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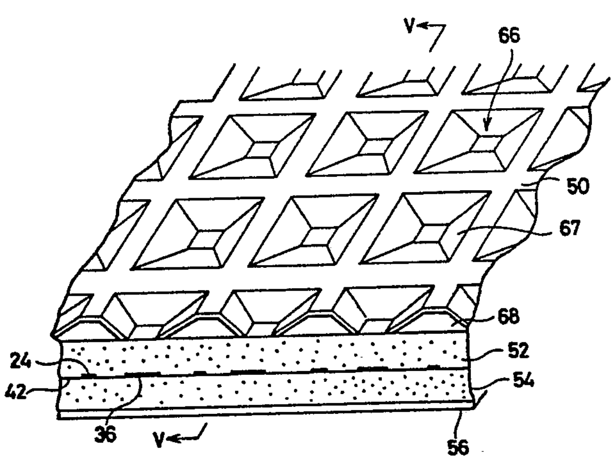
(54) **Planar antenna.**

(57) A planar antenna for receiving satellite broadcasting or the like. The antenna includes a dielectric substrate (42) having a first and a second surfaces; a first conductive plate (50) arranged to face the first surface with a predetermined distance therebetween and having an arrangement of a plurality of openings (66) which allow passage of radio waves therethrough to reach the dielectric substrate (42); a second conductive plate (56) arranged to face the second surface with a predetermined distance therebetween; an arrangement of a plurality of radiating elements (36) each of which is formed on the first surface to have a smaller area than that of one of the openings (66), associated with one of the openings (66), and together with the second conductive plate (56), forming an unbalanced planar circuit resonator which resonates to the radio waves; a signal deriving network (24) formed on the first surface for deriving signals that have been induced by the radio waves in each of the radiating elements (36) to the outside; and a waveguide member (67) provided in each of the openings (66) for guiding the radio waves incident on the opening to the associated radiating element (36) and concentrating the same thereon.

FIG.6



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Planar Antenna

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to planar antennas, and more particularly, to a planar antenna with an arrangement of a plurality of antenna elements which can receive a microwave directly transmitted, for example, from a broadcasting satellite.

Description of the Related Art

With the recent advance in space development technics and telecommunication technology, the so-called Direct Broadcasting from a Satellite (DBS) reception antenna system has acquired a greater importance in terms of industry. This kind of system includes a so-called parabolic antenna or a planar antenna as receiving means. Especially, the planar antenna has many advantages. As it is small in thickness, the planar antenna is not bulky and is easy to handle. Moreover, it is highly immune to damages by wind or snow, is easy to install, and has an appearance superior to the parabolic antenna. Therefore, there exists an increasing demand these days for further development and improvement in the planar antenna.

Fig. 1 is a schematic block diagram of the DBS receiving system including a planar antenna. Referring to the diagram, a planar antenna 20 generally includes a plurality of antenna elements 22 arranged two-dimensionally and combined by a feeder 24. An output terminal 26 of the feeder network is connected to a converter 28 for converting frequency of a microwave transmitted from a broadcasting satellite (not shown) and received by the antenna elements 22 from about 12 GHz into about 1 GHz. The converter 28 is connected through a coaxial cable 30 to a tuner 32, which is connected to a television set 34.

Referring to Fig. 1, operation of a general DBS receiving system will be described. A microwave transmitted from a broadcasting satellite (not shown) simultaneously reaches each of the antenna elements 22 as a plane wave. The antenna elements 22 are excited by the microwave so that high-frequency signals are induced therein. The high-frequency signals are entered in the converter 28 through the feeder 24. The feeder 24 will be selected to be of a length which allows the high-frequency signals from the antenna elements 22 to be combined in the same phase before applied to the converter 28.

The signals that have been converted to be of about 1 GHz frequency and amplified in the converter 28 are applied to the tuner 32. The tuner 32 extracts those on desired channels out of the signals that have been frequency-converted to be in the 1 GHz band, separates them into audio and video signals, and gives them to the television set 34.

A detailed description of the planar antenna is provided, for example, in "PLANAR ANTENNAS FOR SATELLITE RECEPTION" by Koichi Ito et al (IEEE TRANSACTIONS ON BROADCASTING, Vol. 34, No. 4, December 1988, pp. 457-464). In the following, outline of a conventional planar antenna will be described.

Referring to Fig. 3, an antenna element 22 employed in the conventional planar antenna is a suspended line feeder antenna including a dielectric substrate 42, a radiating element 36 formed of a conductor on one side of the dielectric substrate 42, a feeder 24, a first ground plane 38 that is formed of a conductor, arranged to face the surface of the dielectric substrate 42 having the radiating element 36 formed thereon and has a projection 46 extending to contact the dielectric substrate 42 on the periphery of the antenna element 22 and a radiation hole 44 for passing a microwave therethrough at a portion facing the radiating element 36, and a second ground plane 40 formed of a conductor, arranged on the side opposite to the first ground plane 38 with respect to the dielectric substrate 42 and has a projection 48 extending towards the dielectric substrate 42 for supporting, together with the projection 46, the dielectirc substrate therebetween.

Fig. 2 is a diagram showing an arrangement of the radiating elements 36 and the feeder 24. The planar antenna includes a two-dimensional arrangement of 200 to 1000 antenna elements 22 shown in Fig. 3.

Referring to Fig. 3, the antenna element 22 includes a microstrip resonator constituted of the dielectric substrate 42, the radiating element 36, the first ground plane 38 with the radiation hole 44, and the second ground plane 40. The dielectric substrate 42 is supported by the projections 46 and 48 therebetween and suspended at a prescribed distance from the ground planes 38 and 40. The feeder 24 is supported by the dielectric substrate 42 in the air so as to reduce loss of the signals propagated through the feeder 24.

The radiating element 36 has dimensions to resonate to a radio wave of a frequency in the microwave band (about 12 GHz) employed in the

DBS reception. That is, the radiating element 36 is a disc of a microwave-length multiplied by $1.84/\pi$ in diameter or a square with sides of about a half-microwave length.

The microwave transmitted from a broadcasting satellite (not shown) reaches the radiating element 36 through the radiation hole 44 to excite it, inducing a high-frequency signal. The induced high-frequency signal is propagated through the feeder 24 as described above and entered in the converter 28 of Fig. 1. Since a number of high-frequency signals from the antenna elements 22 are combined in the same phase and entered in the converter 28, reception of the satellite broadcasting can be attained with good output.

The conventional planar antenna has, however, drawbacks as will be described below. Each antenna element is too small to provide high gain. Therefore, a number of antenna elements are necessary to receive the DBS with high-fidelity. A number of antenna elements need to be connected together for combining the outputs. This result in a longer feeder, increasing loss of the received signals in the feeder. In addition, as a number of antenna elements are closely arranged, mutual coupling occurs between the feeders and between the feeder and the antenna elements, also increasing loss of the received signals. Consequently, receiving efficiency of the conventional planar antenna has been low.

SUMMARY OF THE INVENTION

The present invention has been made to solve the above-mentioned problems.

An aspect of the present invention is to improve receiving efficiency of a planar antenna.

Another aspect of the present invention is to provide a planar antenna which can offer good reception with fewer antenna elements.

Still another aspect of the present invention is to provide a planar antenna which can receive with a receiving efficiency improved by a smaller number of antenna elements that have been made to show higher gain.

A further aspect of the present invention is to reduce loss of received signals in a feeder which derives them from antenna elements.

A still further aspect of the present invention is to reduce a feeder in length which derives received signals from antenna elements.

The above-mentioned problems are solved by a planar antenna which includes a dielectric substrate having a first and a second surfaces, a first conductive plate arranged to face the first surface of the dielectric substrate with a predetermined first distance therebetween and having an arrangement of a plurality of openings which allow radio waves to pass through to reach the dielectric substrate, a second conductive plate arranged to face the second surface of the dielectric substrate with a second predetermined distance therebetween, an arrangement of a plurality of radiating elements each of which is formed on the first surface of the dielectric substrate to have a smaller area than that of the opening, associated with one of the openings and together with the second conductive plate, constitutes an unbalanced planar circuit resonator, a signal deriving network formed on the first surface of the dielectric substrate for deriving signals induced by radio waves in each radiating element to the outside, and a waveguide member provided to each opening for guiding radio waves which have arrived at the opening to the associated radiating element and concentrating the same thereon.

According to a preferred embodiment of the present invention, each waveguide member includes a sidewall member provided around an opening of the first conductive plate to define a waveguide path for guiding radio waves that have arrived at the opening to the associated radiating element.

According to a more preferred embodiment of the present invention, the sidewall member is conductive.

According to a still more preferred embodiment of the present invention, the waveguide path defined by the sidewall member has a frustum configuration with the opening as a bottom surface and a second smaller opening as a top surface.

Radio waves that have arrived at an opening of the first conductive plate are guided by the waveguide member toward a radiating element and simultaneously concentrated thereon. That is, the incoming radio waves are guided by the waveguide path having a frustum configuration defined by the sidewall, and applied to the radiating element through the second opening.

The second opening has a smaller area than the opening of the first conductive plate and the radio waves travelling in the waveguide path are reflected to concentrate on the second opening. Therefore, amount of the radio waves applied to the radiating element becomes larger when compared with a case where no such waveguide member is used. Accordingly, amount of the signals induced in each of the radiating elements also becomes larger.

With the planar antenna according to the present invention, the incoming radio waves can be received by a smaller number of radiating elements, providing the same outputs as in the conventional planar antenna. The reduction in number of radiating elements makes it possible to reduce the length of a signal deriving network such as a feeder which connects the radiating elements together to derive the induced signal to the outside. With the reduction of feeder length, the feeder loss is also reduced. Furthermore, since the radiating elements with enlarged spacings therebetween provides good output, mutual couplings between the radiating elements and the feeder or between the feeders are reduced in magnitude. As a result, the feeder loss is further reduced, improving receiving efficiency.

Consequently, a planar antenna with an improved receiving efficiency can be provided.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a conventional DBS reception system.

Fig. 2 is a plan view of a plurality of radiating elements and feeders.

Fig. 3 is a sectional view of a single antenna element of a conventional planar antenna.

Fig. 4 is an exploded perspective view of a planar antenna according to a preferred embodiment of the present invention.

Fig. 5 is a sectional view of a part of the planar antenna according to the preferred embodiment of the present invention.

Fig. 6 is a partial fragmentary perspective view of the planar antenna according to the preferred embodiment of the present invention.

Fig. 7 is a sectional side elevation of a first ground plane.

Fig. 8A is a perspective view of a first member of the first ground plane.

Fig. 8B is a perspective view of a second member of the first ground plane.

Fig. 9 is a schematical diagram showing an arrangement of radiating elements, feeders and radiation holes of the planar antenna according to the preferred embodiment of the present invention.

Figs. 10 and 11A are plan views of the first member of the first ground plane.

Figs. 11B and 11C are sectional views of the first member of the first ground plane.

Figs. 12 and 13A are plan views of the second member of the first ground plane.

Figs. 13B and 13C are sectional views of the second member of the first ground plane.

Fig. 14 is a sectional view of an antenna element of a planar antenna according to a second preferred embodiment of the present invention.

Fig. 15 is a plan view of a first ground plane showing a radiation hole formed in a planar antenna according to a third preferred embodiment of the present invention.

Fig. 16 is a sectional view taken in the direction of the arrows XVI-XVI of Fig. 15.

Fig. 17 is a perspective view of the first ground plane and the radiation hole shown in Figs. 15 and 16.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figs. 4 to 6, a planar antenna 58 according to an embodiment of the present invention includes a dielectric substrate 42 having radiating elements 36 and feeders 24 formed on one side, a dielectric spacer 52 arranged on the side of the dielectric substrate 42 on which the radiating elements 36 are formed, a first ground plane 50 formed of a conductor to be arranged on the dielectric spacer 52 and having a plurality of radiation holes 66 of the same dimensions each formed in a position corresponding to one of the radiating elements 36, a dielectric spacer 54 arranged on the opposite side of the dielectric substrate 42 with respect to the first ground plane 50, and a second ground plane 56 formed of a conductor arranged under the dielectric spacer 54.

The first ground plane 50 includes a first member 50a having square openings 62 each of which is formed in a position corresponding to one of the radiating elements 36, and a second member 50b having openings 64 of the same configuration as that of the openings 62. The first and second members 50a and 50b are positioned and bonded to each other such that the openings 62 and 64 fit in with each other.

Referring to Fig. 8A, on any opposite sides of the square opening 62 in the first member 50a, there is formed one pair of isosceles trapezoid extensions 70a and 70b each of which extends downward toward the center of the opening 62. Similarly, referring to Fig. 8B, on the opposite sides of the square opening 64 that do not correspond to the sides of the extensions 70a and 70b, there is formed one pair of isosceles trapezoid extensions 72a and 72b extending downward in the same manner.

The first and second members 50a and 50b, the dielectric spacer 52, the dielectric substrate 42, the dielectric spacer 54 and the second ground plane 56 are fixed to each other by screws 60a to 60d at their corners. The first and second members 50a and 50b are put one upon another such that the openings 62 and 64 fit in with each other as described above, forming the first ground plane 50. Each one of the openings 62 is superposed to one of the openings 64 and forms a radiation hole 66, sides of which are defined by sidewalls 67 formed of one pair of the extensions 70a and 70b and another pair of the extensions 72a and 72b adjoining each other closely.

Configuration and dimension of the extensions 70a, 70b, 72a and 72b are selected such that the radiation hole 66 has a sectional contour of a small square at the bottom (where the first ground plane 50 contacts the dielectric spacer 52) and a sectional contour of a large square at a surface of the first ground plane 50. Therefore, as shown in Figs. 5 to 7, the radiation hole 66 forms an electromagnetic horn which extends to take the form of a frustum of pyramid.

Referring to Fig. 9, an arrangement of the radiating elements 36 and a circuit pattern of the feeders 24 are formed on a dielectric substrate (not shown) by etching a conductive foil. Each of the radiating elements 36 is a square with one side being of about a half-microwave length. The radiating elements 36 and the radiation holes 66 are formed in such positions as will allow them to be superposed in a concentric relationship with each other in assembling.

In this preferred embodiment, each side of the radiating element 36 and each side of the square section of the radiation hole 66 forms, for example, 45° with each other. While theoretically definite reasons therefor have not been found, it has been empirically known that this angle of 45° allows an antenna element to show a highest possible gain. The radiating element 36, together with the second ground plane 56, forms an unbalanced planar circuit resonator.

Referring to Figs. 2 to 9, operation of the planar antenna according to the preferred embodiment of the present invention will be described below. A microwave transmitted from a signal source such as a broadcasting satellite (not shown) reaches the first ground plane 50 of the planar antenna 58 as a planar wave. The microwave which has arrived at an opening of a radiation hole 66 in the first ground plane 50 further travels to the bottom of the radiation hole 66. At this time, such a microwave as having reached sidewalls 67 of the radiation hole 66 is reflected there and further travels toward another opening formed in the bottom of the radiation hole 66 with its travelling direction changed. Therefore, inside the radiation hole 66, the waves reflected by the sidewalls and other direct waves are superposed and concentrated on the radiating element 36.

Since the radiating elements 36 and the second ground plane 56 constitute a resonator, the radiating element 36 is excited by the microwave. In the radiating element 36, a high-frequency signal is induced by the incoming microwave.

The induced high-frequency signals are collected as received signals into the converter 28 through the feeders 24 as shown in Fig. 1.

In the planar antenna according to this preferred embodiment, the radiation holes 66 formed in the first ground plane 50 serve as electromagnetic horns. Therefore, the radio waves that have arrived at a larger area than that of the radiating element 36 are concentrated on the radiating element 36 by the radiation hole 66. Accordingly, the radiating element 36 shows a higher gain, so that even a smaller number of the elements enables full reception of the microwaves.

Furthermore, since the antenna elements need not be arranged closely to each other, mutual couplings between the feeders and between the feeders and the radiating elements are reduced and thus loss of the received radio waves will be reduced. This enables also reduction in the entire length of the feeder, so that the loss of the received radio waves through the feeder will be further diminished.

As shown in Fig. 9, if the feeder 24 is arranged in a position where it is shielded by a cavity 68 formed between adjacent two radiation holes 66, the feeder loss can be further reduced. As a result, a planar antenna superior to the conventional one in its receiving efficiency can be obtained.

The first and second members 50a and 50b, as shown in Figs. 8A and 8B, respectively, may be formed in the following manner. Referring to Fig. 10, a plate formed of a conductor such as a metal plate is prepared for the first member 50a, in which a punched hole 62a as shown by hatching is formed by press work or the like. The hole 62a has a form of a square with two extensions 70a and 70b of isosceles trapezoid cut out from any opposite sides.

Referring to Figs. 11A to 11C, the two isosceles trapezoids 70a and 70b are folded downward at their bases. The isosceles trapezoids 70a and 70b form any opposite sides 67 of the radiation hole 66.

Referring to Figs. 12 to 13C, the second member 50b also has a hole 64a formed therein which leaves likewise two isosceles trapezoids 72a and 72b. The isosceles trapezoids 72a and 72b are also folded downward at their bases.

The first and second members 50a and 50b are bonded to each other by soldering or the like, forming the first ground plane 50. The isosceles trapezoids 70a, 70b, 72a and 72b adjoin each other closely, forming sidewalls 67 of the radiation hole 66. The angles formed between these sidewalls 67 and the first ground plane 50 may be adjusted as desired by changing configuration of the punched holes 60a and 64a.

In the preferred embodiment above, between the dielectric substrate 42 and the first and second ground planes 50 and 56 there are interposed the dielectric spacers 52 and 54, respectively. The present invention is characterized, however, by the three-dimensional configuration of the radiation holes 66 formed in the first ground plane 50, so that those dielectric spacers 52 and 54 are not essential to the invention.

Meanwhile, circuit pattern of the feeders 24 should be of different configurations depending on whether the microwave to be received is a right-handed circular-polarized wave or a left-handed one. These types of the circular-polarized waves assigned to the respective countries are predetermined. Further, on the circuit pattern of the feeders, there may be formed parts such as a chip resistor or an FET (Field Effect Transistor).

Referring to Fig. 14, there is shown an antenna element of a planar antenna according to a second embodiment of the present invention. What is different in the antenna element shown in Fig. 14 from the conventional one in Fig. 3 is that below a first ground plane 38 around a radiation hole 44 there is formed an electromagnetic horn defined by sidewalls 45. In Figs. 14 and 3, like parts are represented by like reference numerals and names. Since like parts have also like functions, detailed description thereof will not be repeated here.

Referring to Fig. 14, due to the electromagnetic horn formed by the sidewalls 45, output of the radiating element 36 is increased when compared with that of the conventional one. Therefore, it is apparent that a planar antenna including the antenna elements according to this second preferred embodiment can receive microwaves at a high efficiency just as the planar antenna according to the first preferred embodiment.

According to the first preferred embodiment, the radiation holes 66 have a square section. However, the present invention is not limited thereto, but radiation holes formed on the first ground plane may have any section if only they can function as electromagnetic horns. Figs. 15 to 17 show the first ground plane of a planar antenna according to a third preferred embodiment of the present invention, where the radiation hole has not only a circular section but also corrugated sidewalls.

Referring to Figs. 15 to 17, according to the third preferred embodiment, the first ground plane 50 of the planar antenna has a plurality of funnel-shaped radiation holes 74 arranged therein. The radiation hole 74 is in the form of a frustum of cone which is defined by a sidewall 75 and has a circular opening formed in a surface of the first ground plane 50 as a bottom surface, and an apex toward a radiating element (not shown) cut off in a direction parallel with the surface of the first ground plane 50. The cut-off side of the frustum forms another opening 78 of the radiation hole 74.

Inside the sidewall 75 of the radiation hole 74, there are formed four annular projections 76a to 76d.

With the first ground plane 50 having the radiation holes 74 of the configuration shown in Figs. 15 to 17, the objects of the present invention can also be achieved. In other words, by concentrating the microwaves incident on the opening 74 with a relatively large area on the other opening 78 with a relatively small area by the radiation hole 74 to apply them to a radiating element (not shown), gains of the radiating elements can be increased. As a result, a planar antenna with a good receiving efficiency can be provided as in the first embodiment.

Meanwhile, the first ground plane 50 of this third preferred embodiment may be obtained by molding, for example, a metalized plastic. It goes without saying that the radiation hole may have any shape such as a hexagon as well as a square or circular one.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

There are described above novel features which the skilled man will appreciate give rise to advantages. These are each independent aspects of the invention to be covered by the present application, irrespective of whether or not they are included within the scope of the following claims.

Claims

1. A planar antenna for receiving incoming radio waves, comprising:
a dielectric substrate (42) having a first and a second surfaces;
a first conductive plate (38, 50) arranged to face said first surface with a predetermined first distance therebetween and having an arrangement of a plurality of openings (44, 66, 74) which allow passage of said radio waves therethrough to reach said dielectric substrate (42);
a second conductive plate (40, 56) arranged to face said second surface with a predetermined second distance therebetween;
an arrangement of a plurality of radiating elements (36) formed on said first surface, each radiating element (36) having a smaller area than that of one of said openings (44, 66, 74) and being associated with one of said openings (44, 66, 74),
each of said radiating elements (36), together with

said second conductive plate (40, 56), forming an unbalanced planar circuit resonator which resonates to said radio waves;
signal deriving means (24) formed on said first surface for deriving signals which have been induced by said radio waves in each of said radiating elements (36) to the outside; and
waveguide means provided in each of said openings (44, 66, 74) for guiding and concentrating said radio waves that arrive at the opening (44, 66, 74) to and on said associated radiating element (36).

2. The planar antenna according to claim 1, wherein
each of said waveguide means is provided around said opening (44, 66, 74) in said first conductive plate (38, 50) and comprises sidewall members (45, 67, 75) defining a waveguide path through which said radio waves that arrive at said opening (44, 66, 74) are guided to said associated radiating element (36).

3. The planar antenna according claim 2, wherein
said sidewall members (45, 67, 75) are conductive.

4. The planar antenna according to claim 3, wherein
said waveguide path defined by said sidewall members (45, 67, 75) is in the form of a frustum which has said opening (44, 66, 74) as a bottom surface and a second opening smaller than said opening (44, 66, 74) as a top surface.

5. The planar antenna according to claim 4, wherein
said frustum is a frustum of cone.

6. The planar antenna according to claim 5, wherein
said waveguide means further comprises projections (76a to 76d) provided on the sides of said sidewall members (75) defining said waveguide path.

7. The planar antenna according to claim 4, wherein
said frustum is a frustum of pyramid.

8. The planar antenna according to claim 7, wherein
said frustum is a frustum of quadrangular pyramid.

9. The planar antenna according to claim 2, further comprising:
first conductive plate supporting means for supporting said first conductive plate (38, 50) in a position spaced said first distance apart from said dielectric substrate (42).

10. The planar antenna according to claim 9, wherein
said first conductive plate supporting means comprises a dielectric layer (52) sandwiched between said first conductive plate (50) and said dielectric substrate (42).

11. The planar antenna according to claim 2, further comprising:
second conductive plate supporting means for supporting said second conductive plate (40, 56) in a position spaced said second distance apart from said dielectric substrate (42).

12. The planar antenna according to claim 11, wherein
said second conductive plate supporting means comprises a dielectric layer (54) sandwiched between said second conductive plate (56) and said dielectric substrate (42).

13. The planar antenna according to claim 2, further comprising:
dielectric substrate supporting means for supporting said dielectric substrate (42) spaced said first distance apart from said first conductive plate (38) and said second distance apart from said second conductive plate (40).

14. The planar antenna according to claim 13, wherein
said dielectric substrate supporting means comprises:
a first projection member (46) provided on a surface of said first conductive plate (38) which faces said dielectric substrate (42) to project and be in contact with said first surface of said dielectric substrate (42); and
a second projection member (48) provided on a surface of said second conductive plate (40) which faces said dielectric substrate (42) to project in association with said first projection member (46) and be in contact with said second surface of said dielectric substrate (42) for supporting, together with said first projection member (46), said dielectric substrate (42) in a suspended manner therebetween.

15. A planar antenna for receiving incoming radio waves, comprising a dielectric substrate (42) carrying on one surface thereof an array of radiating elements (36), means (24) for conducting signals induced in said radiating elements out of the antenna, and first and second conductive plates disposed on respective opposite sides of said dielectric substrate and spaced therefrom, the plate which faces said one surface including an array of openings (44, 66, 74) corresponding to and in register with the array of radiating elements, the area of each opening being greater than the area of the respective radiator, and means (67, 45, 75) being provided for guiding the radio waves passing through said openings toward said radiators.

16. A planar antenna having an array of radiating elements mounted on a surface of a dielectric substrate to receive radio waves which pass through respective openings which are formed in a conductive plate spaced from said surface and which have larger areas than the surface areas of the radiating elements, and waveguides which

guide the waves onto the radiators.

FIG.1

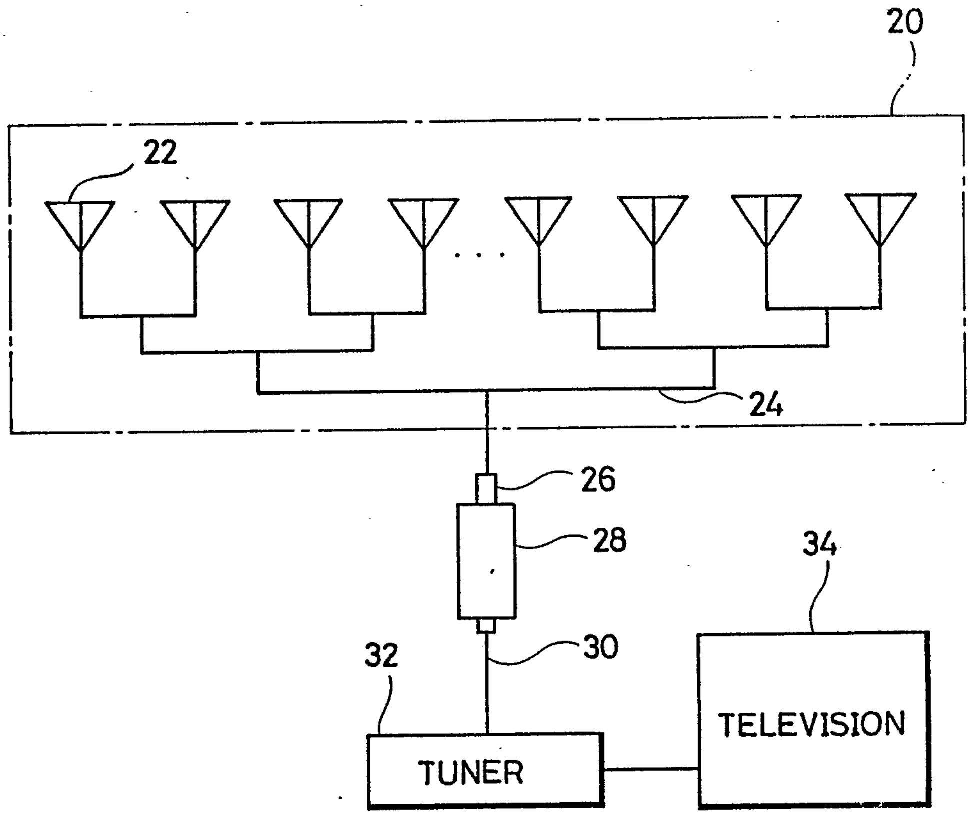

FIG.2

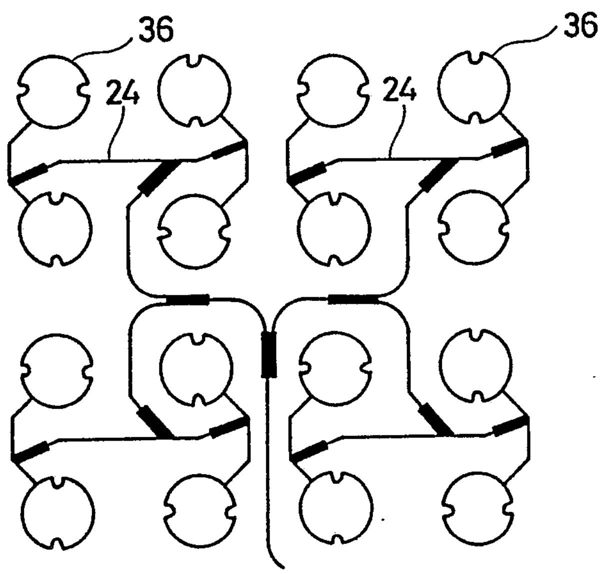

FIG.3 PRIOR ART

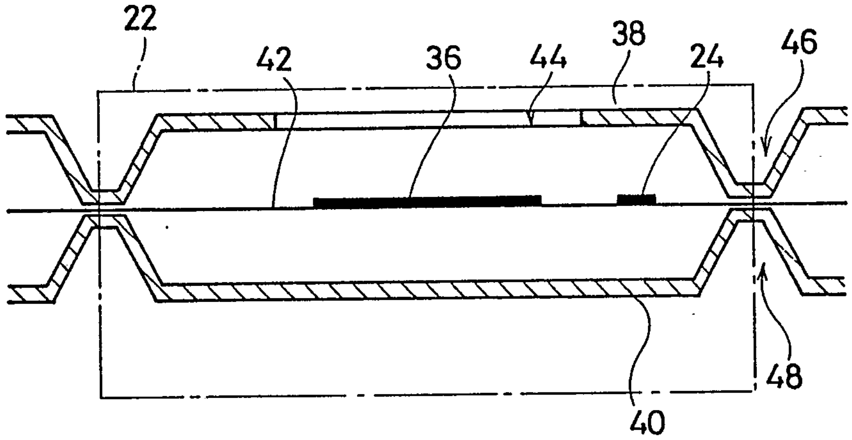

FIG.4

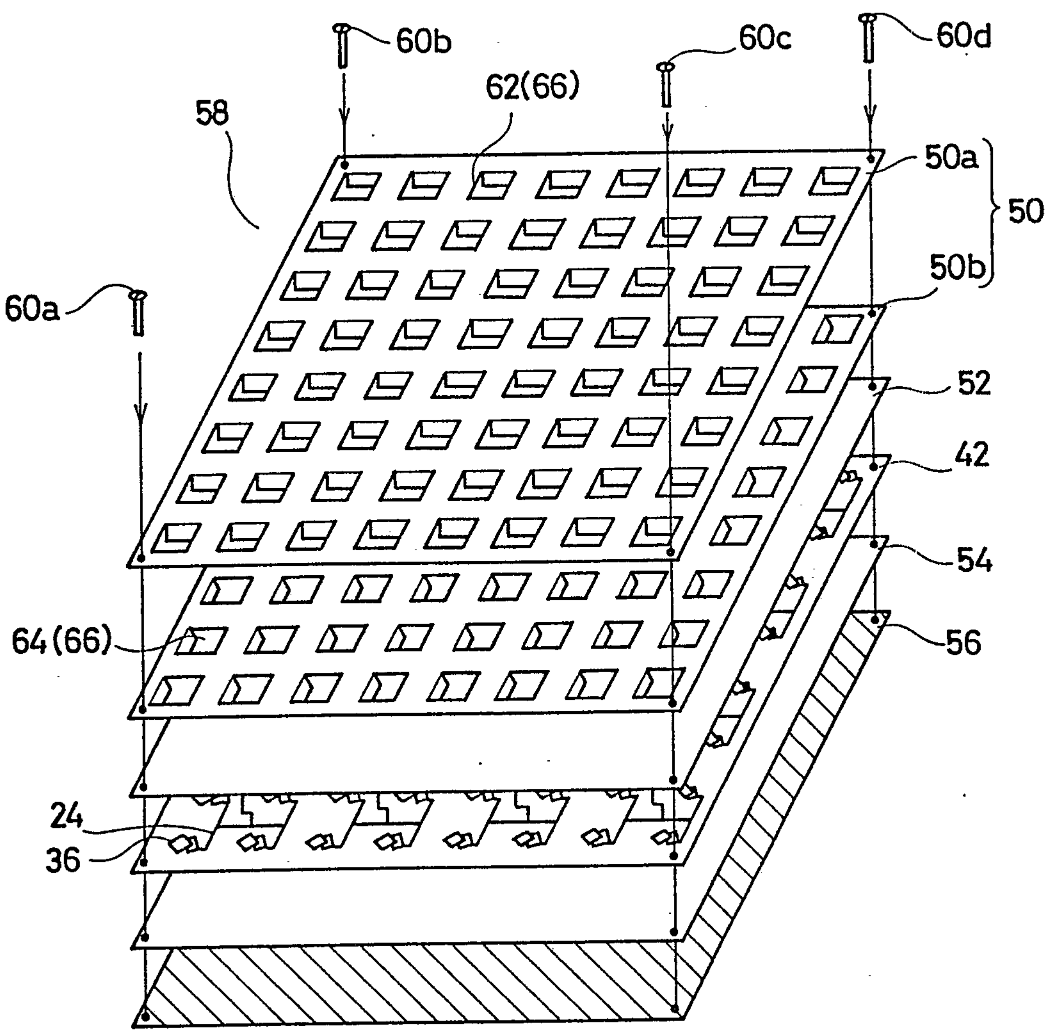

FIG.5

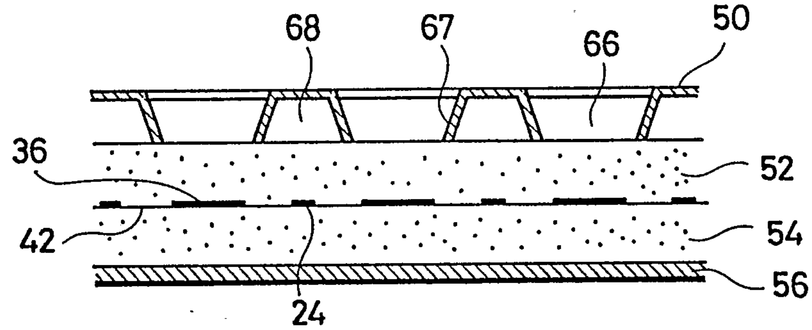

FIG.6

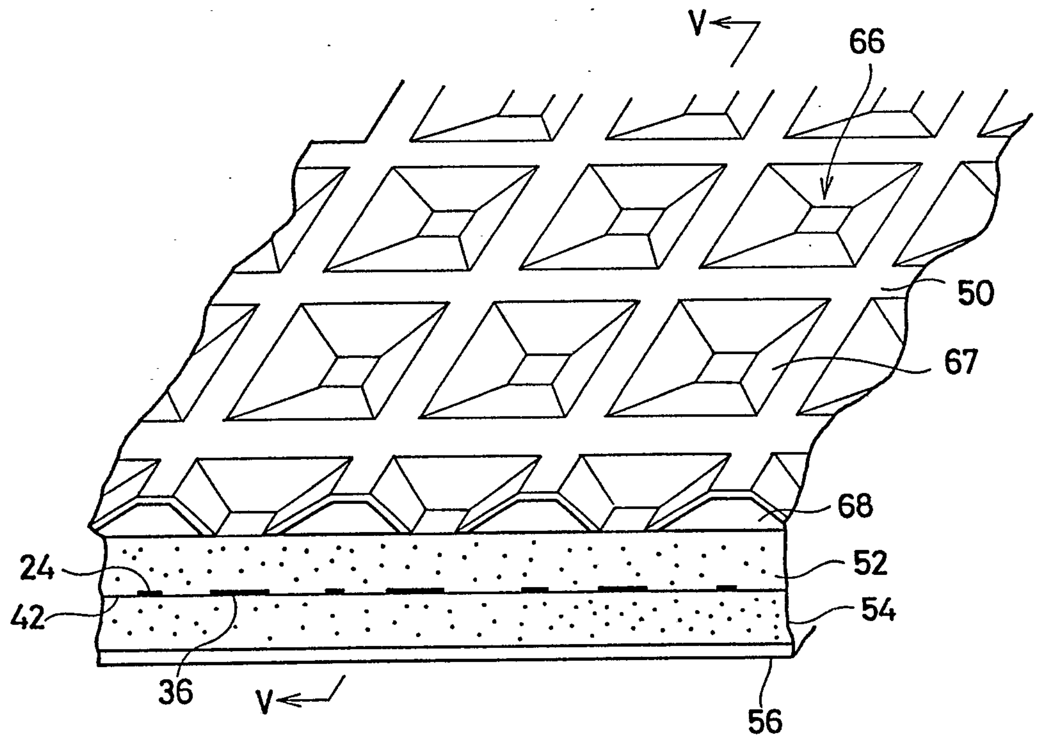

FIG.7

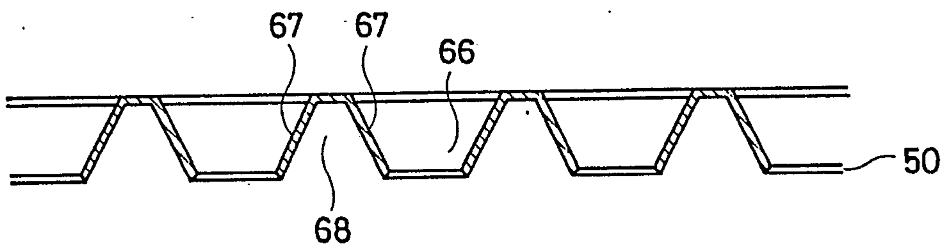

FIG.8A

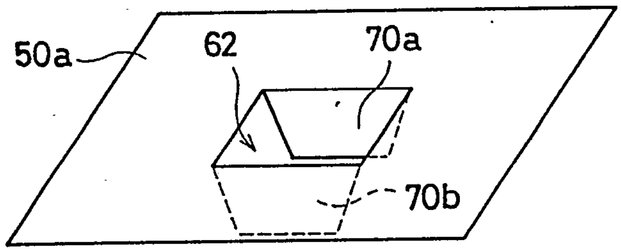

FIG.8B

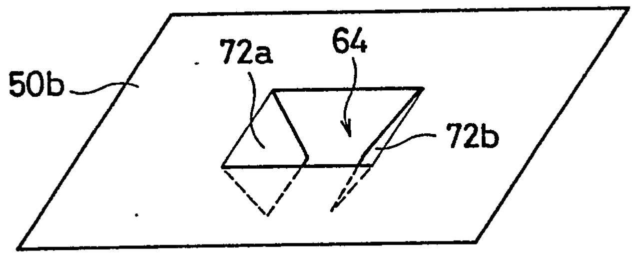

FIG.9

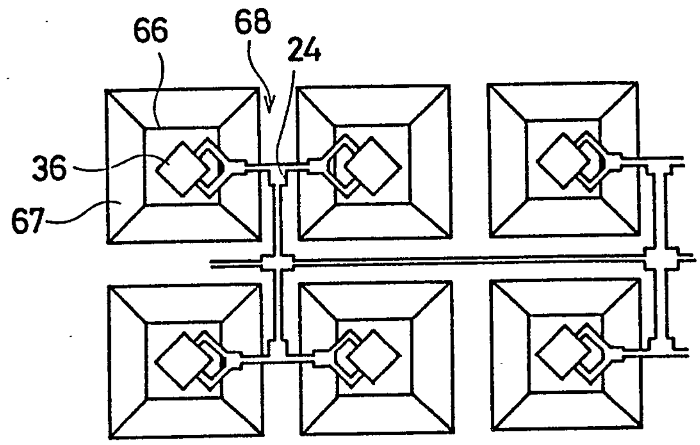

FIG.10

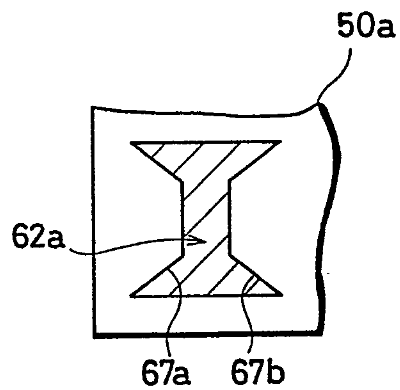

FIG.11A

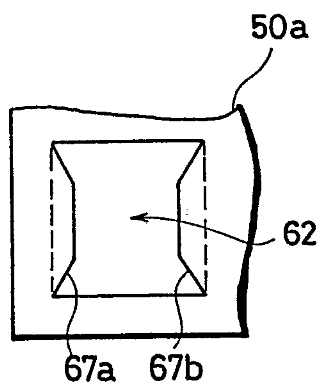

FIG.11C

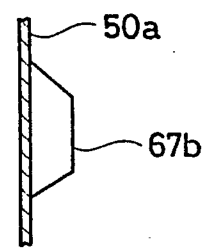

FIG.11B

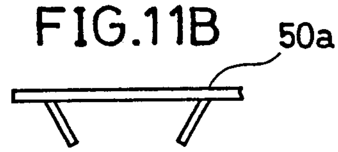

FIG.12

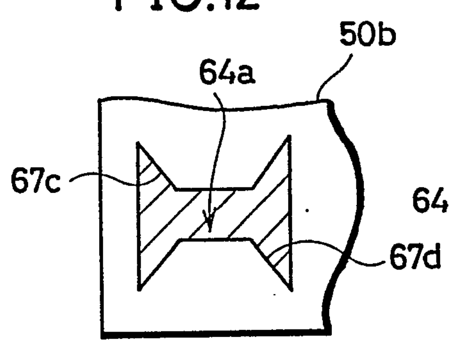

FIG.13A

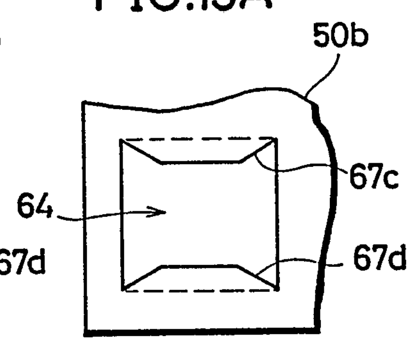

FIG.13C

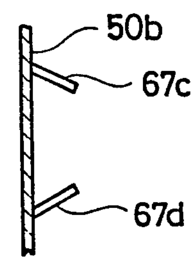

FIG.13B

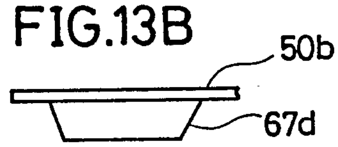

FIG.14

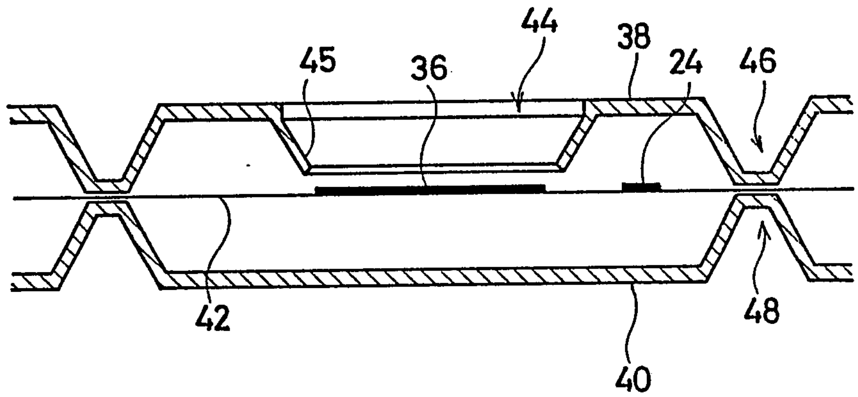

FIG.15

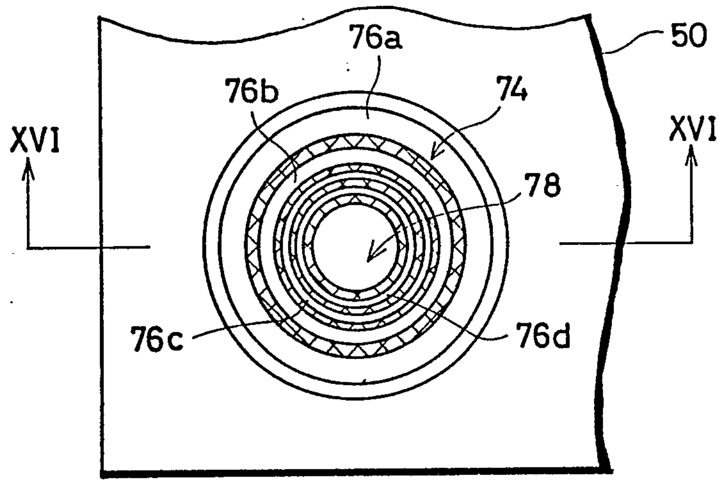

FIG.16

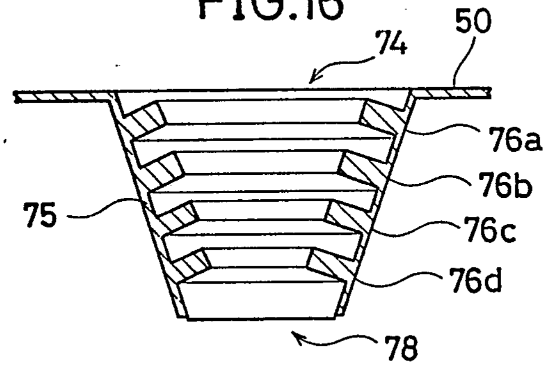

FIG.17