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

(11) EP 0 911 906 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.04.1999 Bulletin 1999/17

(51) Int. Cl.[6]: **H01Q 9/04**, H01Q 1/22, H01Q 5/00

(21) Application number: **98119520.9**

(22) Date of filing: **15.10.1998**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **17.10.1997 US 953251**

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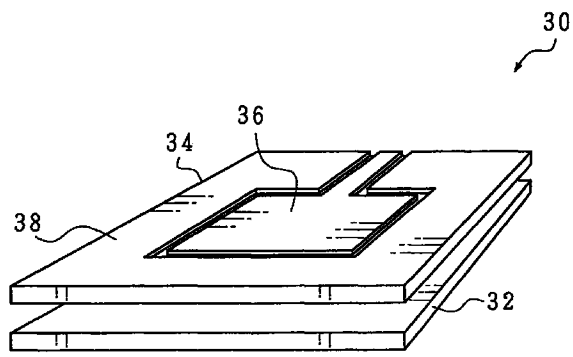
(54) Transparent planar antenna structure

(57) A transparent planar antenna for use over the LCD of a wireless communications unit is provided. The transparent planar antenna is fabricated from a thin film of metal mounted on a transparent insulator. The metal film is etched into either a grid or mesh structure. By proper choice of line widths and the spacing between lines, the conductive surface is made both transparent, and resonant to the opening frequency of the wireless unit. Because of the low resistance of the conductive surfaces, the resulting transparent antenna has substantially the same performance characteristics as traditional patch type antennas.

FIG. 1



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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to a portable wireless communications device and, more particularly, to a transparent planar antenna structure overlying the device's liquid crystal display (LCD).

BACKGROUND OF THE INVENTION

[0002] The size of wireless communications devices continues to shrink, as the use for such devices expands in both well established, and new communication technologies. These communication technologies include pagers, telephones, televisions, GPS and other satellite receivers, and wireless LAN. One of the key elements in the performance of a wireless unit is the unit's antenna. At the same time, the antenna size is a limiting factor in further reducing the size of wireless devices. Whip type antennas are relatively large, and recently, concerns have surfaced regarding the harmful effects of an omni-directional radiation of hand-held transmitters. Further, the whip antenna extends from the chassis and is easily damaged.

[0003] Antennas can be incorporated into, or on the device chassis. One obvious choice of antenna is the so-called patch design. As the name suggests this antenna is built as a thin sheet that can be layered over an existing structure.

[0004] Fig. 13 illustrates the coplanar layout of a panel antenna 10 (prior art). The design of such antennas is well known to consist of a conductive radiating element 12 surrounded by a conductive ground plane 14. The panel antenna 10 can be fabricated, for example, on a PC board with the conductor being a thin film of copper overlying a sheet of dielectric material. The radiating element 12 is patterned to be electrically isolated from the ground plane 14. The radiating element 12 and the ground plane 14 (conductors) are isolated by etching through the copper until a portion 16 of the underlying dielectric material, represented by cross-hatched lines, is exposed.

[0005] Fig. 14 is a partial cross-sectional view of the panel antenna 10 of Fig. 13 (prior art). The radiating element 12 and the ground plane 14 (conductive regions), overlying dielectric layer 18, are represented with cross-hatched lines. The design of an antenna for a coplanar arrangement of the radiating element 12 (radiator) and the ground plane 14 is based on well understood relationships such as the separation between ground planes (b), conductor width (a), the dielectric constant (ε_r) of the dielectric layer 18, thickness (t) of the ground plane 14 (radiator), the thickness (h) of the dielectric layer 18, and the effective wavelength of the intended resonant frequency.

[0006] However, designs which conform to size constrains, often deliver inadequate gain, or highly directional gain. With inadequate gain, the electrical performance of the associated wireless unit is compromised, and information transfer becomes unsure. Even when antennas can be mounted on a chassis, the continuing reduction of chassis sizes makes the placement of antennas, which provide adequate coverage, difficult.

[0007] The design of a cellular telephone illustrates the difficulties of antenna design. Typically, half of the surface area of the phone is occupied with user-operated switches, such as a keypad, and an electronic display for viewing. Usually, the keypad and LCD display are co-located on the same "side" of the phone so that the operator can see the results of keypad manipulations. It is difficult to locate an antenna on this user-interface side of the telephone. Consumer preference for larger displays and improvements in technology increasing the size of LCDs act to further limit the area available for the placement of conventional or patch antennas.

[0008] Even if an antenna can be placed on the opposite side of the phone from the display, the antenna will likely only provide hemispheric, or kidney shaped coverage, in the direction in which the antenna faces. Wireless units with directional antenna gain frequently lose contact with base stations or communicating wireless units as the phone operator changes positions. In the least, communicating base stations must be frequently changed, making communications difficult, and using large amounts of communication overhead to support base station selections. It is possible to use multiple directional antennas in a system to provide combined omni-directional coverage. However, the placement of two antennas on a wireless unit is even more difficult than mounting one antenna, especially when a considerable surface area is occupied by the electronic display and keypad.

[0009] Many communications devices have both a receiver and a transmitter section, operating at the same, or different frequencies. Other devices have multiple receivers and transmitters. Because of the difficulties in mounting multiple antennas on a wireless unit, the single antenna must be designated to interface to all the various transmitters and receivers, and so must operate over a number of frequency bands. To interface a single antenna to multiple wireless sections requires duplexer circuits, or time multiplexed antenna switches. These circuits degrade antenna performance, add considerable cost to the manufacture of the device, and occupy valuable space inside the chassis.

[0010] Antennas have been constructed to overlie the electronic display sections of small wireless units. Woo et al., U.S. Patent No. 5,627,548 disclose a transparent indium-tin oxide patch antenna overlying an LCD. However, the conductivity of indium-tin oxide is poor, so that the antenna gain resulting from the use of such a conductant is poor. The poor gain, high current loss, and resulting IR (current x resistance) heating makes such a material an even poorer choice for a transmitter antenna.

SUMMARY OF THE INVENTION

[0011] It would be advantageous to eliminate the whip antenna from hand-held devices, and provide an antenna that is more rugged and less likely to radiate energy harmful to the user.

[0012] It would be advantageous if a system of chassis mounted antennas could be provided to provide high gain in an omni-directional radiation pattern.

[0013] It would be advantageous if an antenna could be placed on a chassis in the area of the user-operated functions. Specifically, it would be advantageous if an antenna could be designed to co-exist with the relatively large, planar surface of the visual display panel.

[0014] It would be advantageous if multiple antennas could be mounted on a wireless device to eliminate the need for duplexers and antenna switching circuits.

[0015] Accordingly, a wireless communications device comprising a flat panel electronic visual display and a first transparent planar antenna, having a first operating frequency, is provided. The first antenna includes a highly conductive planar radiating element and a highly conductive planar first ground plane. The first antenna overlies the visual display, so that the display is viewable through the antenna.

[0016] The wireless communications device further comprising a first transparent sheet of thin film. The first antenna includes the radiating element and ground plane being located coplanar overlying the first transparent sheet of thin film. The thin film is selected from the group of materials consisting of polyethylene telephthalate (PET), polyethylesulfone (PES), polyetherimide (PEI), polycarbonate, polyimide, polytetrafluoroethylene, acrylic, glass, and combinations of the above mentioned materials.

[0017] The first antenna radiator (first transparent planar radiating element) and the ground plane include a metal film structure overlying the first thin film patterned to electrically isolate the radiator from the ground plane. The metal film structure is selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines. The material of the metal film structure is selected from the group of materials consisting of copper, aluminum, gold, silver, nickel, chromium, titanium, molybdenum, tin, tantalum, magnesium, cobalt, platinum, tungsten, manganese, silicon, zirconium, vanadium, niobium, hafnium, indium and other alloys of the above mentioned materials. The grid-like structure of the conductors permit the first antenna to be greater than 65 percent transmissive in the band of visible light wavelengths.

[0018] In some aspects of the invention, a second transparent antenna having a second operating frequency, has a radiating element located coplanar to the first transparent planar radiating element. The first and second antenna radiating elements are located coplanar to a shared ground plane. Alternately, the second antenna has a radiating element located on a second thin film, overlying the first thin film, and the first and second antenna radiating elements share the first transparent planar ground plane. The second transparent antenna operates either at the same frequency as the first antenna, or at a different frequency.

[0019] Another alternate design includes a first transparent sheet of thin film on which the first radiating element is mounted, and a second transparent sheet of thin film, underlying the first transparent sheet of thin film, on which the first transparent planar ground plane is mounted. With this planar design the antenna is located in two sheets of overlying thin film.

[0020] In the preferred embodiment, the radiating element is a planar rectangle, or oval shape, as is typical in the design of patch antennas. Alternately, the radiating elements are configured inter-digitally using either a grid of parallel oriented metal lines, or a mesh of orthogonal and parallel oriented metal lines.

[0021] A wireless device having a plurality of receivers and transmitters, each operatively connected to an independent transparent antenna, is also provided. The transparent antennas are as described above. The low cost and low profile of the transparent antennas permit each radio frequency (RF) section of the wireless device to have its own antenna, unlike many prior art wireless devices where RF sections must share a single antenna. In this manner, the necessity of a duplexer circuit is eliminated.

[0022] For a fuller understanding of the nature and advantages of the invention, reference should be made to the ensuing detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Fig. 1 is a cross-sectional view of the transparent panel antenna section of a wireless communications device.

Fig. 2 illustrates, in greater detail, the antenna of Fig. 1.

Fig. 3 illustrates the grid metal film structure.

Fig. 4 illustrates the mesh metal film structure.

Fig. 5 is microscope picture illustrating a detailed section of the grid of Fig. 3.

Fig. 6 illustrates a plurality of transparent antennas.

Fig. 7 illustrates a plurality of non-coplanar transparent antennas.

Fig. 8 illustrates a touch panel in use with the present invention.

Fig. 9 illustrates a non-coplanar embodiment of the present invention.

Fig. 10 depicts an inter-digital antenna embodiment of the transparent antenna of the present invention.

Fig. 11 illustrates non-conductive, or dummy sections of grid and mesh metal structures in use with the transparent antenna of the present invention.

Fig. 12 is a schematic block diagram of a wireless device communicating information at a plurality frequencies.

Fig. 13 illustrates the coplanar layout of a panel antenna.

Fig. 14 is a partial cross-sectional view of the antenna of Fig. 13.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] Fig. 1 is a cross-sectional view of the transparent panel antenna section of a wireless communications device 30. The wireless communications device 30 comprises a flat panel electronic visual display 32. In the preferred embodiment of the invention, the flat panel electronic visual display 32 is a liquid crystal display (LCD). The wireless communications device 30 also comprises at least a first transparent planar antenna 34, having a first operating frequency, a highly conductive planar radiating element 36, and a highly conductive first transparent planar ground plane 38. The first transparent planar antenna 34 overlies the flat panel electronic visual display 32 so that the display 32 is viewed through the first transparent planar antenna 34.

[0025] Fig. 2 illustrates, in greater detail, the first transparent planar antenna 34 of Fig. 1. The wireless communications device 30 further comprises a first transparent sheet of thin film 40. The first transparent planar antenna 34 includes the first transparent planar radiating element 36 and the first transparent planar ground plane 38 being located coplanar and overlying the first transparent sheet of thin film 40, whereby the first transparent planar antenna 34 is located on the single transparent sheet of thin film 40. Alternately, the first transparent planar radiating element 36 and the first transparent planar ground plane 38 are mounted under the first transparent sheet of thin film 40, so that the first transparent sheet of thin film 40 overlies the first transparent planar radiating element 36, the first transparent planar ground plane 38, and the flat panel electronic visual display 32.

[0026] The first transparent sheet of thin film 40 is selected from the group of materials consisting of polyethylene telephthalate (PET), polyethylesulfone (PES), polyetherimide (PEI), polycarbonate, polyimide, polytetrafluoroethylene, acrylic, glass, and combinations of the above mentioned materials. The first transparent sheet of thin film 40 has a thickness t_{42} in the range between 100 and 400 microns.

[0027] The first transparent planar radiating element 36 and the first transparent planar ground plane 38 include a metal film structure 44 overlying the first transparent sheet of thin film 40 patterned to electrically isolate the first transparent planar radiating element 36 (radiator) from the first transparent planar ground plane 38, whereby the metal permits high electrical conductivity in the first transparent planar antenna 34. Typically, the metal film structure 44 is fabricated by depositing a sheet of the metal film material overlying the first transparent sheet of thin film 40. Then, the metal film structure 44 is etched with a variety of processes that are well known in the art of integrated circuit (IC) processing, such as using a patterned photo-resist profile as an etch mask. These processes remove metal material to form the shape of the metal film structure 44, and to electrically isolate the first transparent planar radiating element 36 from the first transparent planar ground plane 38. The metal film structure 44 is selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines. Fig. 3 illustrates the grid metal film structure 44. The conductive lines appear as parallel bars. Fig. 4 illustrates the mesh metal film structure 44. The conductive lines appear as a screen.

[0028] The material of the metal film structure 44 is selected from the group of materials consisting of copper, aluminum, gold, silver, nickel, chromium, titanium, molybdenum, tin, tantalum, magnesium, cobalt, platinum, tungsten, manganese, silicon, zirconium, vanadium, niobium, hafnium, indium and other alloys of the above mentioned materials.

[0029] Fig. 5 is a microscope picture illustrating a detailed section of the grid of Fig. 3. The metal lines have a width in the range between 1 and 30 microns (μm). Specifically, Fig. 5 shows a line width of 10 microns. The parallel oriented metal lines are separated by a distance, or gap in the range between 30 microns and 1 mm. Specifically, Fig. 5 shows a gap of 40 microns. The gap between conductive lines is calculated in response to the operating, or resonant first frequency of the first transparent planar antenna 34. In some cases, the gap is chosen, at least partially, in response to pitch, or the spacing between electrical elements of underlying LCD 32 (not shown). Specifically, by forming each metal line of the metal film structure 44 so as to correspond to a pixel pitch of the flat panel electric visual display 32 (the metal lines which are the non-transparent section of the metal film structure are formed in the non-display area between pixels of the flat panel display section), an improved visibility of the flat panel display section can be achieved. The non-display area between adjacent pixels of the flat panel electric visual display 32 indicates, for example, a space between pixel electrodes of the liquid crystal display, where a black matrix is formed.

[0030] Generally, the gap is chosen to be no greater than one-tenth of the effective first wavelength. The effective wavelength is calculated in response to the thickness t_{46} of the metal film structure 44, and the dielectric constant (ε_r) and thickness t_{42} of the first transparent sheet of thin film 40 (Fig. 2). Because the above-mentioned metal materials are good conductors, and the shape of the metal film structure 44 insures good conductivity, the metal film structure 44 remains very conductive when the metal film thickness t_{46} is thin. The metal film thickness t_{46} is in the range between 300 and 100,000 Å.

[0031] The line widths and gaps forming the metal film structure 44 are also shaped to provide optical transparency. The minimum gap which provides transparency is approximately 30 microns, which is about the width of 1 pixel in an LCD, and the minimum line width is approximately 1 micron. Generally, line widths and gaps between lines are chosen so that the first transparent planar antenna 34 is greater than 65 percent transmissive in the band of visible light wavelengths.

[0032] When the metal film structure 44 is a mesh, as shown in Fig. 4, the gap between parallel and intersecting lines varies from a square shape to a rectangular shape. The square shape has gap dimensions from 30 microns to 1 mm between the parallel lines oriented in a first direction. Alternately, the gap between one set of parallel lines differs from the gap between the set of parallel lines oriented orthogonal to the first direction so that a rectangle is formed. The present invention is not limited to any particular pattern of metal lines, although regularly placed lines and gaps are easier to fabricate. The key feature of the present invention is that the metal film structure 44 be both highly conductive and transparent.

[0033] In some aspects of the invention, the metal film structure 44 is selected from the group of materials consisting of indium-tin, indium-tin oxide, and tin oxide. These materials are not as conductive as the metal, named above. Therefore, the thickness t_{46} (Fig. 2) must be greater to provide equivalent conductance to the metals. Then, the metal film structure 44 has a metal film thickness t_{46} in the range between 0.1 and 10 microns.

[0034] Fig. 6 illustrates a plurality of transparent antennas. In some aspects of the invention, the wireless communications device 30 further comprises a second transparent planar antenna 50 having a second operating frequency, different than the first operating frequency. The second transparent planar antenna 50 has a second transparent planar radiating element 52 located coplanar to the first transparent antenna radiating element 36. The first and second transparent planar radiating elements 36, 52 are located coplanar to a shared first transparent planar ground plane 38. Alternately, the second transparent planar antenna 50 has an operating frequency the same as the first operating frequency. The second transparent planar antenna 50 has the second transparent planar radiating element 52 located coplanar to the first transparent antenna radiating element 36, and the first and second transparent planar radiating elements 36, 52 are located coplanar to the shared first transparent planar ground plane 38.

[0035] The wireless communications device 30 further comprises a plurality of transparent antennas, including at least third and fourth transparent planar antennas 54 and 56. It can be seen from Fig. 6 that the size of the metal film structure 44 is variable to provide enough space for several antennas. For simplicity, only four antennas are shown. Each of the plurality of transparent planar antennas 50, 54, and 56 have a transparent planar radiating element (52, 58 and 60) located coplanar to the first transparent antenna radiating element 36. The plurality of transparent planar radiating elements 36, 52, 58 and 60 are located coplanar to the first transparent planar ground plane 38.

[0036] Fig. 7 illustrates a plurality of non-coplanar transparent antennas. The wireless communications device 30 further comprises a second transparent sheet of thin film 62 overlying the first transparent sheet of thin film 40. The wireless communications device 30 also comprises a second transparent planar antenna 50 having a second operating frequency different than the first operating frequency. The second transparent planar antenna 50 has the second transparent planar radiating element 52 located overlying the second transparent sheet of thin film 62. The first and second transparent planar radiating elements 36 and 52 share the first transparent planar ground plane 38. Alternately, the second transparent planar antenna 50 has an operating frequency the same as the first operating frequency.

[0037] In some aspects of the invention, the wireless communications device 30 further comprises a plurality of sheets of thin film overlying the first transparent sheet of thin film 40, and a plurality of transparent antennas having a plurality of corresponding radiating elements. Each one of the plurality of transparent planar radiating elements overlies a corresponding one of the plurality of sheets of thin film, and each radiating element shares the first transparent planar ground plane 38. For simplicity and clarity, only a third transparent planar antenna 54, including a third transparent sheet of thin film 70 and a third transparent planar radiating element 58, are shown in Fig. 7. However, it can be seen that additional antennas are stackable overlying the third transparent planar antenna 54. A cross-section of the third transparent planar antenna 54 is shown removed to provide a clear view of the second transparent planar antenna 50.

[0038] Fig. 8 illustrates a touch panel in use with the present invention. The wireless communications device 30 further comprises a transparent user-activated touch panel 74 overlying the flat panel electronic visual display 32. The use of touch panels, such as touch panel 74, overlying computer screens and electronic displays is a well known computer interface for use either without, or in addition to, a keypad. The touch panel 74 including user-activated sensors 75 corresponding to visual prompts represented on the flat panel electronic visual display 32 visible through the first transparent planar antenna 34 and the transparent touch panel 74. The thin film materials and thicknesses of the touch panel 74 are similar to the first transparent sheet of thin film 40 of the first transparent planar antenna 34. Alternately, the touch panel 74 is placed between the first transparent planar antenna 34 and the flat panel electronic visual display 32. In one aspect of the invention, the transparent touch panel 74 and the first transparent planar antenna 34 are both mounted on the first transparent sheet of thin film 40. For example, the first transparent planar antenna 34 and the touch panel 74 are fabricated on the same transparent sheet of thin film 40 with the conductive regions of the first transparent planar antenna 34 and the touch panel 74 on opposite sides of the first transparent sheet of thin film 40.

[0039] Fig. 9 illustrates a non-coplanar embodiment of the present invention. The wireless communications device 30 comprises a fourth transparent sheet of the thin film 76 on which the first transparent radiating element 36 is mounted, and a fifth transparent sheet of thin film 78, underlying the fourth transparent sheet of thin film 76, on which the first transparent planar ground plane 38 is mounted. The first transparent planar antenna 34 is located on two sheets of overlying sheets of thin film 76 and 78.

[0040] Fig. 10 depicts an inter-digital antenna embodiment of the transparent antenna of the present invention. The wireless communications device 30 of Fig. 1 further comprises a second transparent planar antenna 50 having a second operating frequency. The second transparent planar radiating element 52 is located coplanar to the first transparent antenna radiating element 36. The first and second transparent planar radiating elements 36 and 52 are co-located in the inter-digital metal film structure 44. The first and second transparent planar antennas 34 and 50 are located with a coplanar ground plane (not shown, see Fig. 1). Alternately, the ground is on a different plane (not shown, see Fig. 9) from the transparent planar radiating elements (36, 52). The spacing between the digits of the first and second transparent planar radiating elements 36 and 52 is dependent are the operating frequencies of the first and second transparent planar antennas 34 and 50, the effective wavelengths, and the mutual parasitic effects of antennas being closely located.

[0041] Fig. 10 is not drawn to scale. The digits, as drawn, appear visible with respect to the overall panel only for the purpose of showing the alternating digits of the first and second transparent planar antennas 34 and 50. Since the grid and mesh line widths and gaps are actually on the order of microns, they are not typically visible to the human eye. As explained above and shown in Figs. 3 through 5, the inter-digital metal structure 44 is selected from the group consisting of a grid of parallel oriented lines and a mesh of orthogonal and parallel oriented metal lines. The metal lines have a width in the range between 1 and 30 microns, with a spacing between parallel oriented metal lines in the range between 30 microns and 1 mm. As shown in Fig. 10, the space between lines or sections of mesh include the digits of another antenna. A mesh version of the second transparent planar radiating element 52 is shown in Section A, and the grid versions of the transparent planar radiating elements 36 and 52 are shown in Section B of Fig. 10.

[0042] Fig. 11 illustrates non-conductive, or dummy sections of grid and mesh metal structures 80 in use with the first transparent planar antenna 34 of the present invention. The non-conductive metal film structure 80 overlies the first transparent sheet of thin film 40 (not shown) and is patterned to be an electrical isolator. The non-conductive metal film structure 80 is selected from the group consisting of a grid of parallel oriented non-conductive metal lines and a mesh of orthogonal and parallel oriented non-conductive metal lines. The non-conductive grid, Section A of Fig. 11, and the non-conductive mesh, Section B of Fig. 11, are similar to the conductive grid and mesh metal structures 44, discussed above and shown in Figs. 3, 4 and 5. However, there are breaks in the grid and mesh patterns so that they do not conduct electrically. Typically, the non-conductive grid and mesh structures 80 are used in the same antenna as conductive grid and mesh structures 44 to normalize transparency. That is, to make the transparency through the non-conductive areas surrounding the first transparent radiating element 36 and the first transparent planar ground plane 38 the same as the first transparent planar radiating element 36 and the first transparent planar ground plane 38.

[0043] Fig. 12 is a schematic block diagram of the wireless communications device 30 communicating information at a plurality of frequencies. The wireless communications device 30 comprises at least a first receiver 90 (first communicating section) having an input operatively connected to a line 92 to receive information at a first operating frequency. The wireless communications device 30 further comprises at least a second receiver 94 (second communicating section) having an input operatively connected to a line 96 to receive information at a second operating frequency, different than the first operating frequency. The wireless communications device 30 comprises the first transparent planar antenna 34 including a highly conductive first transparent planar radiating element 36 and the first transparent planar ground plane 38, as described above and shown in Figs. 1-5 and 8-11. The first transparent planar antenna 34 is operatively connected to the first receiver 90 without any operative connection to the second receiver 94. The wireless communications device 30 comprises the second transparent planar antenna 50 as described above and shown in Figs. 6 and 7. The second transparent planar antenna 50 includes the highly conductive second transparent planar radiating element 52 and the first transparent planar ground plane 38. The first transparent planar ground plane 38 is coplanar with the second transparent planar radiating element 52 as shown in Fig. 6. Alternately, the first transparent planar ground plane 38 is on a different plane than the second transparent planar radiating element 52, as shown in Fig. 7. The second transparent planar antenna 50 is operatively connected to the second receiver 94 without any operative connection to the first receiver 90.

[0044] The first and second transparent planar radiating elements 36 and 52 and the first transparent planar ground plane 38 are the metal film structures 44 selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines, as described above and shown in Figs. 3-5. The use of two antennas eliminates the need for a duplexer circuit as is needed in many wireless communications devices to de-couple multiple receivers when they share only one antenna.

[0045] Alternately, the second receiver 94 is replaced with at least a transmitter 98 (second communicating section) having a second operating frequency, different than the first operating frequency. In another aspect of the invention, the second operating frequency is the same as the first operating frequency. The wireless communications device 30 has separate antennas, the first transparent planar antenna 34 operatively connected to the first receiver 90, and the second transparent planar antenna 50 operatively connected to the transmitter 98. As described above, the use of two antennas eliminates the need for a duplexer circuit. Because of the low cost and low profile of the present invention transparent antenna, the wireless communications device 30 is able to provide a separate antenna for each radio frequency section of the communications device without the use of either duplexers or antenna switches. The use of independent transparent antennas for each of a plurality of receiver and transmitter sections is also an application of the present invention.

[0046] Typically, additional circuitry such as amplifiers and filters interface between the first and second transparent planar antennas 34 and 50, and receivers 90 and 94, and transmitter 98, as is well known in the art. Further, the above mentioned devices must be interfaced with conductive lines having precisely defined impedances. The conductive lines interfacing the first and second transparent planar radiating elements 36 and 52 are transparent when mounted on the thin film, and fabricated with conductive grid and mesh metal structures 44. In some aspects of the invention, amplifiers, filters, and other circuit components are mounted on thin film, even though these elements are not transparent. The non-transparent structures are placed where visibility of underlying the flat panel electronic visual display 32 is not critical.

[0047] The present invention allows one of the largest surface areas of a wireless communications device, the flat panel LCD, to be used for a second purpose, as a surface to mount an antenna. The fabrication of an antenna from thin films of conductive material on a transparent thin film permits the antenna of the present invention to have the performance characteristics of prior art patch antennas, while being transparent enough to allow the user to view the display through the antenna.

[0048] The small profile of the transparent antennas makes it relatively easy to design an antenna system of transparent panel antennas with a summing network to add the direction gain of several antennas, yielding an omni-directional antennas gain pattern. Alternately, the use of just a single transparent antenna, providing essentially hemispherical coverage, to minimize RF output in the direction of the wireless device user, is desirable when RF emissions are a health concern. Other embodiments of the present invention will occur to those skilled in the art.

[0049] As described, the first transparent antenna of the present invention is characterized by including: a first transparent sheet of thin film and a first transparent planar radiating element having a first operating frequency and overlying the first transparent sheet of thin film, whereby structures underlying the first transparent sheet of thin film are visible.

[0050] The described transparent antenna is a planar antenna having the transparent planar radiating element formed on the surface of the transparent sheet of thin film. The transparent antenna is composed of transparent members, so that the underlying structures are visible. According to the described structure, for example, when mounting the transparent antenna on the wireless communications device, a display section which is one of members occupying the largest surface areas of the wireless device can be used as a surface to mount an antenna, and an increased degree of freedom can be achieved when mounting the antenna. It is preferable to use of just a single transparent antenna when RF emissions are a health concern, as it provides essentially hemispherical coverage, to minimize RF output in the direction of the wireless device user.

[0051] The second transparent antenna based on the structure of the first transparent antenna is characterized by further including a first transparent planar ground plane.

[0052] According to the described structure of the second transparent antenna, an improved performance of the planar transparent antenna can be achieved in addition to the effects as achieved from the first transparent antenna.

[0053] The third transparent antenna based on the structure of the second transparent antenna is characterized in that the first transparent planar ground plane overlies the first transparent sheet of thin film, whereby the first transparent planar radiating element and the first transparent planar ground plane are located coplanar to each other.

[0054] According to the described arrangement, by forming the transparent planar radiating element and the transparent planar ground plane on a single transparent sheet of thin film, a thinner transparent antenna of an improved transparency can be achieved in addition to the effects as achieved from the second transparent antenna.

[0055] The fourth transparent antenna based on any of the described structures of the first through third transparent antennas is characterized in that the first transparent sheet of thin film has a thickness in the range between 100 and 400 microns.

[0056] The fifth transparent antenna based on the structure of the second transparent antenna is characterized by further including: a second transparent sheet of thin film underlying the first transparent sheet of thin film, in which the first transparent ground plane is mounted on the second transparent sheet of thin film, whereby the first transparent planar antenna is located on two transparent sheets of overlying thin film.

[0057] According to the described structure, by forming the transparent planar radiating element and the transparent planar ground plane on respective transparent sheets of thin film of a laminated structure, a transparent antenna having a high gain can be achieved even for a relatively small surface to mount an antenna in addition to the effects as achieved from the second transparent antenna.

[0058] The sixth transparent antenna based on the structure of the second transparent antenna is characterized in that the first transparent planar radiating element and the first transparent planar ground plane include highly conductive metal film structures selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines.

[0059] According to the described structure, by the use of the transparent planar radiating element of a metal film structure of a plurality of metal lines formed at predetermined gaps which offer a desired transparency, a highly conductive transparent planar radiating element can be achieved. As a result, a planar antenna which can be mounted on the display section and which can ensure the same characteristics as the conventional whip antenna can be achieved. Furthermore, by adopting the grid or mesh metal film structure, a uniform metal film structure having relatively small variations in electrical conductivity can be achieved with ease in addition to the effects as achieved from the second transparent antenna.

[0060] The seventh transparent antenna based on the structure of the fifth transparent antenna is characterized in that: the metal film structures are selected from the group of materials consisting of copper, aluminum, gold, silver, nickel, chromium, titanium, molybdenum, tin, tantalum, magnesium, cobalt, platinum, tungsten, manganese, silicon, zirconium, vanadium, niobium, hafnium, indium and other alloys of the above mentioned materials.

[0061] According to the described structure, by forming the metal lines of the metal film structure by the electrically conductive metals or the alloys thereof, a thinner transparent antenna of an improved transparency which provides a high gain can be achieved in addition to the effects as achieved from the seventh transparent antenna.

[0062] The eighth transparent antenna based on the structure of the sixth or seventh transparent antenna is characterized in that the metal lines have a width in the range between 1 and 30 microns, and in which parallel oriented metal lines are separated by a distance in the range between 30 microns and 1 mm.

[0063] According to the described arrangement, by proper choice of line widths and the gaps between metal lines, a sufficient transparency for the visibility of the underlying structure can be ensured in addition to the effects as achieved from the sixth or seventh transparent antenna.

[0064] The eighth transparent antenna based on any of the structures of the fifth through seventh transparent antennas is characterized in that the metal film structure overlying the first transparent sheet of thin film has a metal film thickness in the range between 300 and 100,000 Å.

[0065] The ninth transparent antenna based on the structure of the fifth transparent antenna is characterized in that the material of the metal film structures is selected from the group of materials consisting of indium-tin, indium-tin oxide, tin oxide, and in which the metal film has a metal film thickness in the range between 0.1 and 10 microns.

[0066] As described, for the metal lines of the metal film structure, indium-tin, indium-tin oxide, tin oxide, etc., may be adopted. In this case, by selecting the film thickness of the metal film in a range between 0. 1 and 10 μm, in addition to the effects as achieved from the structure of the sixth transparent antenna, a transparent antenna which provides a sufficient transparency for the visibility of the underlying structure and a high gain can be achieved.

[0067] The described structure being composed of metal lines formed at predetermined gaps has an advantageous feature over the structure of U.S. Patent Woo et al. (No. 5,627,548), wherein the electrically conductive film made of transparent indium thin oxide is formed in a sheet of thin film.

[0068] The eleventh transparent antenna based on any of the structures of the first through tenth transparent antenna is characterized in that the antenna is greater than 65 percent transmissive in the band of visible light wavelengths.

[0069] The twelfth transparent antenna based on the structure of the third transparent antenna is characterized by further including a second transparent planar radiating element, in which the second transparent planar radiating element is located coplanar to the first transparent planar radiating element, whereby the first and second transparent planar radiating elements are located coplanar to the first transparent planar ground plane.

[0070] According to the described structure having a plurality of transparent planar radiating elements (plurality of antenna units), by forming a plurality of transparent planar radiating elements coplanar to the transparent planar ground plane, a thinner transparent antenna of an improved transparency can be achieved in addition to the effects as achieved from the first transparent antenna.

[0071] The thirteenth transparent antenna based on the structure of the third transparent antenna is characterized by further including: a plurality of transparent planar radiating elements, in which the plurality of transparent planar radiating elements are located coplanar to the first transparent planar radiating element and the first transparent planar ground plane.

[0072] According to the described arrangement including a plurality of transparent planar radiating elements (i.e., a plurality of antenna units), by forming the plurality of transparent planar radiating elements coplanar to the transparent planar ground plane, a thinner transparent antenna of an improved transparency can be achieved in addition to the effects as achieved from the third transparent antenna.

[0073] As described, the first wireless communications device of the present invention which includes a flat panel electronic visual display, and at least a first transparent planar antenna having a first operating frequency is characterized in that the first transparent planar antenna includes a highly conductive first transparent planar radiating element and a highly conductive first transparent planar ground plane, the first transparent planar antenna overlying the flat panel electronic visual display, whereby the flat panel electronic visual display is viewed through the first transparent planar antenna.

[0074] According to the described arrangement, a planar transparent antenna is constituted by transparent components so that the underlying structures are visible. The present invention allows one of the largest surface areas of a wireless communications device, the flat panel LCD, to be used as a surface to amount an antenna. Alternately, it is preferable to use just a single transparent antenna when RF emissions are a health concern, as it provides not omni-directional but essentially hemispherical coverage, to minimize RF output in the direction of the wireless device user.

[0075] The second wireless communications device of the present invention based on the structure of the first wireless communications device is characterized by including: a first transparent sheet of thin film, wherein the first transparent planar radiating element and the first transparent planar ground plane of the first transparent planar antenna are located coplanar and overlying the first transparent sheet of thin film, whereby the first transparent planar antenna is located on a single transparent sheet of thin film.

[0076] According to the described arrangement, by forming both the transparent planar radiating element and the transparent planar ground plane on a single sheet of thin film, a thin transparent antenna of improved transparency can be achieved, thereby providing improved visibility of the planar panel display section in addition to the effects as achieved from the first wireless communications device.

[0077] The third wireless communications device based on the structure of the second wireless communications device is characterized in that the first transparent sheet of thin film is selected from the group of materials consisting of polyethylene telephthalate (PET), polyethylesulfone (PES), polyetherimide (PEI), polycarbonate, polyimide, polytetrafluoroethylene, acrylic, glass, and combinations of the above-mentioned materials.

[0078] According to the above arrangement, by forming metal lines of the metal film structure by highly conductive metals or alloys thereof, a thin transparent antenna which offers a high antenna gain can be achieved in addition to the effects as achieved from the second wireless communications device.

[0079] The fourth wireless communications device based on the structure of the second or third wireless communications device is characterized in that the first transparent sheet of thin film 40 has a thickness in the range between 100 and 400 microns.

[0080] The fifth wireless communications device based on any of the structures of the second through fourth wireless communications device is characterized in that the first transparent planar radiating element and the first transparent planar ground plane include a metal film structure overlying the first transparent sheet of thin film patterned to electrically isolate the first transparent planar radiating element from the first transparent planar ground plane, whereby the metal of the metal film structure permits high electrical conductivity in the antenna.

[0081] The sixth wireless communications device based on the fifth structure of the wireless communications device is characterized in that the metal film structure is selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines.

[0082] According to the described arrangement, by adopting the grid or mesh metal structure, a uniform metal film structure with relatively small variations in electrical conductivity can be obtained in addition to the effects as achieved from the fifth wireless communications device.

[0083] The seventh wireless communications device based on the structure of the fifth or sixth wireless communications device is characterized in that the material of the metal film structure is selected from the group of materials consisting of copper, aluminum, gold, silver, nickel, chromium, titanium, molybdenum, tin, tantalum, magnesium, cobalt, platinum, tungsten, manganese, silicon, zirconium, vanadium, niobium, hafnium, indium and other alloys of the above mentioned materials.

[0084] According to the described structure, by forming the metal lines of the metal film structure by highly conductive metal materials or alloys thereof, a thin transparent antenna of an improved transparency, which provides a high antenna gain can be achieved in addition to the effects as achieved from the fifth or sixth wireless communications device.

[0085] The eighth wireless communications device based on the structure of any of the fifth through seventh wireless communications device is characterized in that the metal lines have a width in the range between 1 and 30 microns, and parallel oriented metal lines are separated by a distance in the range between 30 microns and 1 mm.

[0086] According to the described arrangement, by proper choice of line widths and gaps between metal lines, a transparent antenna which offers a sufficient transparency for the visibility of the underlying structure and a high antenna gain can be achieved in addition to the effects as achieved from any of the fifth through seventh wireless communications devices.

[0087] The ninth wireless communications device based on the structure of the fifth wireless communications device is characterized in that the metal film structure has a metal film having a thickness in the range between 300 and 100,000 Å.

[0088] The tenth wireless communications device as in any of the structures of the fifth through ninth wireless communications device is characterized by further including a dummy section of a non-conductive metal film structure having a same transparency as that of the metal film structure, wherein the dummy section includes the same metal lines as the plurality of metal lines of the metal film structure, and the dummy section has a non-conductive film structure prepared by cutting a part of each of the metal lines.

[0089] According to the described arrangement, the non-conductive dummy section prepared by cutting a part of each metal line has substantially the same metal film structure and the same transparency as the metal film structure. By forming the dummy section outside the metal film structure, the transparency of the transparent antenna as a whole can be made more uniform. Especially, according to the wireless communications device of the present invention wherein the transparent antenna is formed on the planar panel display section, by the use of the dummy section in the part which is not covered with the metal film structure, a display of an improved visibility can be achieved in addition to the effects as achieved from any of the first through ninth wireless communications device.

[0090] The eleventh wireless communications device based on the structure of the fifth communications device is characterized in that the material of the metal film structure is selected from the group of materials consisting of indium-tin, indium-tin oxide, and tin oxide, and the metal film structure has a metal film thickness in the range between 0.1 and 10 microns.

[0091] The twelfth wireless communications device based on any of the structures of the first through eleventh wireless communications device is characterized in that the first transparent planar antenna is greater than 65 percent transmissive in the band of visible light wavelengths.

[0092] The thirteenth wireless communications device based on any of the structures of the first through twelfth wireless communications device is characterized in that a flat panel electronic visual display is a liquid crystal display (LCD).

[0093] The fourteenth wireless communications device based on the second wireless communications device is characterized by further including: a second transparent planar antenna having a second operating frequency, different than the first operating frequency, in which the second transparent planar antenna has a second transparent planar radiating element located coplanar to the first transparent planar radiating element, and in which the first and second transparent planar radiating elements are located coplanar to a shared first transparent planar ground plane.

[0094] According to the described arrangement, a plurality of transparent antennas of a thin structure which offers a high transparency can be achieved, thereby improving a visibility of the plat panel display section in addition to the effects as achieved from the second wireless communications device.

[0095] The fifteenth wireless communications device based on the structure of the second wireless communications device is characterized by further including a second transparent antenna having a second operating frequency, the same as the first operating frequency, in which the second transparent planar antenna has a second transparent planar radiating element located coplanar to the first transparent antenna radiating element, and in which the first and second transparent planar radiating elements are located coplanar to a shared first transparent planar ground plane.

[0096] According to the described arrangement, a plurality of transparent antennas of a thin structure which offers a high transparency can be achieved, thereby improving a visibility of the plat panel display section in addition to the effects as achieved from the second wireless communications device.

[0097] The sixteenth wireless communications device based on the structure of the first wireless communications device is characterized by further including: a second transparent sheet of thin film overlying the first transparent sheet of thin film; and a second transparent planar antenna having a second operating frequency different than the first operating frequency, in which the second transparent planar antenna has a second transparent planar radiating element located overlying the second transparent sheet of thin film, and in which the first and second transparent planar radiating elements share the first transparent planar ground plane.

[0098] According to the described arrangement, in the structure composed of a plurality of transparent planar antennas (for example, the structure including a plurality of transparent antennas of different gains for realizing an omni-directional antenna gain pattern), a single transparent planar ground surface is used in common among a plurality of transparent antennas, and each transparent planar radiating element and the transparent planar ground plane of a plurality of transparent antennas are formed on the same plane. As a result, a thinner transparent antenna group of an improved transparency can be achieved, thereby achieving an improved visibility of the planar panel display section.

[0099] The seventeenth wireless communications device based on the structure of the first wireless communications device is characterized by further including: a second transparent sheet of thin film overlying the first transparent sheet of thin film; and a second transparent planar antenna having a second operating frequency the same as the first operating frequency, wherein the second transparent planar antenna includes a first transparent planar radiating element located overlying the second transparent sheet of thin film, and the first transparent planar radiating element and the second transparent planar radiating element share the first transparent planar ground plane.

[0100] According to the described structure, by forming the transparent planar radiating element and the transparent planar ground plane on respective transparent sheets of thin film of a laminated structure, a transparent antenna having a high gain can be achieved even for a relatively small surface to mount an antenna.

[0101] The eighteenth wireless communications device based on the structure of the first wireless communications device is characterized by further including: a plurality of transparent planar antennas, in which the plurality of antennas each have a transparent planar radiating element located coplanar to the first transparent planar radiating element, and in which each of the plurality of transparent planar radiating elements is located coplanar to the first transparent planar ground plane.

[0102] The nineteenth wireless communications device based on the structure of the first wireless communications device is characterized by further including: a plurality of transparent sheets of thin film overlying said first transparent sheet of thin film; a plurality of transparent planar antennas having a plurality of corresponding transparent planar radiating elements, with each one of said plurality of radiating elements overlying a corresponding one of said plurality of sheets of thin film, and in which each said radiating elements shares said first transparent planar ground plane.

[0103] According to the described arrangement, in the structure composed of a plurality of transparent planar antennas (for example, the structure including a plurality of transparent antennas of different gains for realizing an omni-directional antenna gain pattern), a single transparent planar ground surface is used in common among a plurality of transparent antennas, and each transparent planar radiating element and the transparent planar ground plane of a plurality of transparent antennas are formed on the same plane. As a result, a thinner transparent antenna group of an improved transparency can be achieved, thereby achieving an improved visibility of the planar panel display section.

[0104] The twentieth wireless communications device based on the structure of the first wireless communications device is characterized by further comprising: a transparent user-activated touch panel overlying the planer panel electronic display, the user-activated transparent touch panel including user-activated sensors corresponding to visual prompts represented on the planer panel electric display visible through the first transparent planar antenna and the transparent touch panel.

[0105] The twenty-first wireless communications device based on the twentieth wireless communications device is characterized in that: the transparent touch panel and the first transparent planar antenna are both mounted on the first transparent sheet of thin film.

[0106] The twenty-second wireless communications device based on the structure of the first wireless communications device is characterized by further including: a first transparent sheet of thin film on which the first transparent radiating element is mounted; and a second transparent sheet of thin film, underlying the first transparent sheet of thin film, on which the first transparent planar ground plane is mounted, whereby the first transparent planar antenna is located on two sheets of overlying thin film.

[0107] According to the described arrangement, by forming the transparent planar radiating element and the transparent planar ground plane on different transparent sheets of thin film of a laminated structure, a transparent antenna which provides a high gain can be achieved even with a relatively small flat panel display section (i.e., surface to amount an antenna) in addition to the effects as achieved from the first wireless communications device.

[0108] The twenty-third wireless communications device based on the structure of the first wireless communications device is characterized by further including: a second transparent planar antenna having a second operating frequency, the second transparent planar radiating element being located coplanar to the first transparent planar radiating element; in which the first and second transparent planar radiating elements are co-located in an inter-digital metal film structure; in which the inter-digital metal film structure is selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines; and in which the metal lines have a width in the range between 1 and 30 microns, with a spacing between parallel oriented metal lines in the range between 30 microns and 1 mm.

[0109] According to the described arrangement, in the structure composed of two transparent antennas, the transparent planar radiating element of each transparent antenna can be formed inter-digitally within a single metal film structure. As a result, two transparent antennas of a thin structure (high transmittance) and a high gain can be achieved.

[0110] The twenty-fourth wireless communications device based on the structure of the sixth or twenty-third wireless communications device is characterized in that: each metal line of the metal film structure is formed in a non-display part between pixels of the planar panel electric visual display.

[0111] The non-display part between pixels of the planar panel display section indicates, for example, a spacing between adjoining pixel electrodes of a liquid crystal display, i.e., a spacing where a black matrix is formed.

[0112] According to the described arrangement, a metal line of the metal film structure is formed so as to correspond to a pixel pitch of the planar panel display section. Specifically, it is arranged such that the non-display section between adjoining pixels of the planar panel display section matches the non-transparent metal lines of the metal film structure, thereby achieving an improved visibility of the plat panel display section.

[0113] The twenty-fifth wireless communications device for communicating information at a plurality of frequencies is characterized by further including: a first communicating section for communicating information at a first operating frequency; a second communicating section for communicating information at a second operating frequency which is different from the first operating frequency; a first transparent planar antenna including a highly conductive transparent planar radiating element and a highly conductive transparent planar ground plane, the first transparent planar antenna being operably connected to the first communicating section without any operative connection to the second communicating section; and a second transparent planar antenna including a highly conductive transparent planar radiating element and a highly conductive transparent planar ground plane, the second transparent planar antenna being operably connected to the second communicating section without any operative connection to the first communicating section, and in which the transparent planar radiating elements and transparent planar ground planes are metal film structures selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines, whereby the use of two transparent planar antennas eliminates the need for a duplexer circuit.

[0114] According to the described arrangement, the respective transparent planar radiating element and the transparent planar ground planes of the first and second transparent antennas have metal film structures composed of a plurality of metal lines provided at predetermined gaps, and the profile is small. Therefore, by the use of the first and second transparent antennas as dedicated antennas for the first and second communicating sections, duplexes circuits, or time multiplexed antenna switches required in the conventional arrangement of a single antenna can be omitted. As a result, not only improved antenna performances but also a reduction in manufacturing cost and a space inside the chassis can be achieved.

[0115] The twenty-sixth wireless communications device based on the structure of the twenty-fifth wireless communications device is characterized in that: the first communicating section is a first receiving section provided with an input section for receiving information at the first operating frequency, and the second communicating section is a second receiving section provided with an input section for receiving information at the second operating frequency different from the first operating frequency.

[0116] The twenty-seventh wireless communications device based on the structure of the twenty-fifth wireless communications device is characterized in that: the first communicating section is a receiving section provided with an input section for receiving information at the first frequency, and the second communicating section is a transmitting section provided with an output section for transmitting information at the second operating frequency different from the first operating frequency.

[0117] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modification as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A wireless communications device which includes a flat panel electronic visual display (32), and at least a first transparent planar antenna (34) having a first operating frequency, characterized in that:

   said first transparent planar antenna (34) includes a highly conductive first transparent planar radiating element (36) and a highly conductive first transparent planar ground plane (38),
   said first transparent planar antenna (34) is located overlying said flat panel electronic visual display (32), whereby said flat panel electronic visual display (32) is viewed through said first transparent planar antenna (34).

2. The wireless communications device as in claim 1, characterized by further comprising:

   a first transparent sheet of thin film (40),
   wherein said first transparent planar radiating element (36) and said first transparent planar ground plane (38) of said first transparent planar antenna (34) are located coplanar and overlying said first transparent sheet of thin film (40), whereby said first transparent planar

antenna (34) is located on a single transparent sheet of thin film (40).

3. The wireless communications device as in claim 2, characterized in that:

said first transparent sheet of thin film 40 is selected from the group of materials consisting of polyethylene telephthalate (PET), polyethylesulfone (PES), polyetherimide (PEI), polycarbonate, polyimide, polytetrafluoroethylene, acrylic, glass, and combinations of the above-mentioned materials.

4. The wireless communications device as in claim 2 or 3, characterized in that:

said first transparent sheet of thin film 40 has a thickness in the range between 100 and 400 microns.

5. The wireless communications device as in claim 2, 3 or 4, characterized in that:

said first transparent planar radiating element (36) and said first transparent planar ground plane (38) include a metal film structure (44) overlying said first transparent sheet of thin film (40) patterned to electrically isolate said first transparent planar radiating element (36) from said first transparent planar ground plane (38), whereby said metal of said metal film structure (44) permits high electrical conductivity.

6. The wireless communications device as in claim 5, characterized in that:

said metal film structure (44) is selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines.

7. The wireless communications device as in claim 5 or 6, characterized in that:

the material of said metal film structure (44) is selected from the group of materials consisting of copper, aluminum, gold, silver, nickel, chromium, titanium, molybdenum, tin, tantalum, magnesium, cobalt, platinum, tungsten, manganese, silicon, zirconium, vanadium, niobium, hafnium, indium and other alloys of the above mentioned materials.

8. The wireless communications device as in claim 5, 6 or 7, characterized in that:

said metal lines have a width in the range between 1 and 30 microns, and

parallel oriented metal lines are separated by a distance in the range between 30 microns and 1 mm.

9. The wireless communications device as in claim 5, characterized in that:

said metal film structure (44) has a metal film having a thickness in the range between 300 and 100,000 Å.

10. The wireless communications device as in any of claims 5 through 9, characterized by further comprising:

a dummy section of a non-conductive metal film structure (80) having a same transparency as that of said metal film structure (44),
wherein said dummy section (80) includes the same metal lines as the plurality of metal lines of said metal film structure (44), and
said dummy section (80) has a non-conductive film structure by cutting a part of each of said metal lines.

11. The wireless communications device as in claim 5, characterized in that:

the material of said metal film structure (44) is selected from the group of materials consisting of indium-tin, indium-tin oxide, and tin oxide, and
said metal film structure (44) has a metal film thickness in the range between 0.1 and 10 microns.

12. The wireless communications device as in any of claims 1 through 11, characterized in that:

said first transparent planar antenna (34) is greater than 65 percent transmissive in the band of visible light wavelengths.

13. The wireless communications device as in any of claims 1 through 12, characterized in that:

said flat panel electronic visual display (32) is a liquid crystal display (LCD).

14. The wireless communications device as in claim 2, characterized by further comprising:

a second transparent planar antenna (50) having a second operating frequency, different than the first operating frequency, in which said second transparent planar antenna (50) has a second transparent planar radiating element located coplanar to said first transparent planar radiating element (36), and in which said first and second transparent planar radiating elements (36, 52) are located coplanar to a shared first transparent planar ground plane (38).

15. The wireless communications device as in claim 2, characterized by further comprising:

a second transparent planar antenna (50) having a second operating frequency, the same as the first operating frequency, in which said second transparent planar antenna (50) has a second transparent planar radiating element (52) located coplanar to said first transparent antenna radiating element (36), and in which said first and second transparent planar radiating elements (36, 52) are located coplanar to a shared first transparent planar ground plane (38).

16. The wireless communications device as in claim 1, further comprising:

a second transparent sheet of thin film (62) overlying said first transparent sheet of thin film (40); and
a second transparent planar antenna (50) having a second operating frequency different than the first operating frequency, in which said second transparent planar antenna (50) has a second transparent planar radiating element (52) located overlying said second transparent sheet of thin film (62), and in which said first and second transparent planar radiating elements (36, 52) share said first transparent planar ground plane (38).

17. The wireless communications device as in claim 1, characterized by further comprising:

a second transparent sheet of thin film (62) overlying said first transparent sheet of thin film (40); and
a second transparent planar antenna (50) having a second operating frequency the same as the first operating frequency,
wherein said second transparent planar antenna (50) includes a first transparent planar radiating element (52) is located overlying said second transparent sheet of thin film (62), and said first transparent planar radiating element (36) and said second transparent planar radiating element (52) share said first transparent planar ground plane (38).

18. The wireless communications device as in claim 1, characterized by further comprising:

a plurality of transparent planar antennas (50, 54, 56), in which said plurality of antennas each have a transparent planar radiating element (52, 58, 60) located coplanar to said first transparent planar radiating element (36), and in which each of said plurality of transparent planar radiating elements (52, 58, 60) is located coplanar to said first transparent planar ground plane (38).

19. The wireless communications device as in claim 1, characterized by further comprising:

a plurality of transparent sheets of thin film (62, 70) of a laminated structure,
a plurality of transparent planar antennas (50, 54, 60), said plurality of transparent planar antennas including transparent planar radiating elements (52, 58 and 60) respectively, and sharing said first transparent planar ground plane (38), and
said plurality of transparent planar antennas (50, 54, 56), with each one of said plurality of transparent planar radiating elements (52, 58, 60) overlying a corresponding one of said plurality of sheets of thin film (62,70,76).

20. The wireless communications device as defined in claim 2, characterized by further comprising:

a transparent user-activated touch panel (74) overlying said planer panel electronic display (32), said transparent user-activated touch panel including user-activated sensors (75) corresponding to visual prompts displayed on said planer panel electric display visible through said first transparent planar antenna (34) and said transparent touch panel (74).

21. The wireless communications device as in claim 20, characterized in that:

said transparent touch panel (74) and said first transparent planar antenna (34) are both mounted on said first transparent sheet of thin film (40).

22. The wireless communications device as in claim 1, characterized by further comprising:

a first transparent sheet of thin film (40) on which said first transparent radiating element (36) is mounted; and
a second transparent sheet of thin film (62), underlying said first transparent sheet of thin film (40), on which said first transparent planar ground plane (38) is mounted, whereby said first transparent planar antenna (34) is located

on two sheets of overlying thin film (40, 62).

23. The wireless communications device as in claim 1, characterized by further comprising:

a second transparent planar antenna (50) having a second operating frequency, said second transparent planar radiating element (52) being located coplanar to said first transparent planar radiating element (36);
in which said first and second transparent planar radiating elements (36, 38) are co-located in an inter-digital metal film structure (44);
in which said inter-digital metal film structure (44) is selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines; and
in which said metal lines have a width in the range between 1 and 30 microns, with a spacing between parallel oriented metal lines in the range between 30 microns and 1 mm.

24. The wireless communications device as in claim 6 or claim 23, characterized in that:

each metal line of said metal film structure (44) is formed in a non-display part between pixels of said planar panel electric visual display (32).

25. The wireless communications device for communicating information at a plurality of frequencies, characterized by comprising:

a first communicating section (90) for communicating information at a first operating frequency;
a second communicating section (94, 98) for communicating information at a second operating frequency which is different from said first operating frequency;
a first transparent planar antenna (34) including a highly conductive transparent planar radiating element (36) and a highly conductive transparent planar ground plane (38), said first transparent planar antenna (34) being operably connected to said first communicating section (90) without any operative connection to said second communicating section (94, 98); and
a second transparent planar antenna (50) including a highly conductive transparent planar radiating element (52) and a highly conductive transparent planar ground plane (36), said second transparent planar antenna (34) being operably connected to said second communicating section (94, 98) without any operative connection to said first communicating section (90), and
in which said transparent planar radiating elements (36, 52) and transparent planar ground planes (38) are metal film structures (44) selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines, whereby the use of two transparent planar antennas (34, 50) eliminates the need for a duplexer circuit.

26. The wireless communications device as in claim 25, characterized in that:

said first communicating section (90) is a first receiving section (90) provided with an input section for receiving information at the first operating frequency, and
said second communicating section (94, 98) is a second receiving section (94) provided with an input section for receiving information at the first operating frequency.

27. The wireless communications device as in claim 25, characterized in that:

said first communicating section (90) is a receiving section (90) provided with an input section for receiving information at the first frequency, and
said second communicating section (94, 98) is a transmitting section (98) provided with an output section for transmitting information at the first operating frequency.

28. A transparent antenna, characterized by comprising:

a first transparent sheet of thin film (40); and
a first transparent planar radiating element (36) having a first operating frequency and overlying said first transparent sheet of thin film (40), whereby structures underlying said first transparent sheet of thin film (40) are visible.

29. The transparent antenna as in claim 28, characterized by further comprising:

a first transparent planar ground plane (38).

30. The transparent antenna as in claim 29, characterized in that:

said first transparent planar ground plane (38) overlies said first transparent sheet of thin film (40), whereby said first transparent planar radiating element (36) and said first transparent planar ground plane (38) are located coplanar to each other.

31. The transparent antenna as in any of claim 28 through 30 characterized in that:

said first transparent sheet of thin film (40) has a thickness in the range between 100 and 400 microns.

32. The transparent antenna as in claim 29, characterized by further comprising:

a second transparent sheet of thin film (62) underlying said first transparent sheet of thin film (40);
in which said first transparent ground plane (38) is mounted on said second transparent sheet of thin film (62), whereby the first transparent planar antenna (34) is located on two transparent sheets of overlying thin film (40, 62).

33. The transparent antenna as in claim 29, characterized in that:

said transparent planar radiating element (36) and said first transparent planar ground plane (38) include highly conductive metal film structures (44) selected from the group consisting of a grid of parallel oriented metal lines and a mesh of orthogonal and parallel oriented metal lines.

34. The transparent antenna as in claim 33, characterized in that:

said metal film structures (44) are selected from the group of materials consisting of copper, aluminum, gold, silver, nickel, chromium, titanium, molybdenum, tin, tantalum, magnesium, cobalt, platinum, tungsten, manganese, silicon, zirconium, vanadium, niobium, hafnium, indium and other alloys of the above mentioned materials.

35. The transparent thin film as in claim 33 or 34, characterized in that:

said metal lines have a width in the range between 1 and 30 microns, and in which parallel oriented metal lines are separated by a distance in the range between 30 microns and 1 mm.

36. The transparent antenna as in any of claims 33 through 35, characterized in that:

said metal film structure (44) overlying said first transparent sheet of thin film (40) has a metal film thickness in the range between 300 and 100,000 Å.

37. The transparent antenna as in claim 33, characterized in that:

the material of said metal film structures (44) is selected from the group of materials consisting of indium-tin, indium-tin oxide, tin oxide, and in which said metal film has a metal film thickness in the range between 0.1 and 10 microns.

38. The transparent antenna as in any of claims 28 through 37, characterized in that:

the antenna is greater than 65 percent transmissive in the band of visible light wavelengths.

39. The transparent antenna as in claim 30, characterized by further comprising:

a second transparent planar radiating element (52), in which said second transparent planar radiating element (52) is located coplanar to said first transparent planar radiating element (38), whereby said first and second transparent planar radiating elements (38, 52) are located coplanar to said first transparent planar ground plane (38).

40. The transparent antenna as in claim 30, characterized by further comprising:

a plurality of transparent planar radiating elements (52, 58, 60), in which said plurality of transparent planar radiating elements (52, 58, 60) are located coplanar to said first transparent planar radiating element (36) and said first transparent planar ground plane (38).

FIG. 1

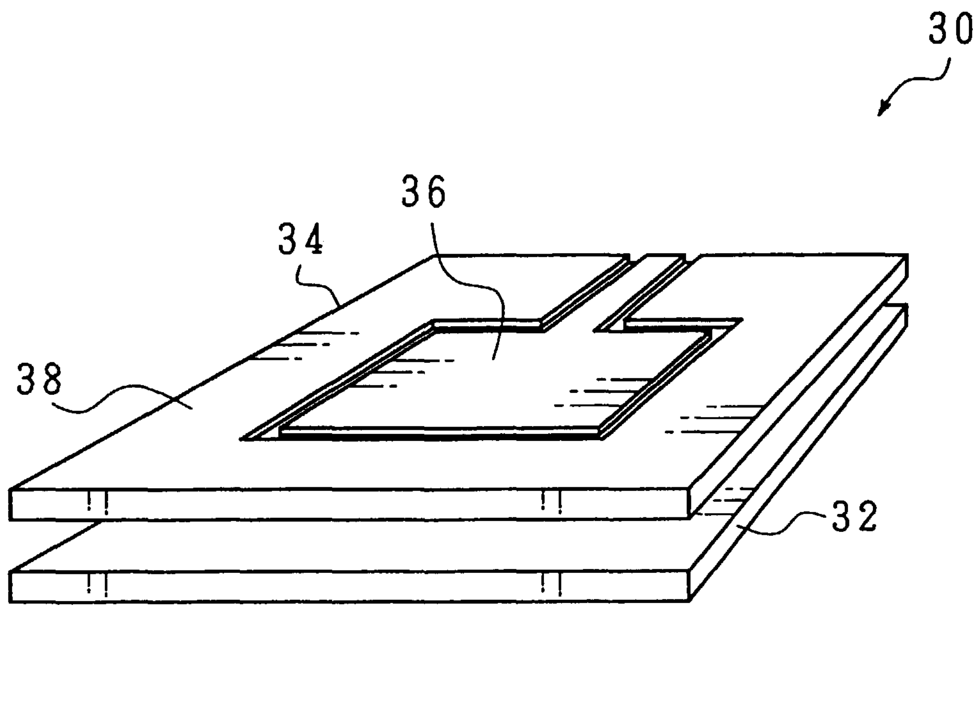

FIG. 2

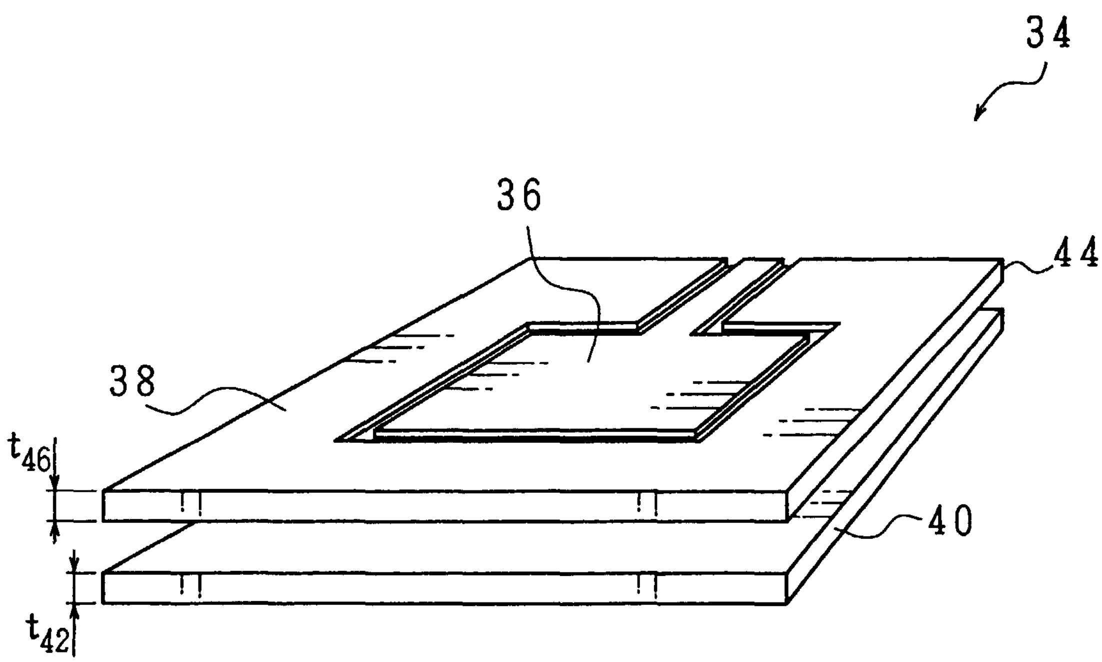

FIG. 3

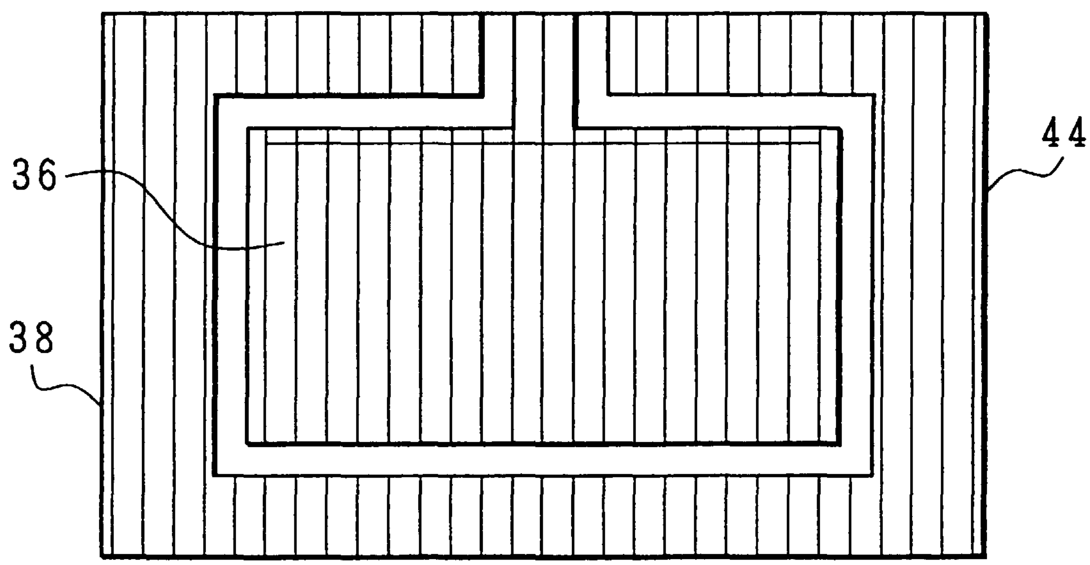

FIG. 4

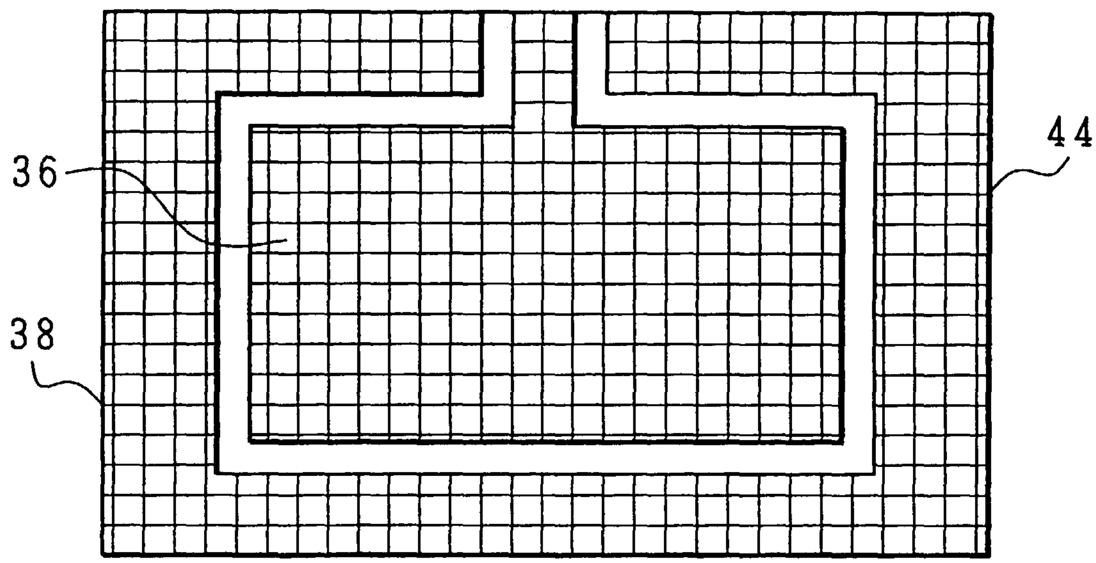

FIG. 5

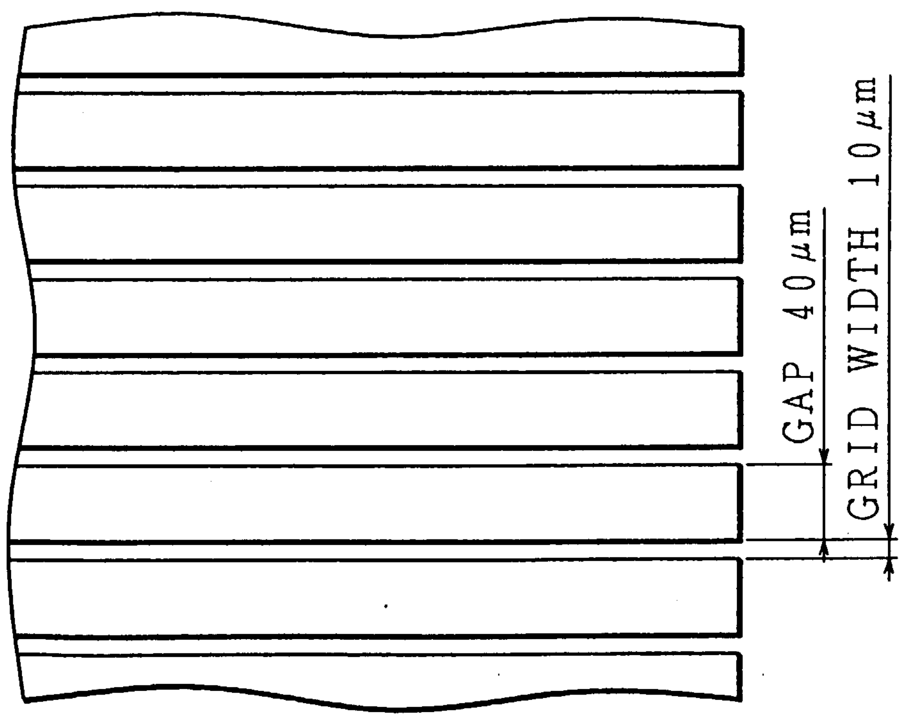

FIG. 6

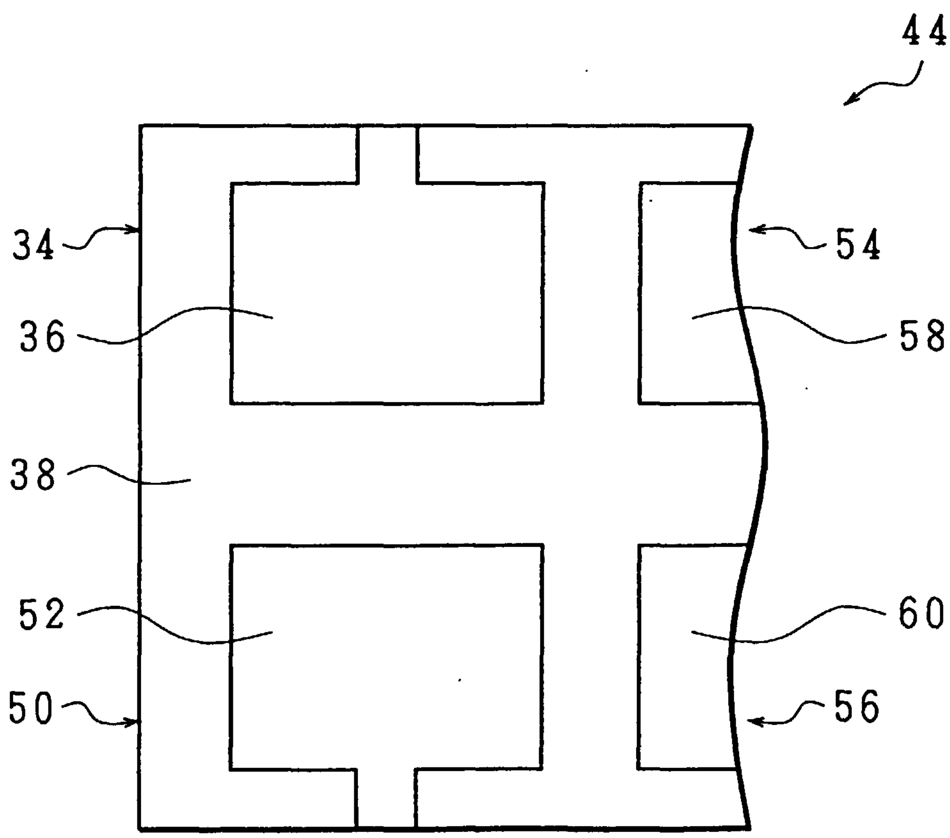

FIG. 7

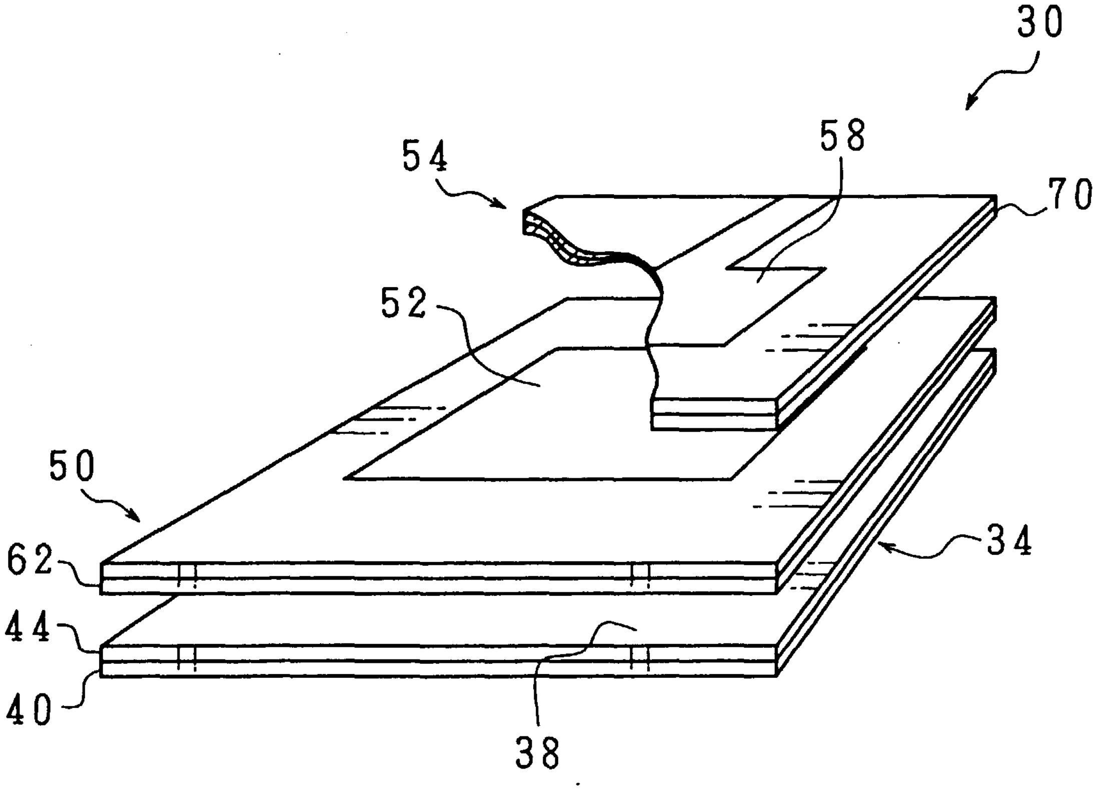

FIG. 8

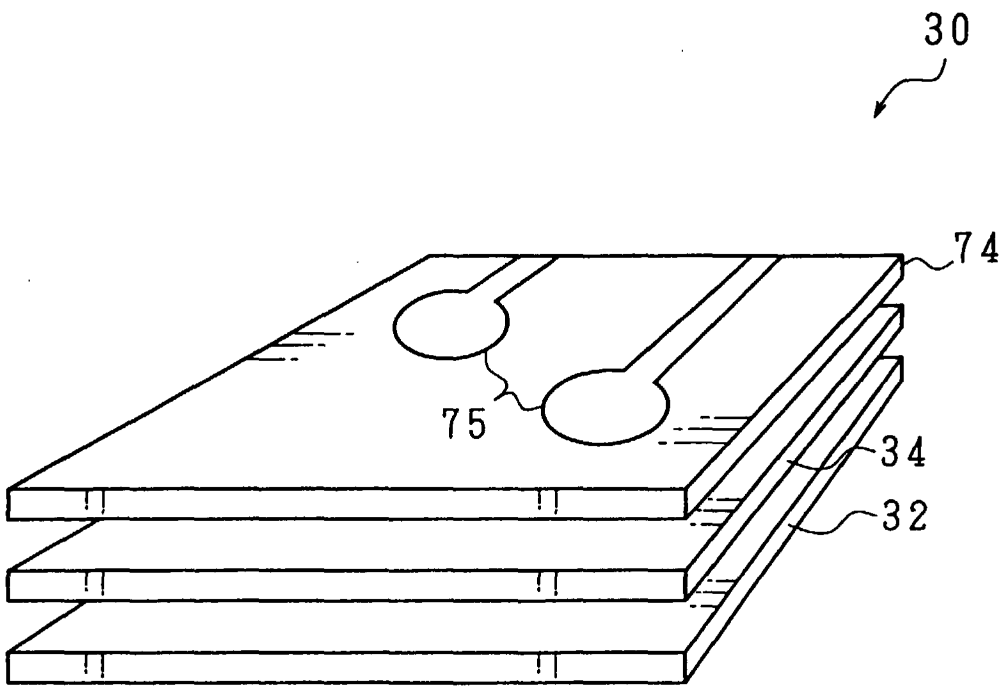

FIG. 9

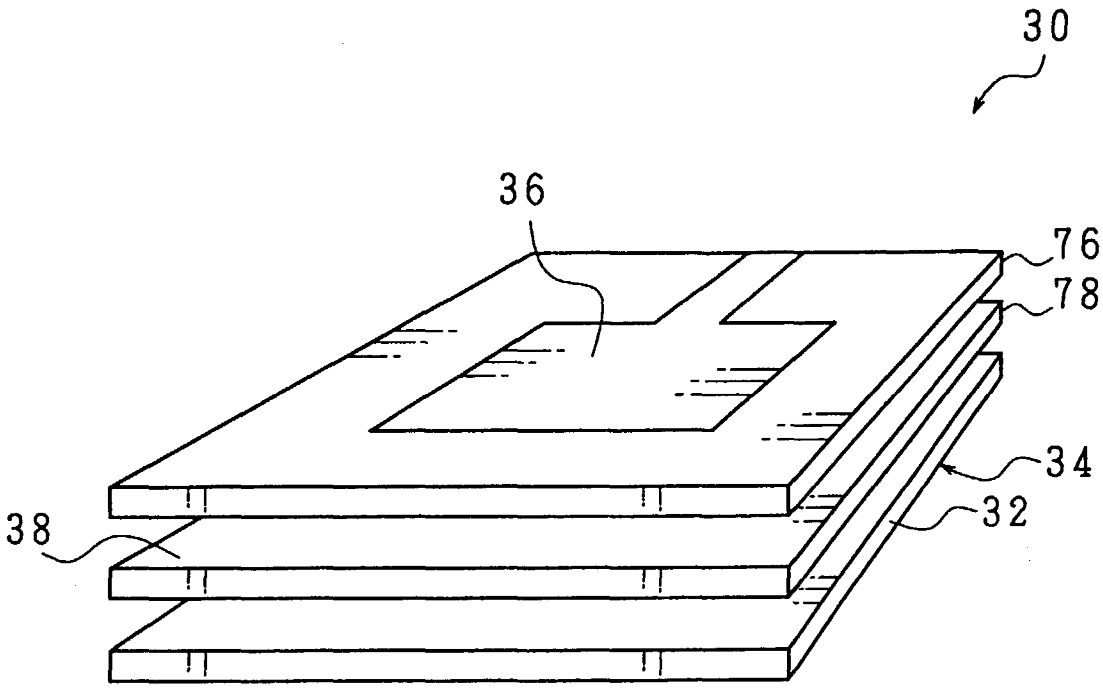

FIG.10

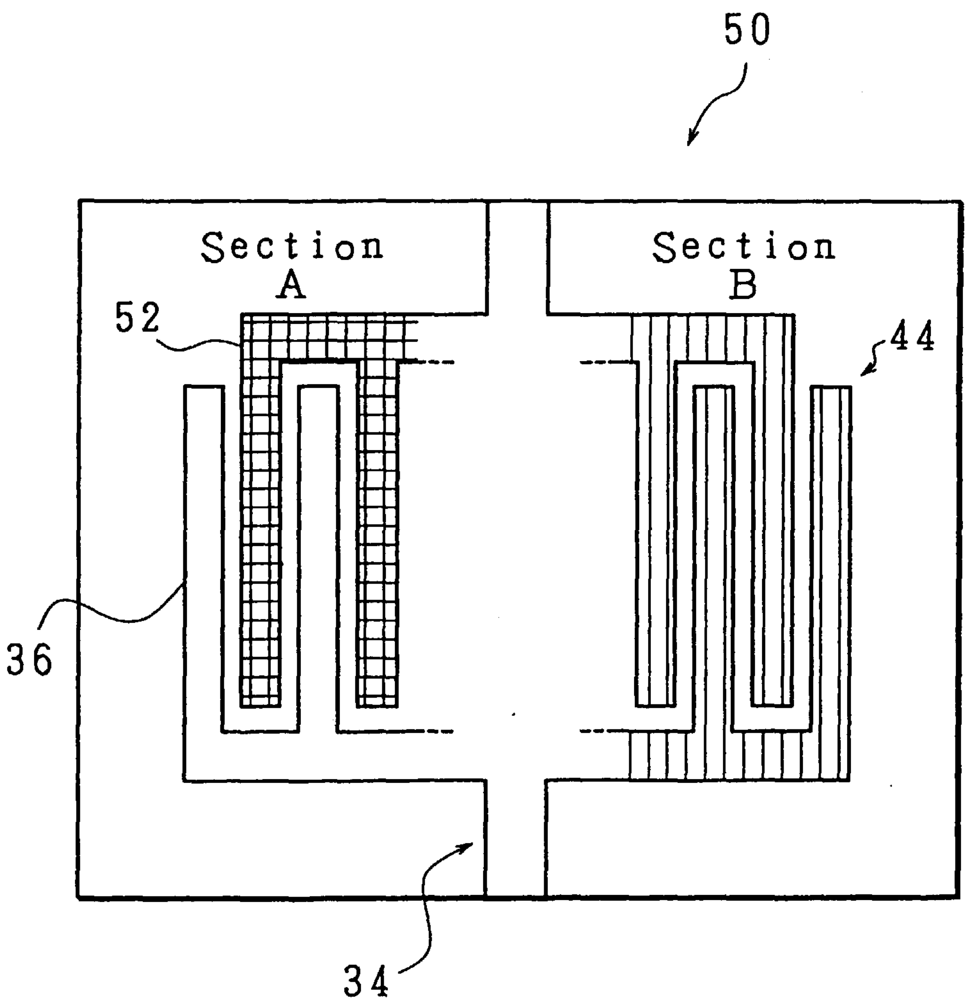

FIG. 11

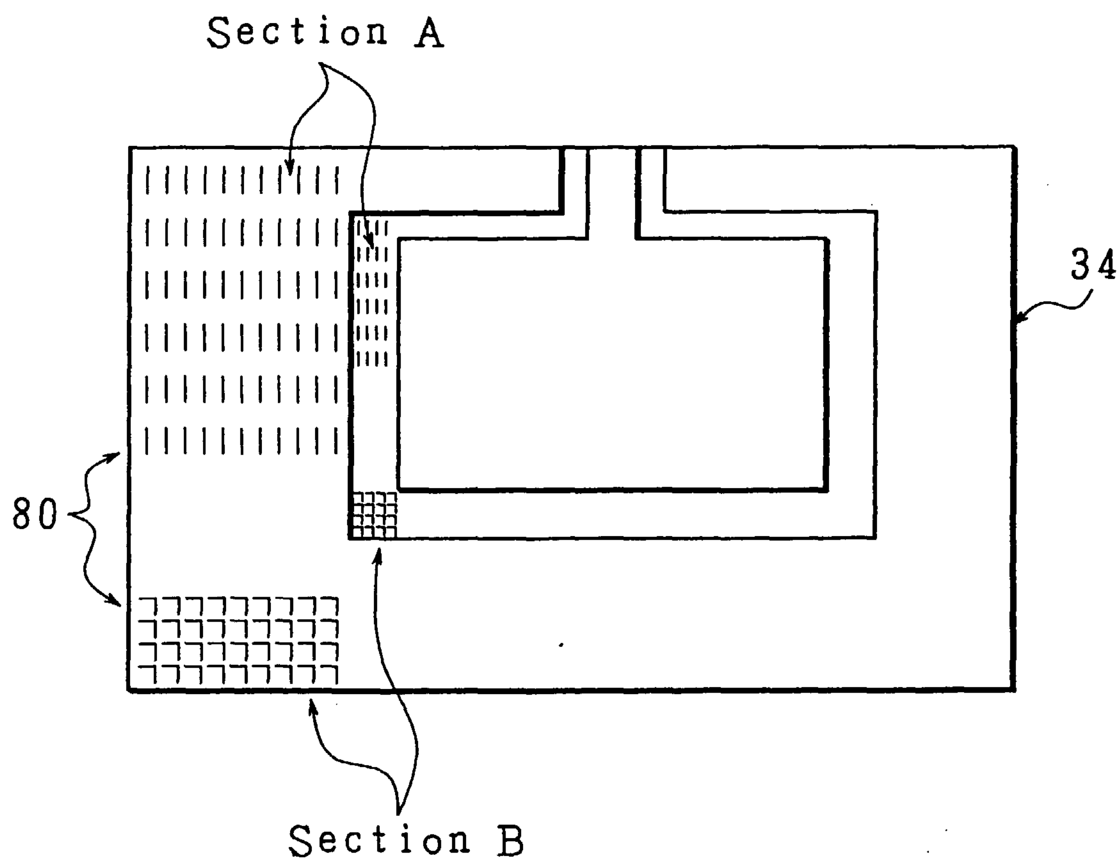

FIG. 12

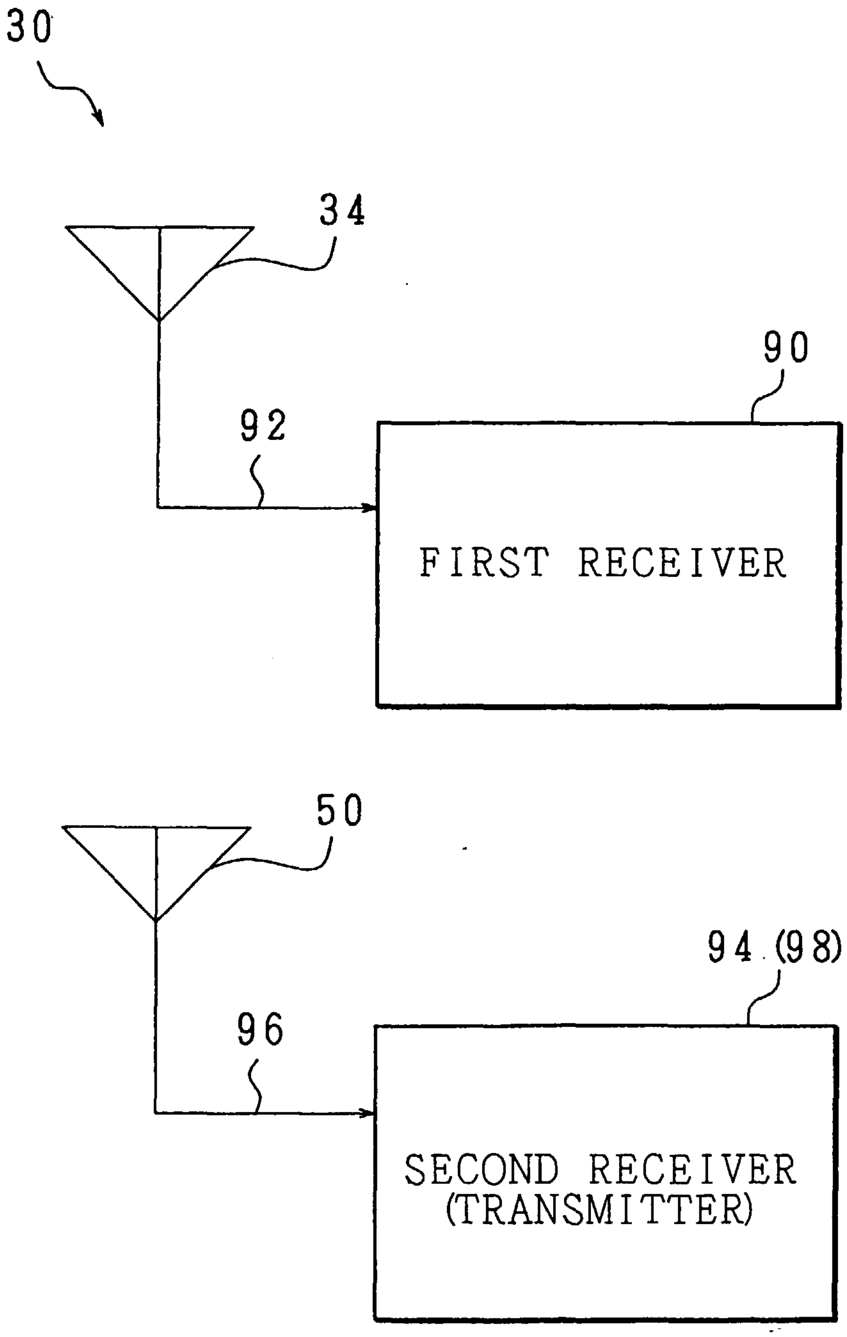
30
34
90
92
FIRST RECEIVER
50
94 (98)
96
SECOND RECEIVER
(TRANSMITTER)

FIG.13

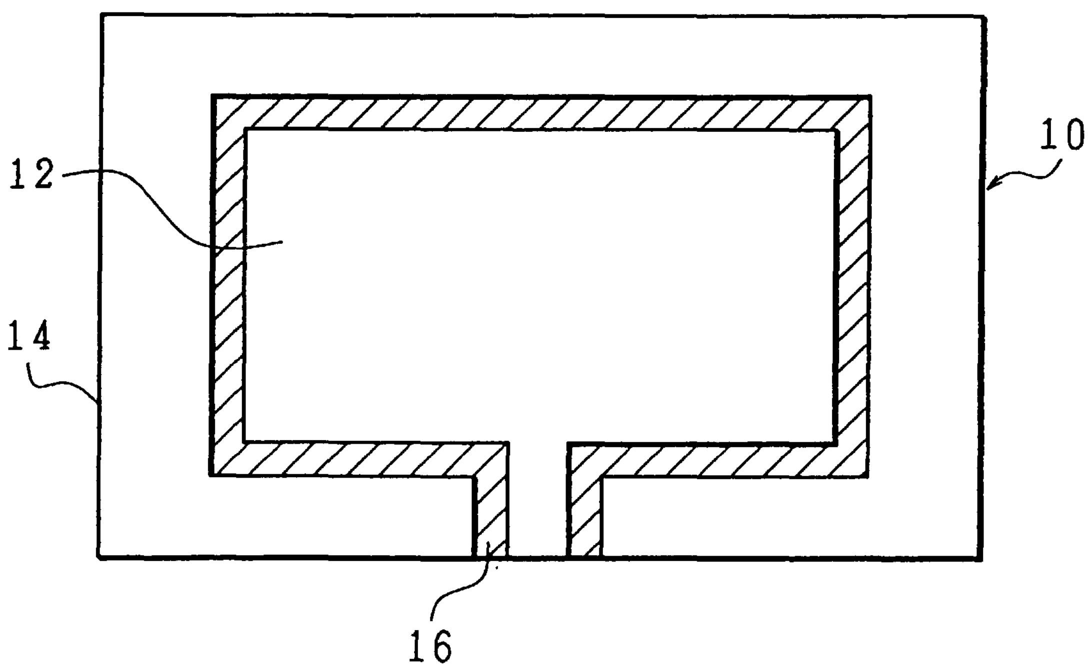

FIG. 14