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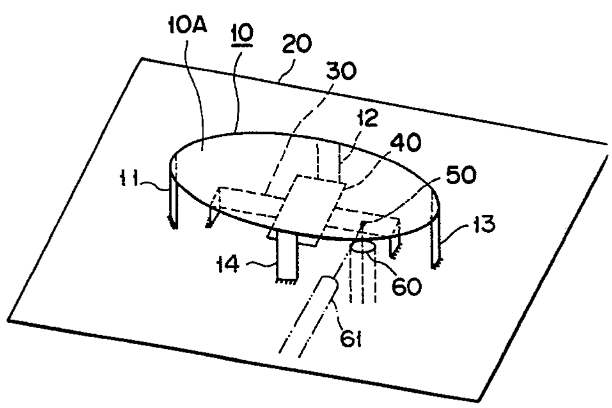
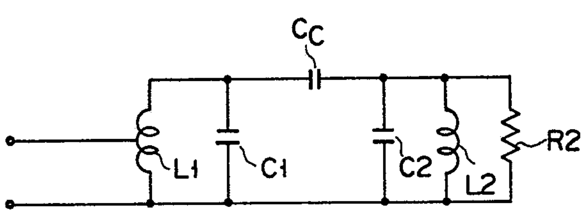
(54) **Flat-plate antenna for use in mobile communications.**

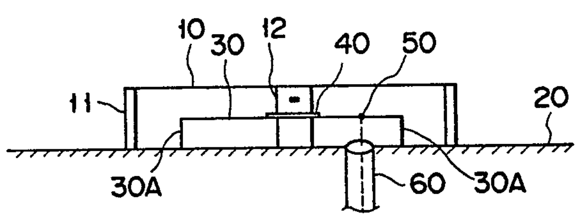
(57) A flat-plate antenna for mobile communications used in automobiles, etc. including a table form antenna element (10) made up of a conductive flat-plate section (10A) and a plurality of leg sections which connect to the flat-plate section to a ground plate (20), a strip line resonator (30) provided beneath the table form antenna with a space in between, and a capacitor electrode (40) provided on the strip line resonator directly under the center of the table form antenna element. A feeding line is connected to the strip line resonator.



F I G. 1A



F I G. 1C



F I G. 1B

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Flat-plate antenna for use in mobile communications

The present invention relates to an antenna for use in mobile communications such as automobile telephones and MCA (multi-channel access), etc. which is flat-plate shaped and installed in a flat portion such as roof, trunk lid, etc. of the body of a vehicle such as an automobile, etc.

Various types of wire-form or linear antennas have been used in the past as antennas for mobile communications. The reasons for this are that wire-form antennas have maximum radiative characteristics in the horizontal direction, as required for mobile communications, and such antennas can easily be endowed with characteristics which are non-directional in the horizontal plane. Furthermore, antennas used for automobile telephones and MCA require broad-band characteristics, and since broad-band techniques have been well established for wire-form antennas, the design and development of such antennas are relatively easy.

In recent years, flat-plate antennas have received attention as antennas for use in mobile communications. The reason for this is that when a flat-plate antenna is attached to an automobile, there is no projecting object as in the case of conventional and antennas, and there is no deleterious effect on the style of the automobile, and wind noise occurring during operation of the automobile is decreased. Furthermore, since there is no danger that the antenna will contact car-wash machinery, garages or roadside trees, etc., the problem of damage to the antenna from such sources is eliminated. In these and other respects, such antennas have great practical merit.

In flat-plate antennas it is necessary to endow the antenna with broad-band characteristics. For this reason, antennas with a multi-layer structure have been proposed in the past. Such multi-layer antennas, however, has a complex integral structure and is therefore difficult to adapt as a commercial product.

Accordingly, the object of the present invention is to provide a flat-plate antenna for use in mobile communications which has sufficient broad-band characteristics and has a simple structure.

In the present invention, a strip line resonator is provided inside or underneath a table type antenna element and a capacitor electrode is installed on the strip line resonator at a position directly facing the center of the table type antenna element.

Thus, since in the present invention, a strip line resonator is inside a table type antenna element and a capacitor electrode is installed on the strip line resonator so that it directly faces the center of the table type antenna element. The structure of this antenna is simple and has adequate broad-band characteristics.

This invention can be more fully understooc from the following detailed description when taker in conjunction with the accompanying drawings, ir which:

Fig. 1A is a perspective view of one embodiment of the present invention;

Fig. 1B is a front view thereof.,

Fig. 1C is a circuit diagram which illustrate an equivalent circuit thereof;

Fig. 2A is an explanatory diagram of a table type antenna element of Fig. 1A operating in th monopole mode;

Fig. 2B is an equivalent circuit diagram c the impedance characteristics in the vicinity of th resonant frequency as viewed from the center c the circular plate;

Fig. 3A is a perspective view which illustrates a strip line resonator of Fig. 1A;

Fig. 3B is an equivalent circuit diagram c the impedance characteristics thereof as viewe from the feeding point of the feeder line in thi case;

Fig. 4A is a perspective view of anothe embodiment of the present invention;

Fig. 4B is a front view thereof;

Fig. 5, Fig. 6A and Fig. 6B are perspectiv views of modifications of the table type antenn element of the present invention;

Fig. 7 is a graph which illustrates the reflection loss characteristics with varying coupling capacitance in the embodiment;

Figs. 8A and 8B are graphs which respectively illustrate the reflection loss characteristic and impedance characteristics in the embodimen and

Fig. 9 is a graph which illustrates the directionality of the antenna in the vertical plane in th embodiment.

Fig. 1A is a perspective view of the antenna c the present invention and Fig. 1B is a front vie thereof with a connecting plate omitted. Fig. 1C a circuit diagram showing an equivalent circuit c the antenna of Fig. 1A.

The antenna of the present invention include the following components: A table type antenr element 10, a ground plate 20 which is under th antenna element 10, a strip line resonator 30 whic is installed inside or underneath the table typ antenna element 10, and a capacitor electrode 4 which is installed on the strip line resonator 30 in position opposite the central portion of the tab type antenna element 10. In other words, the elec trode 40 is directly below the center of the antenr element 10. Furthermore, the antenna of th present invention includes a feeder line 60 which has a feeding point at a prescribed position on the strip line resonator 30.

In particular, the table type antenna element 10 includes a circular or oblong conductive flat-plate 10A and a multiple number of connecting parts 11, 12, 13 and 14, which electrically connect the flat-plate 10A to the ground plate 20. This antenna element 10 is excited in the monopole mode.

Both ends of the strip line resonator 30 are grounded to the ground plate 20 via legs 30A. This strip line resonator 30 also serves as an impedance transformer. The electrostatic capacitance C_c is provided between the capacitor electrode 40 and the table type antenna element 10 and indicated by the capacitor symbol in Fig. 1B. Moreover, in Fig. 1A, the feeder line 60 is shown as being led out from beneath the ground plate 20; however, it may also be installed parallel to the ground plate 20 as indicated by reference numeral 61 in Fig. 1A.

Fig. 2A illustrates the relationship between the feeder line 60 and the table type antenna element 10 excited in the monopole mode in the embodiment.

In cases where the table type antenna element 10 is excited in the monopole mode, i.e., where the current flowing through the flat-plate 10A flows uniformly from the center toward the periphery, and the top plate resonates in the lowest-order mode ($\lambda/2$), the voltage distribution reaches the maximum in the central portion of the table type antenna element 10, and the impedance characteristics as viewed from the center of the flat plate 10A may be treated as those of a parallel resonance circuit of the type shown in Fig. 2B in the vicinity of the resonant frequency.

Fig. 3A shows the strip line resonator 30 which has both ends grounded and is equipped with the capacitor electrode 40 in the above-described embodiment.

When the resonator shown in Fig. 3A resonates in the lowest-order mode ($\lambda/2$), the voltage in the area of the capacitor electrode 40 reaches the maximum, and the impedance characteristics as viewed from the feeding point 50 of the feeder line 60 may be treated as those of a tapped parallel resonance circuit of the type shown in Fig. 3B in the vicinity of the resonant frequency.

The embodiment illustrated in Figs. 1A and 1B may be viewed as a combination of the table type antenna element 10 shown in Fig. 2A and the strip line resonator shown in Fig. 3A. In this case, the feeder line 60a of Fig. 2A is omitted, and the feeder line 60 is used instead. As a result, a primary resonance circuit formed by the strip line resonator 30 and a secondary resonance circuit formed by the table type antenna element 10 are electrostatically coupled by the electrostatic capacitance C_c between the electrode plates. Accorc ingly, in the embodiment illustrated in Fig. 1A, double tuning circuit based on capacitive couplin is formed in apparent terms in the vicinity of th resonant frequency, as shown in Fig. 1C.

Here, the resonant frequency on the primar side and the resonant frequency on the secondar side are tuned to the frequency being used, th coupling capacitance C_c is set at the critical cou pling value, and the position of the feeding point 5 is selected, so that the impedance of the flat-plat antenna of Fig. 1A and the impedance of the feec er line are in a matched state. As a result, th reflection loss of the flat-plate antenna for use i mobile communications shown in Fig. 1A can b reduced, and a good VSWR value can be obtaine across a broad band.

Normally, the necessary conditions for a fla plate antenna for use in mobile communicatior such as automobile telephones, etc. is that th antenna must be excellent in certain respects: Firs the antenna must have superior directional cha acteristics. In other words, the antenna must sho maximum radiative characteristics in the horizont direction and must be non-directional within th horizontal plane. Second, the antenna must hav broad-band characteristics. For example, in th case of an automobile telephone, the band wid must adequately cover 80 MHz band. In Additio the antenna must have superior impedance matcl ing (matching between the feeder line 60 and th flat-plate antenna for use in mobile communicatior must be adequately achieved across a broa band), and the antenna should also be superior terms of its mechanical structure. That is, the struc ture should be simple and easy to manufactur and mechanical errors occurring in the manufactu ing process should not have any great effect on th antenna characteristics.

First, in regard to the directional characteristic the table type antenna element 10 is shaped s that it is excited in the monopole mode. In oth words, the antenna is shaped so that it has a axially symmetrical flat-plate 10A and a multip number of connecting parts which electrically co nect this flat-plate 10A to the ground plate 20. As result, the required directional characteristics ca be obtained.

Secondly, in regard to broad-band characteri tics, flat-plate antennas which are excited in th monopole mode generally have a narrow bar width. Broad-band characteristics can be obtaine to some extent by connecting the circular plate to ground plate via a grounding post. However, the are limits to the improvement that can be achieve in this way. Accordingly, in the above-mentione embodiment, broad-band characteristics are o tained by installing a strip line resonator 30 insic the table type antenna element 10, and electrostatically coupling this resonator 30 with the antenna element 10.

The next thing to be considered is an impedance matching. In order to cause stable excitation in the monopole mode, it is ordinarily necessary to position the feeding point in the central portion of the antenna. However, since the center of the antenna is where the voltage is at the maximum, it is difficult to achieve matching between the antenna and the feeder line 60. Accordingly, in the above-described embodiment, feeding is accomplished with the table type antenna element 10 and strip line resonator 30 coupled via the electrostatic capacitance C_c. Consequently, the impedance of the flat-plate antenna for use in mobile communications and the impedance of the feeder line 60 can be matched by varying the position of the feeding point 50 between one grounded end of the strip line resonator 30 and the capacitor electrode 40. By using a method in which impedance matching is accomplished by varying the position of the feeding point 50, i.e., by varying the position of the tap, any effect on the antenna proper in terms of directional characteristics and broad-band characteristics, etc., is minimized. Accordingly, the most appropriate position for the feeding point can be selected relatively easily in the development and design stages of the flat-plate antenna.

The mechanical structure of the above-described embodiment is as follows: The table type antenna element 10 and strip line resonator 30 are finished separately from each other in mechanical terms and then these two parts are simply combined. As a result, the mechanical demand in the antenna manufacturing process is minimal. Accordingly, the cost of the product is reduced, and as long as ordinary working precision is maintained, there is no deterioration in the antenna characteristics or insufficiency in terms of the mechanical strength of the antenna. Furthermore, if there is a mechanical dimensional error at the time of assembly tends to result in a change in the coupling capacitance. Even in such cases, however, the only effect will be a certain change in the band width; accordingly, there is no essential effect on the antenna characteristics.

Fig. 7 is a graph which shows the change in the reflection loss of the antenna that occurs when the coupling capacitance C_c is varied in the above described embodiment.

Fig. 8A is a graph which shows measurements of the reflection loss in the embodiment; and Fig. 8B is a graph which shows one example of impedance characteristics in the embodiment indicated by means of a Smith chart. As for the radiative directional characteristics of the antenna in the embodiment, the direction of maximum radiation of a table-form flat-plate antenna resonating in th monopole mode is more or less horizontal, an such an antenna is more or less non-directiona within the horizontal plane.

Fig. 9 is a graph which shows one example c directional characteristics in the vertical plane in case where the flat-plate antenna of the embod ment is attached to a circular plate-form groun plate with a diameter of 1.5 m.

In.the characteristics shown in Fig. 9, the direc tionality is oriented slightly upward, since a groun plate of finite length is used. However, in case where a ground plate of an undefined much greate length is used, the directionality is more or les horizontal.

Fig. 4A is a perspective view which illustrate another embodiment of the present invention. Fig 4B is a front view thereof with the connecting pa 14 shown in Fig. 4A omitted.

In this embodiment, a strip line resonator 3 which is approximately half the length of the stri line resonator 30 of the previous embodiment, an is installed on one side only, is used instead of th strip line resonator 30. In this case as well, th capacitor electrode 40 is positioned so that it located roughly in the center of the table typ antenna element 10. Furthermore, in this case a well, an equivalent circuit is formed which is simila to that shown in Fig. 1C.

Moreover, in the embodiment illustrated in Fi 4A, the strip line resonator 31 resonates at one fourth (λ/4) the wavelength of the frequency used.

Figs. 5, 6A and 6B illustrate modifications the table type antenna element 10.

In the table type antenna element 10a of Fig. the positions of the connecting parts 11a, 12a, 13 and 14a are set not at the edges of the table typ antenna element 10a, but rather at prescribe points which are all substantially equidistant fro the center of the antenna. Furthermore, the tab type antenna element 10b is constructed using flat-plate which has the shape of a regular octago Connecting parts 11b, 12b, 13b and 14b are co nected to this flat-plate 10b. In addition to circul and octagonal flat-plates, it would also be possib to use the flat-plate design with other regular pol gonal shapes, e.g., hexagonal, etc. Furthermor the table type antenna 1°C may have rod-for connecting parts 11c, 12c, 13c and 14c.

In addition, the resonant frequency of the tab type antenna can be adjusted by adjusting the si (length, width, diameter) of the connecting part Furthermore, it would also be possible to use thre connecting parts, or five or more connecting part instead of four connecting parts as in the case the aforementioned connecting parts 11 throug 14, 11a through 14a, 1lb through 14b and 1 through 14c.

As in detail, the structure of the antenna is simple and has adequate broad-band characteristics.

Claims

1. A flat-plate antenna for use in mobile communications characterized in that said antenna comprises:
a table type antenna element (10) which is equipped with a conductive flat-plate part (10A) and a multiple number of connecting parts (11, 12, 13, 14) which electrically connect said flat-plate part to a ground plate (20);
a strip line resonator (30) which is installed inside said table type antenna; and
a capacitor electrode (40) which is installed on said strip line resonator and directly under the central portion of said table type antenna element.

2. A flat-plate antenna according to claim 1, characterized in that both ends of said strip line resonator are grounded, and said capacitor electrode is installed substantially at the center of said strip line resonator, said strip line resonator as a whole being installed at substantially the central location inside said table type antenna, and said strip line resonator being caused to resonate at one-half ($\lambda/2$) the wavelength of frequency used.

3. A flat-plate antenna according to claim 1, characterized in that one end of said strip line resonator is grounded while the other end of said strip line resonator is open, said capacitor electrode is connected to said open portion of said strip line resonator, said strip line resonator as a whole is positioned so that said capacitor electrode is located at a substantially central position inside said table type antenna element and said strip line resonator is caused to resonate at one-fourth ($\lambda/4$) the wavelength of frequency used.

4. A flat-plate antenna according to claim 1, characterized in that a feeding point is installed between one grounded end of said strip line resonator and capacitor electrode.

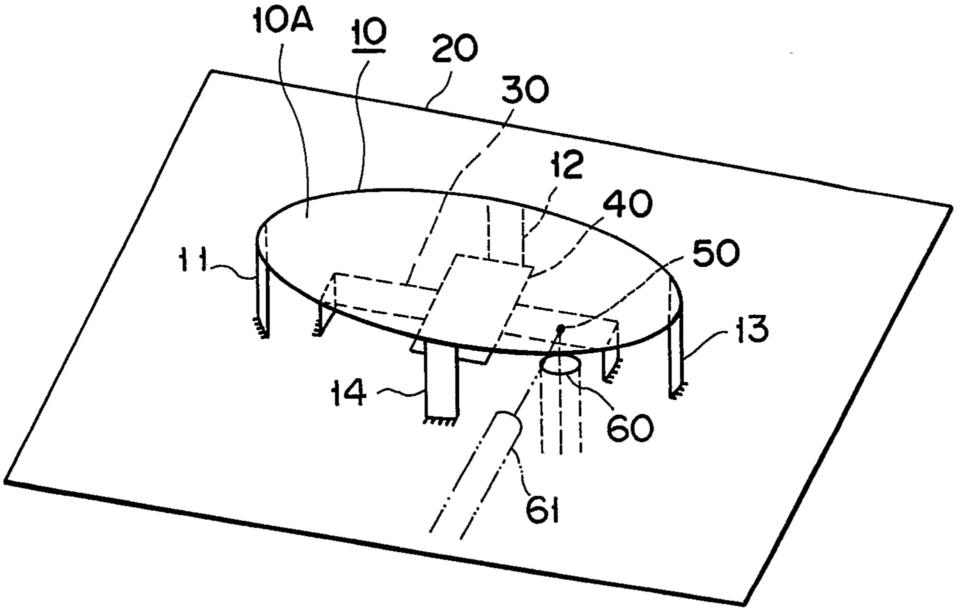
5. A flat-plate antenna according to claim 1, characterized in that the impedance of said flat-plate antenna element and the impedance of the feeder line of said antenna are matched by varying the position of said feeding point in the area between one grounded end of said strip line resonator and capacitor electrode.

6. A flat-plate antenna according to claim 1, characterized in that said flat-plate portion of said table type antenna element is circular or regular polygon in shape.

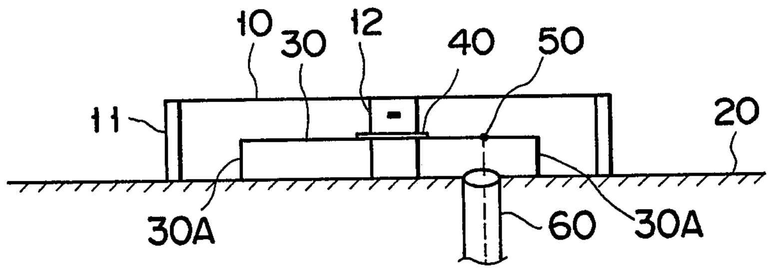
7. A flat-plate antenna according to claim 1, characterized in that said connecting parts are rod-form or plate-form conductors.

8. A flat-plate antenna according to claim 1 characterized in that the resonant frequency of said table type antenna element is adjusted by adjusting the size (length, width and/or diameter) of said connecting parts.

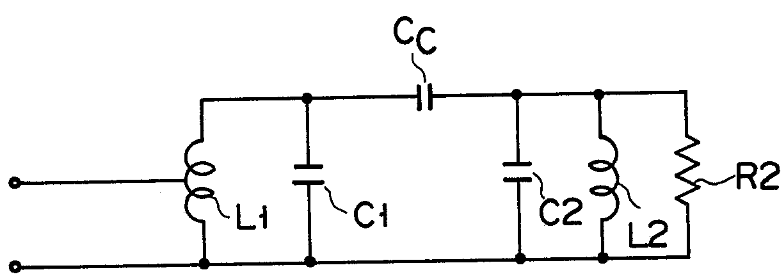
9. A flat-plate antenna according to claim 1 characterized in that said capacitor electrode is installed so that the electrostatic capacitive coupling between said table type antenna and strip line resonator is more or less in a state of critical coupling.



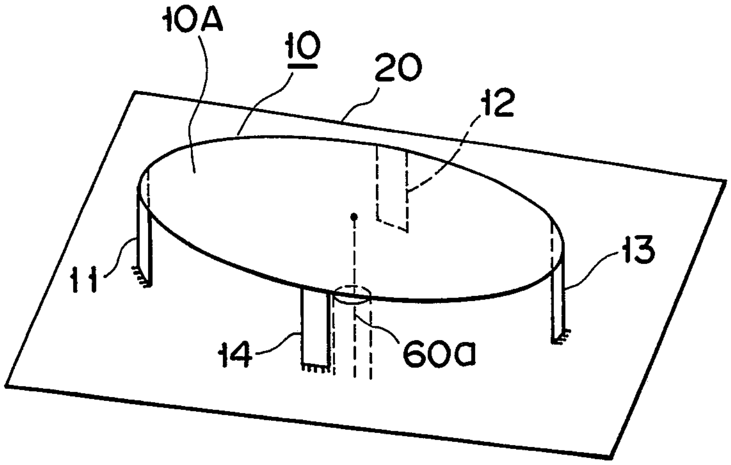
F I G. 1A



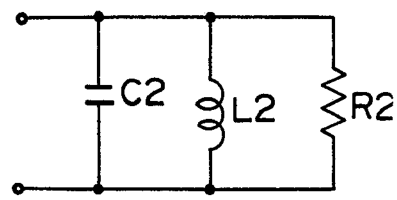
F I G. 1B



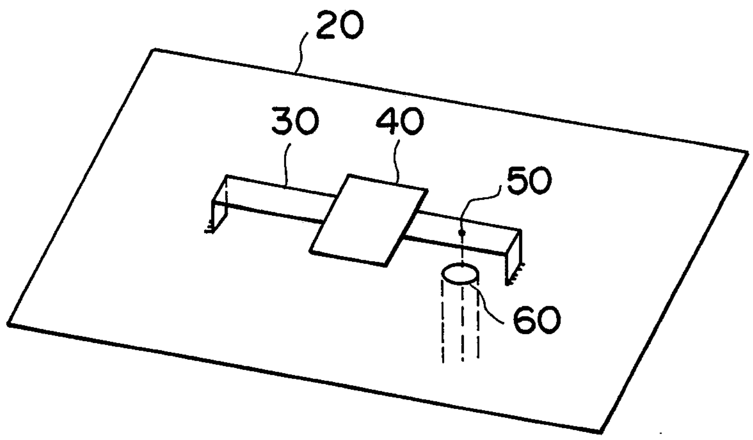
F I G. 1C



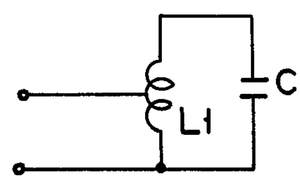
F I G. 2A



F I G. 2B



F I G. 3A



F I G. 3B

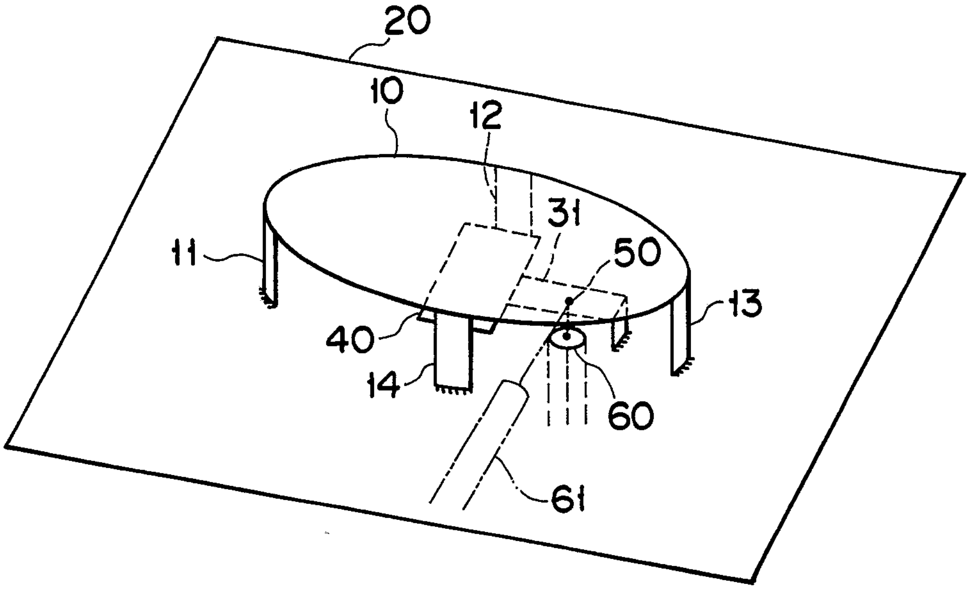


FIG. 4A

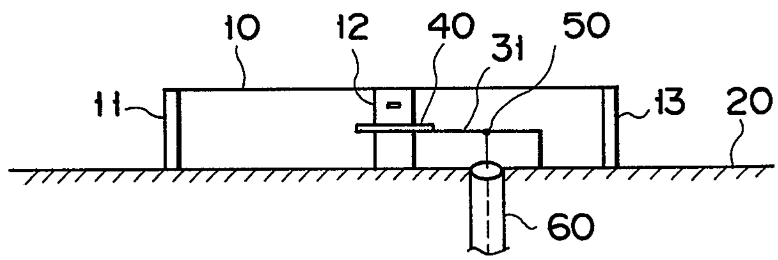


FIG. 4B

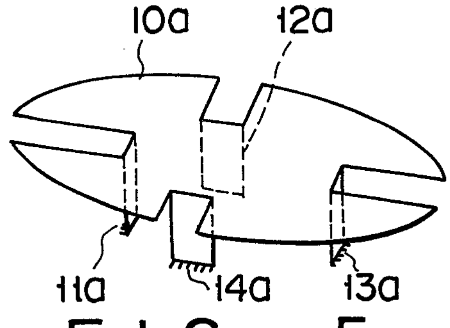


FIG. 5

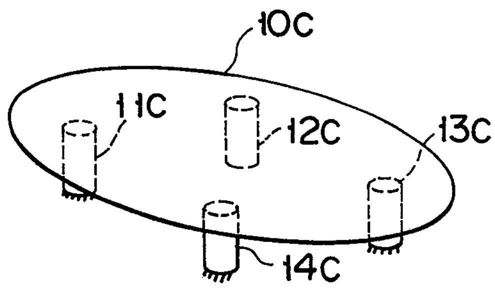


FIG. 6B

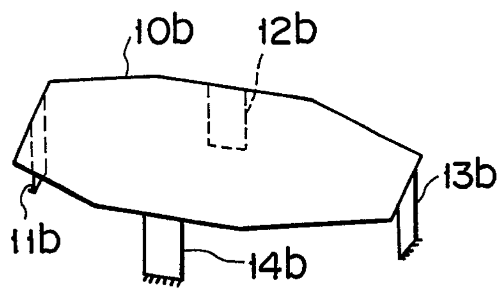


FIG. 6A

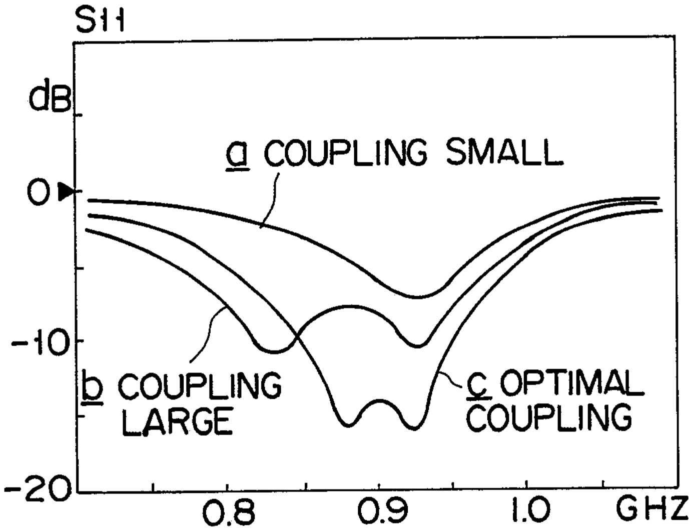


FIG. 7

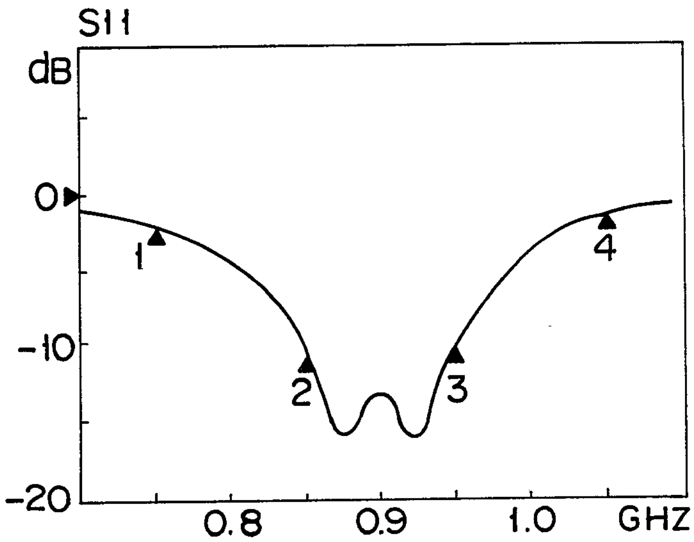


FIG. 8A

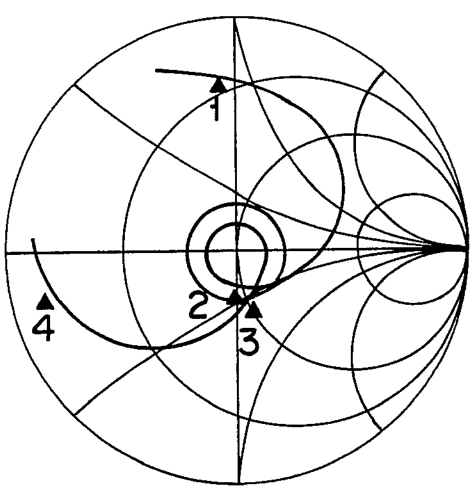


FIG. 8B

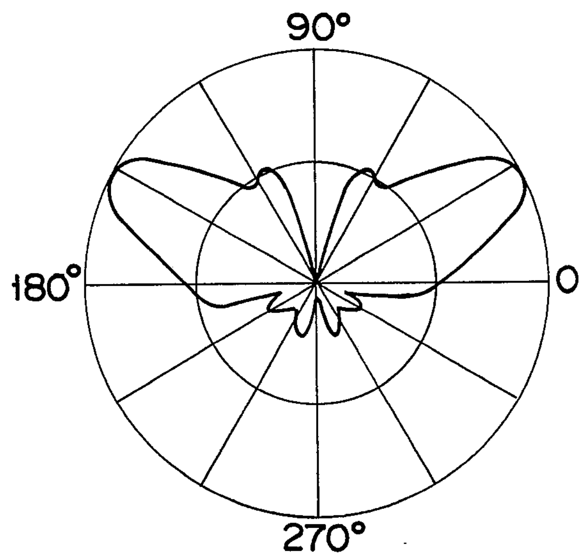


FIG. 9