (21-24) formed on a radio apparatus cabinet (41) or on a substrate packaged on the surface of the radio apparatus cabinet (1);

a plurality of inductance elements (25-27) for interconnecting together said divisions of antenna elements, said inductance elements being inductive lumped constant elements or distributed constant elements; and

a capacitance element (28) connected in parallel with at least one of said inductance elements to form a resonance circuit which resonates with a frequency band used.

2. Antenna apparatus according to Claim 1 wherein said antenna elements are put together by bending an antenna element or elements.

3. An antenna apparatus comprising:

a plurality of divisions (31-34) profuced by dividing a linear antenna (42);

a plurality of lumped constant elements or distributed constant elements (35-37) having inductive inductance and adapted to interconnect together said divisions; and

a capacitance element (38) connected in parallel with at least one of said interconnected inductive inductance elements, said inductance and capacitance elements in parallel connection being operable to resonate with a frequency band used.

4. An antenna apparatus according to Claim 1 wherein values of said inductance and capacitance elements are set such that the antenna resonates with the highest one of different frequencies used.

5. An antenna comprising:

divisions of antenna elements (53-54) formed by print pattern technique on a printed wiring board (52) in the form of a film; and

surface packaged type coils (57) for interconnecting together said divisions of antenna elements, said coils being effective to reduce the antenna length.

FIG. 1A

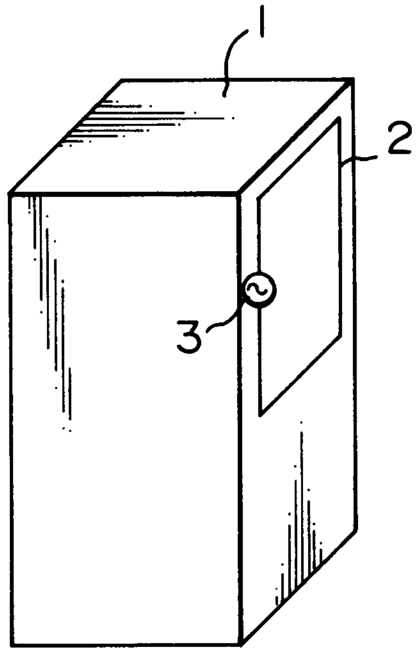

FIG. 1B

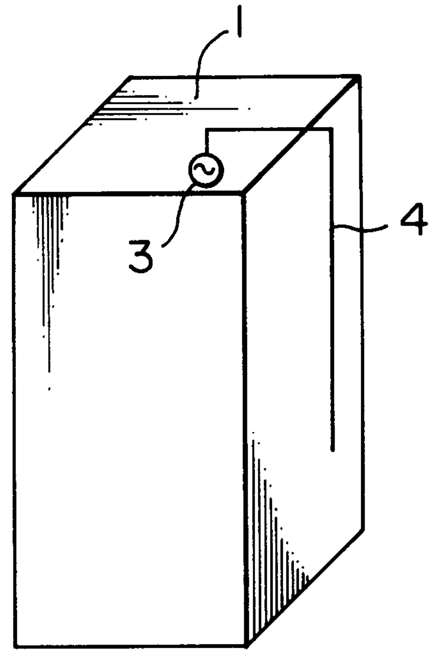

FIG. 2

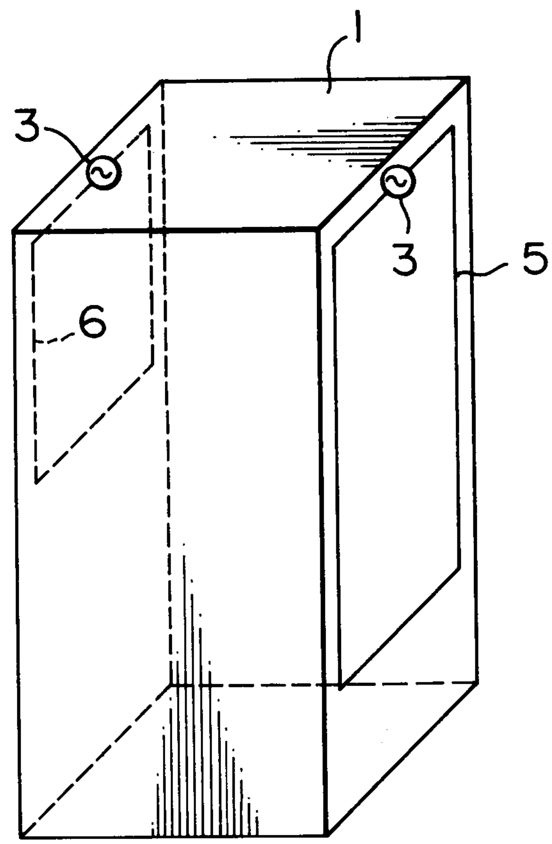

FIG. 3

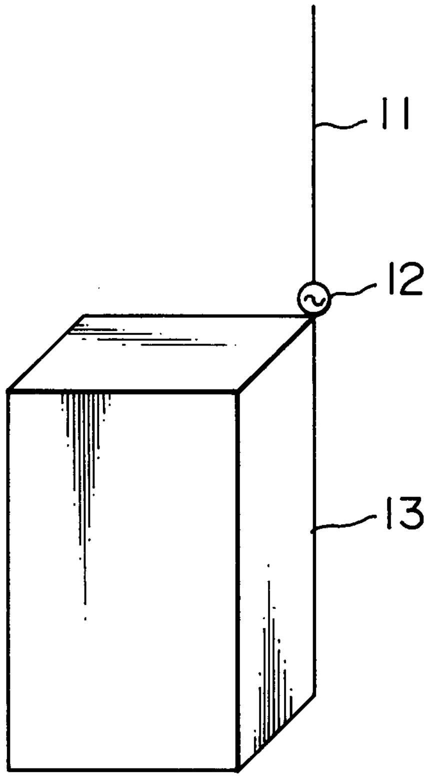

FIG. 4

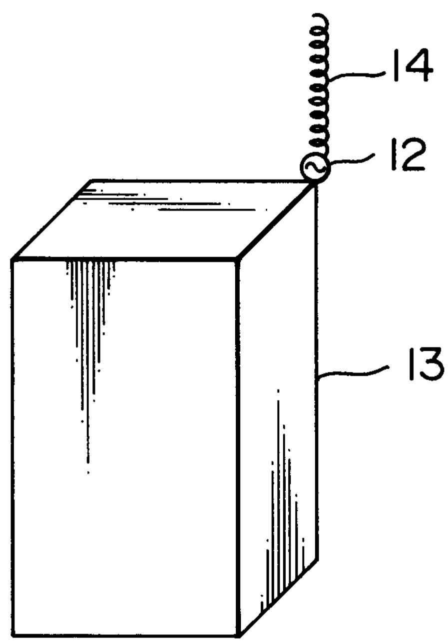

FIG. 7

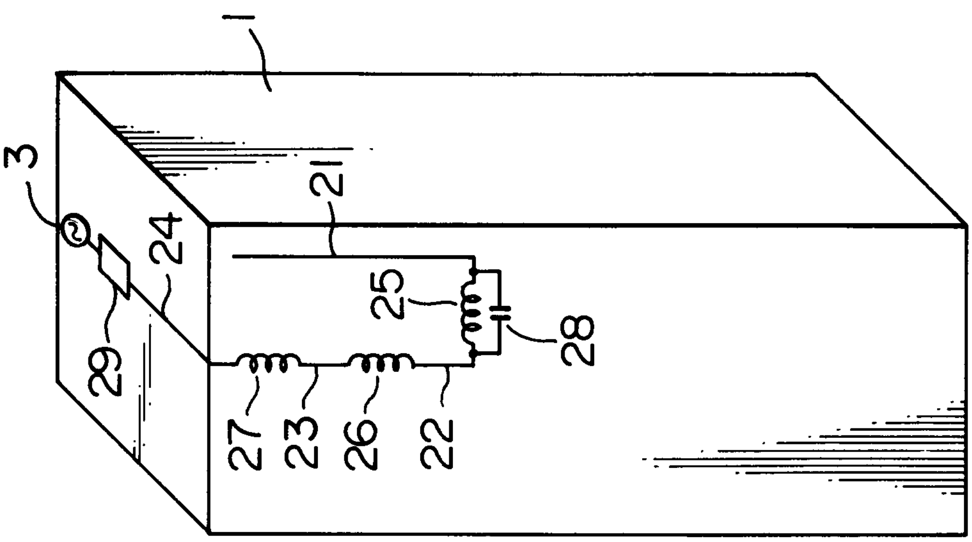

FIG. 5

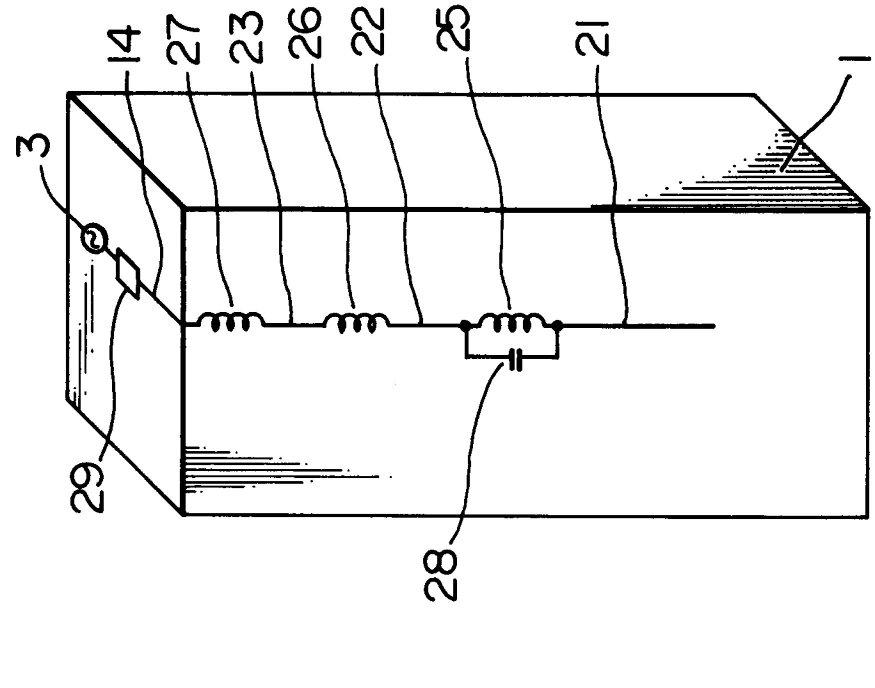

FIG. 6A

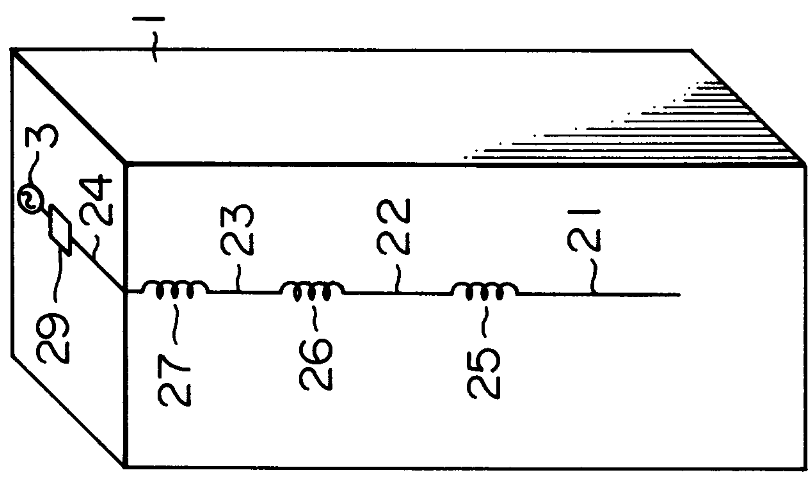

FIG. 6B

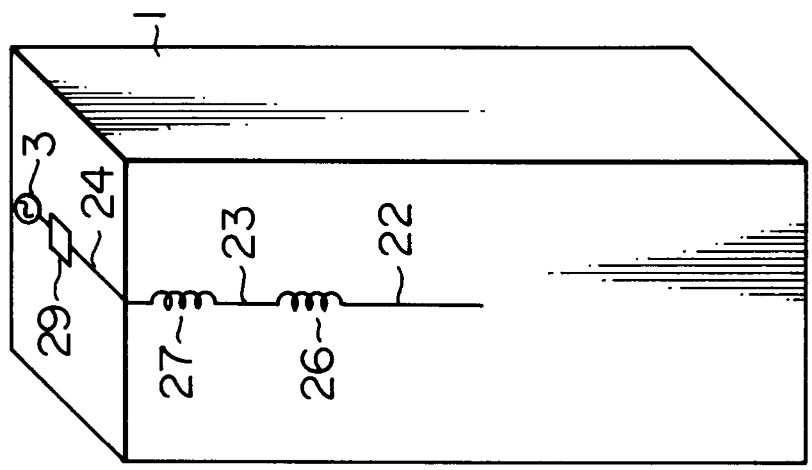

FIG. 8

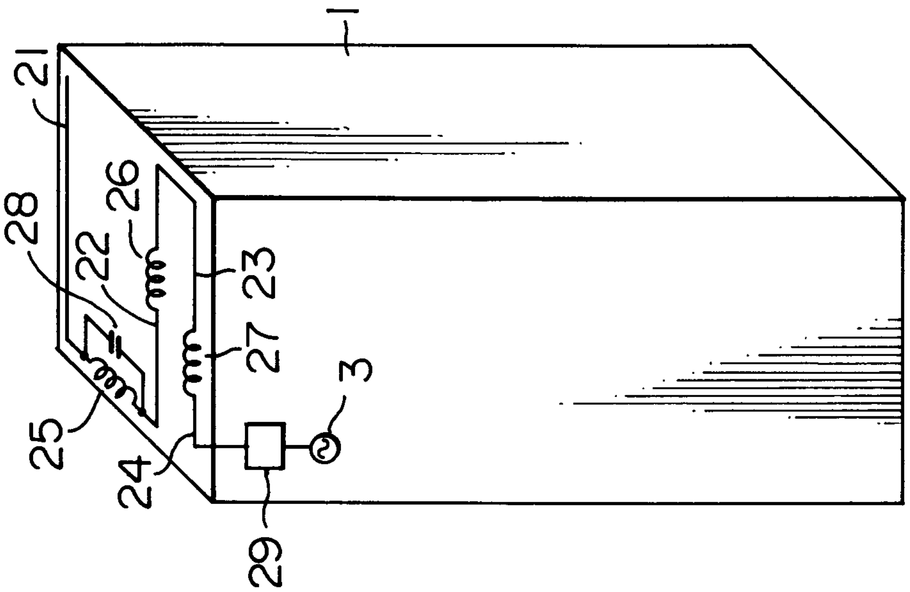

FIG. 9

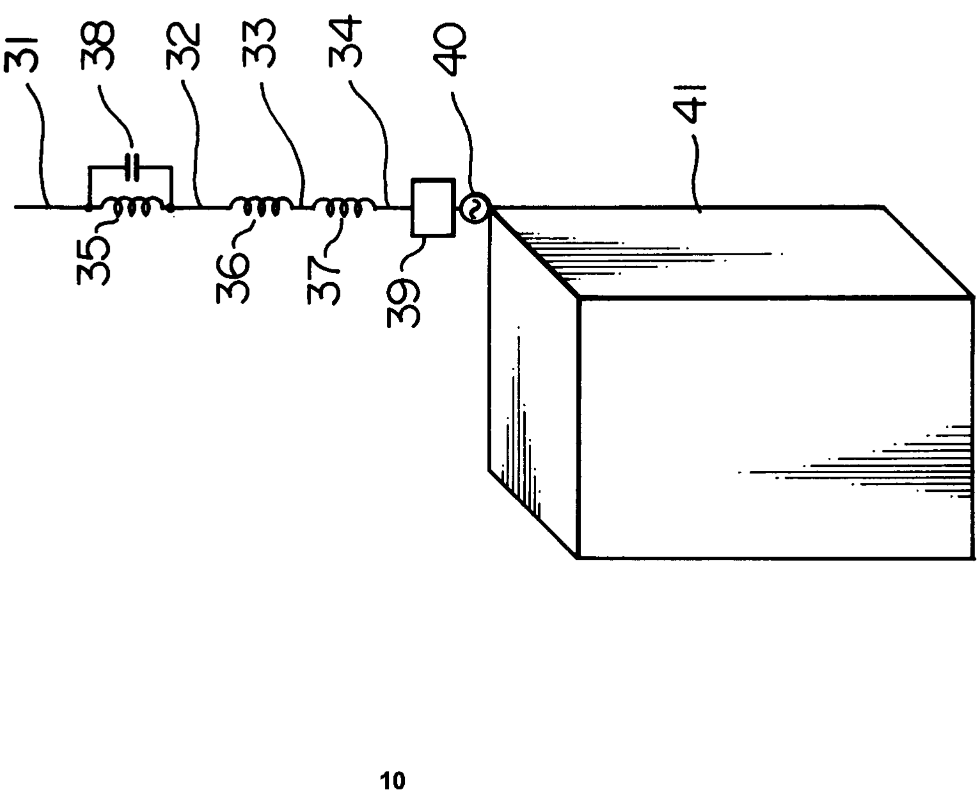

FIG. 10

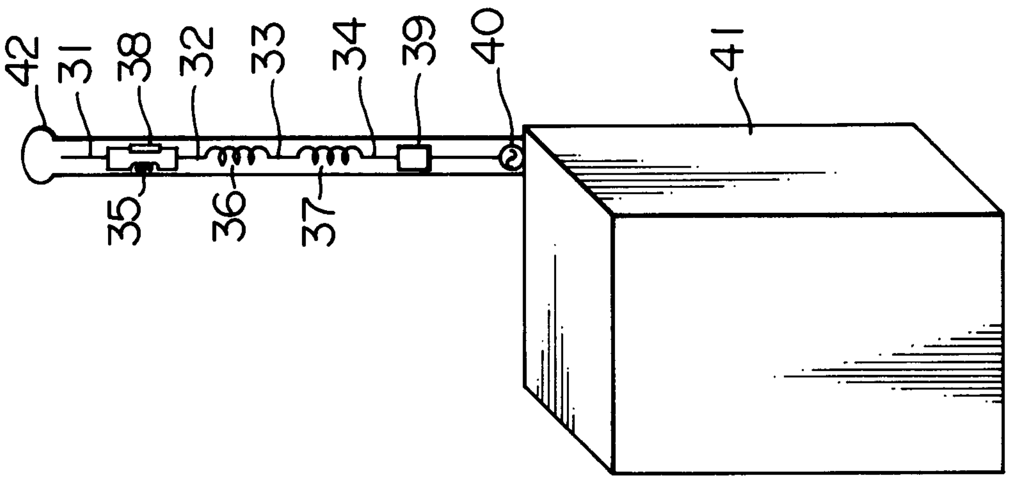

FIG. 11A

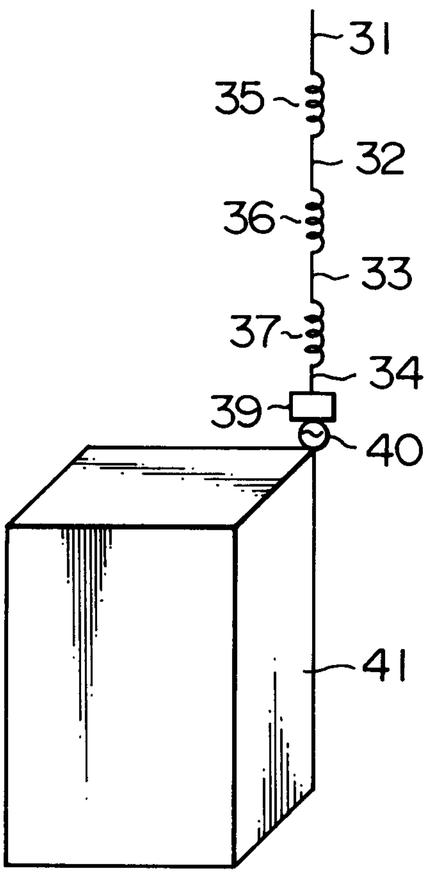

FIG. 11B

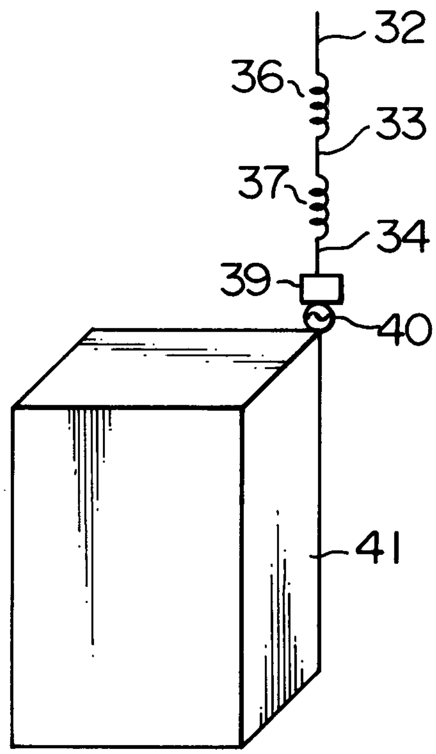

FIG. 12

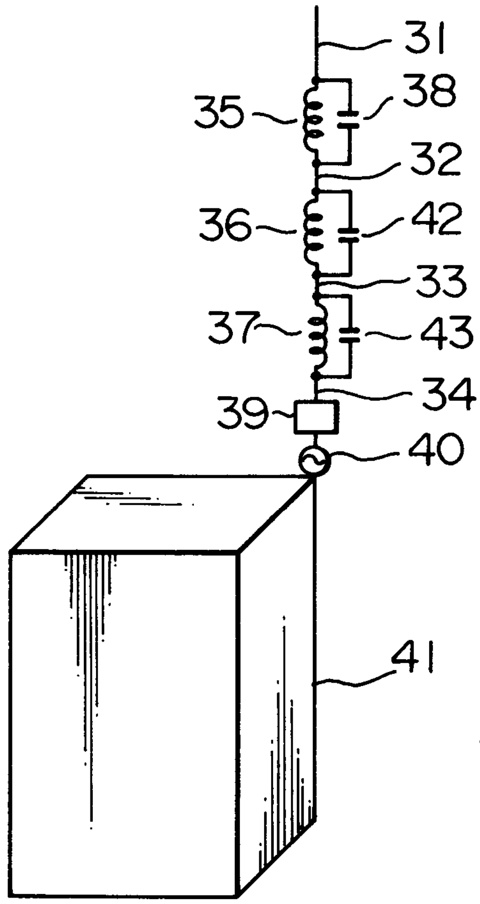

FIG. 13

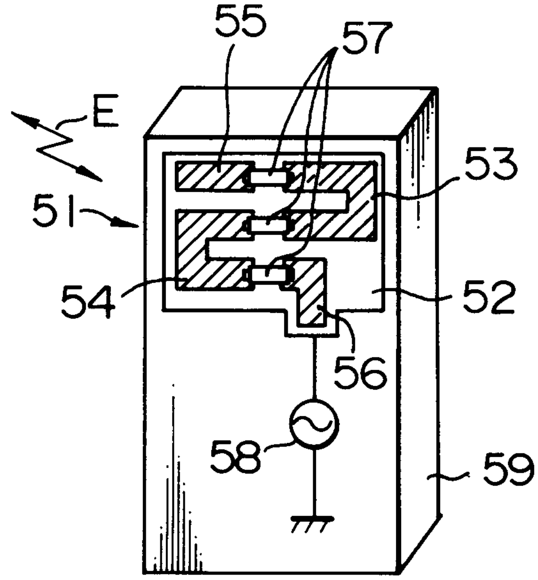

FIG. 14