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(54) **ANTENNA DEVICE AND DISPLAY DEVICE INCLUDING THE SAME**

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(57) **ABSTRACT**

An antenna device according to an embodiment may include a dielectric layer, a first radiator disposed on an upper surface of the dielectric layer, a transmission line whose one end is connected with the first radiator on the upper surface of the dielectric layer, a signal pad connected to the other end of the transmission line, ground pads disposed around the signal pad, and a second radiator extending from the ground pad parallel to the transmission line and including one or more uneven parts.

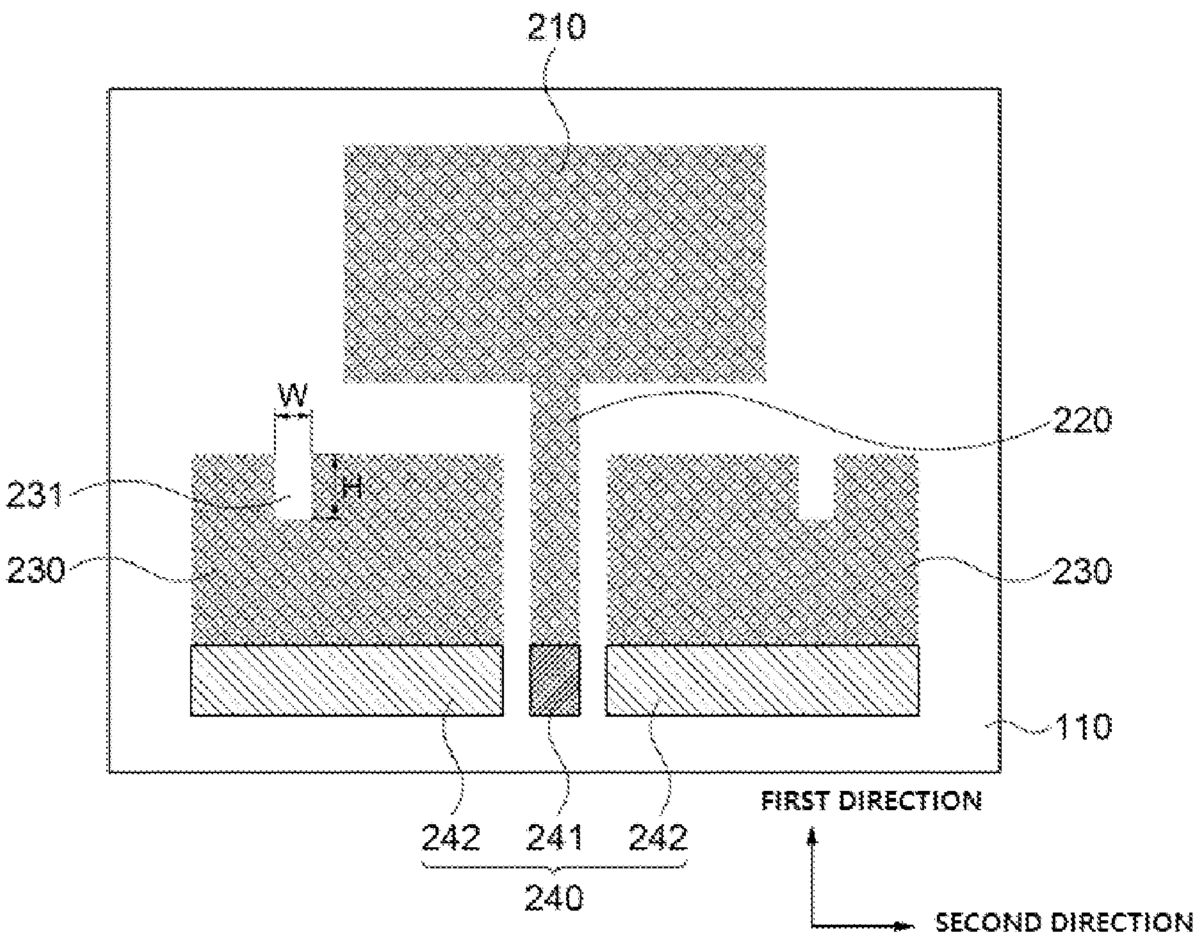


FIG. 1

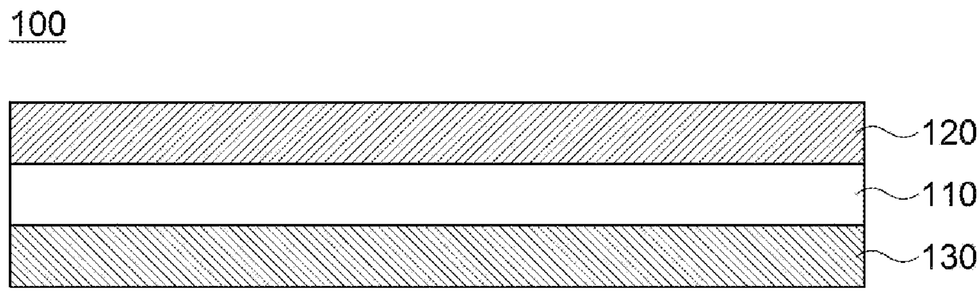

100
120
110
130

FIG. 2

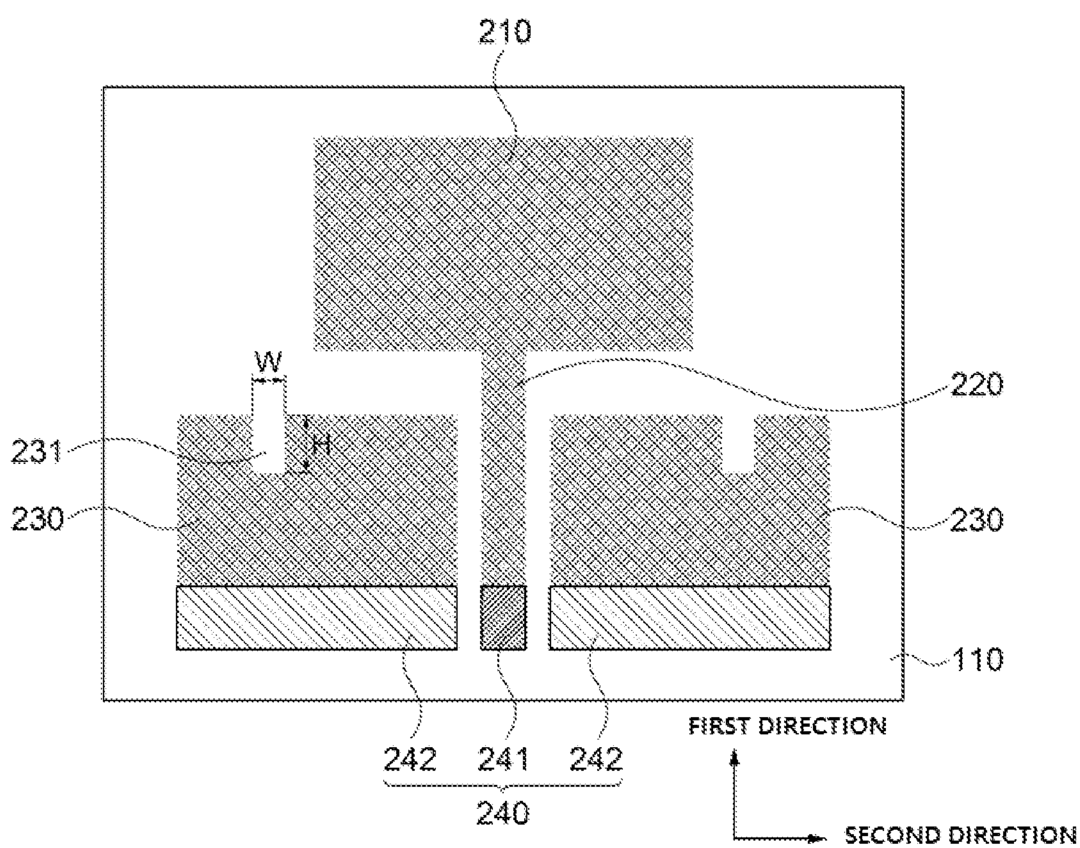

210
W
H
220
231
230
230
110
242
241
242
240
FIRST DIRECTION
SECOND DIRECTION

FIG. 3

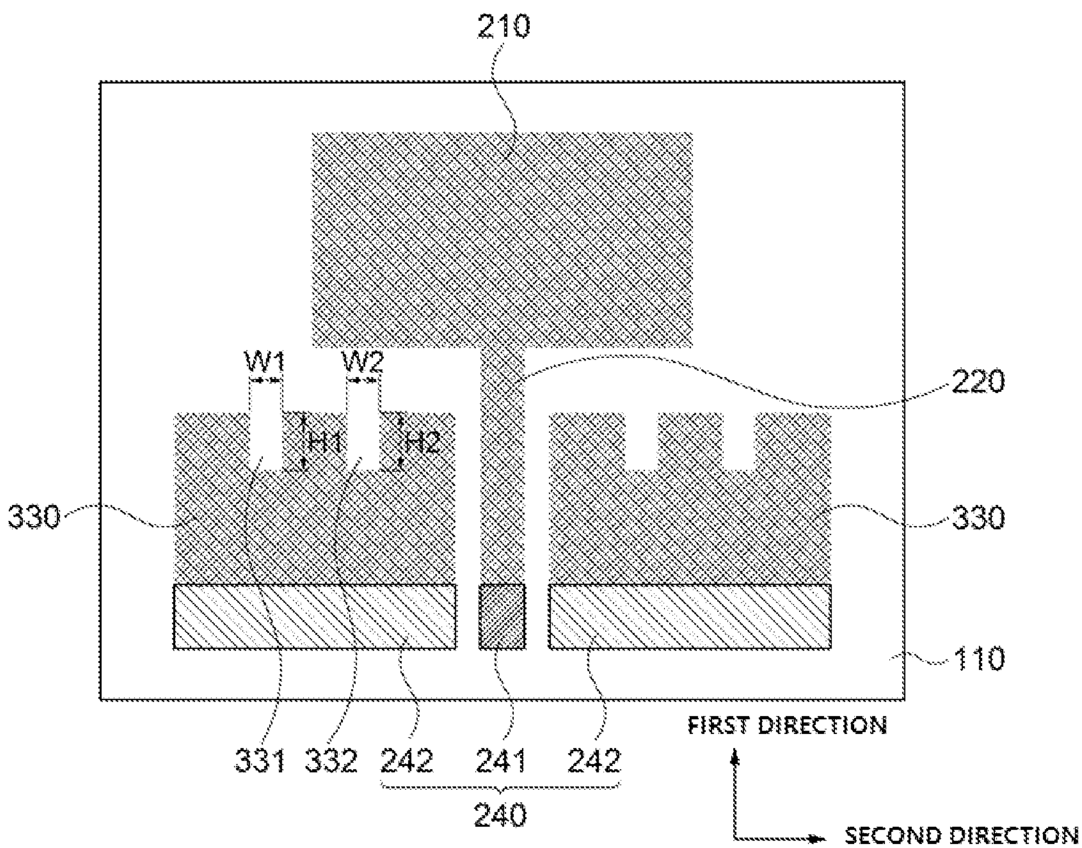

210
W1
W2
H1
H2
220
330
330
110
FIRST DIRECTION
331
332
242
241
242
240
SECOND DIRECTION

FIG. 4

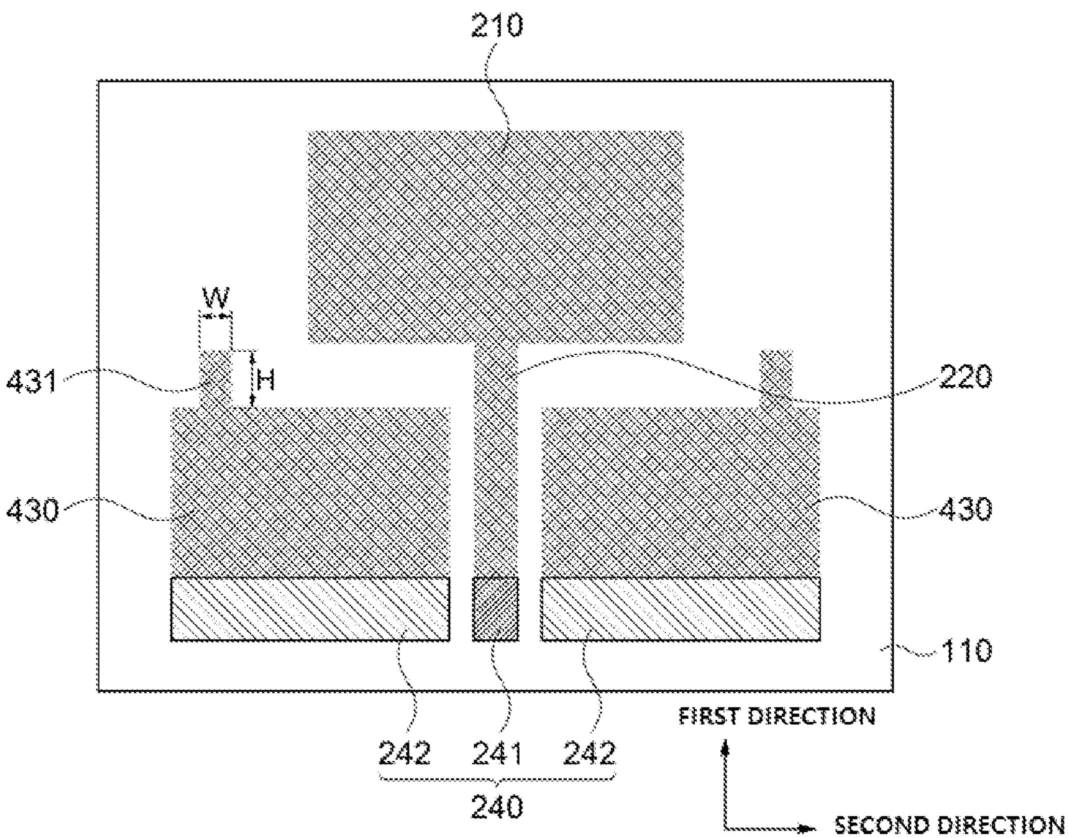
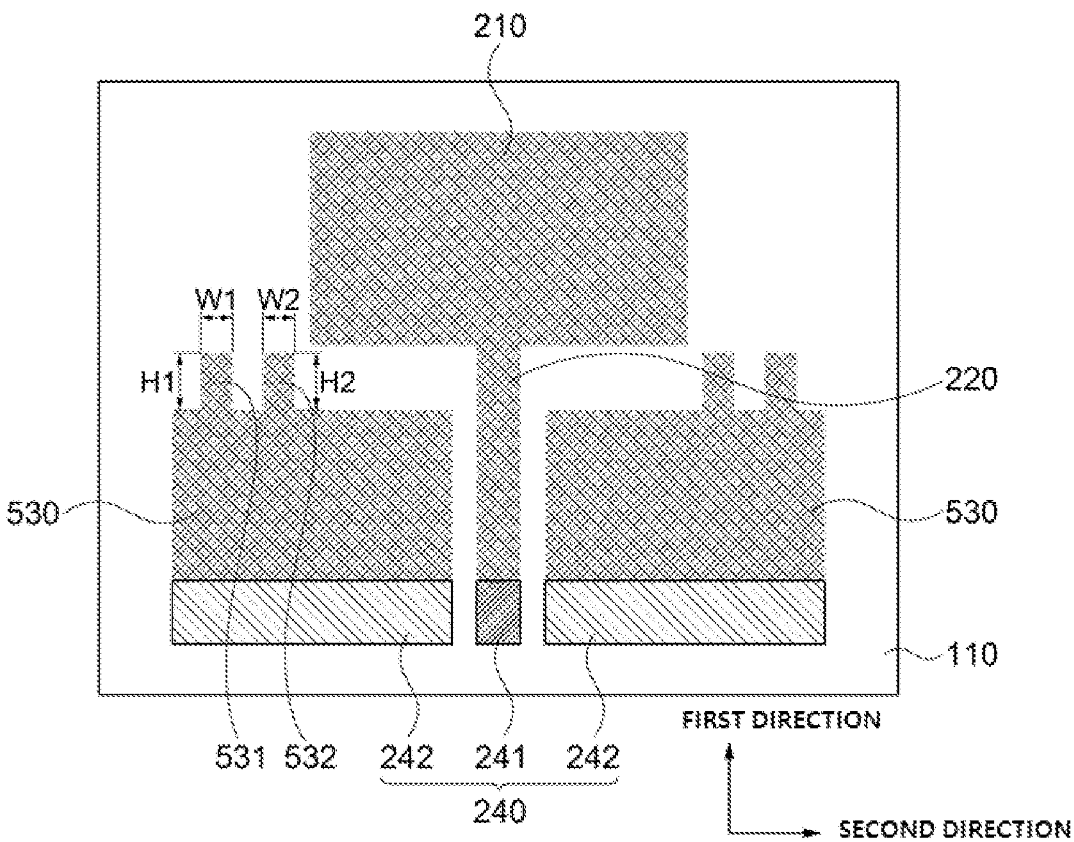

210
W
H
431
220
430
430
110
242
241
242
240
FIRST DIRECTION
SECOND DIRECTION

FIG. 5



210
W1
W2
H1
H2
220
530
530
110
531
532
242
241
242
240
FIRST DIRECTION
SECOND DIRECTION

FIG. 6

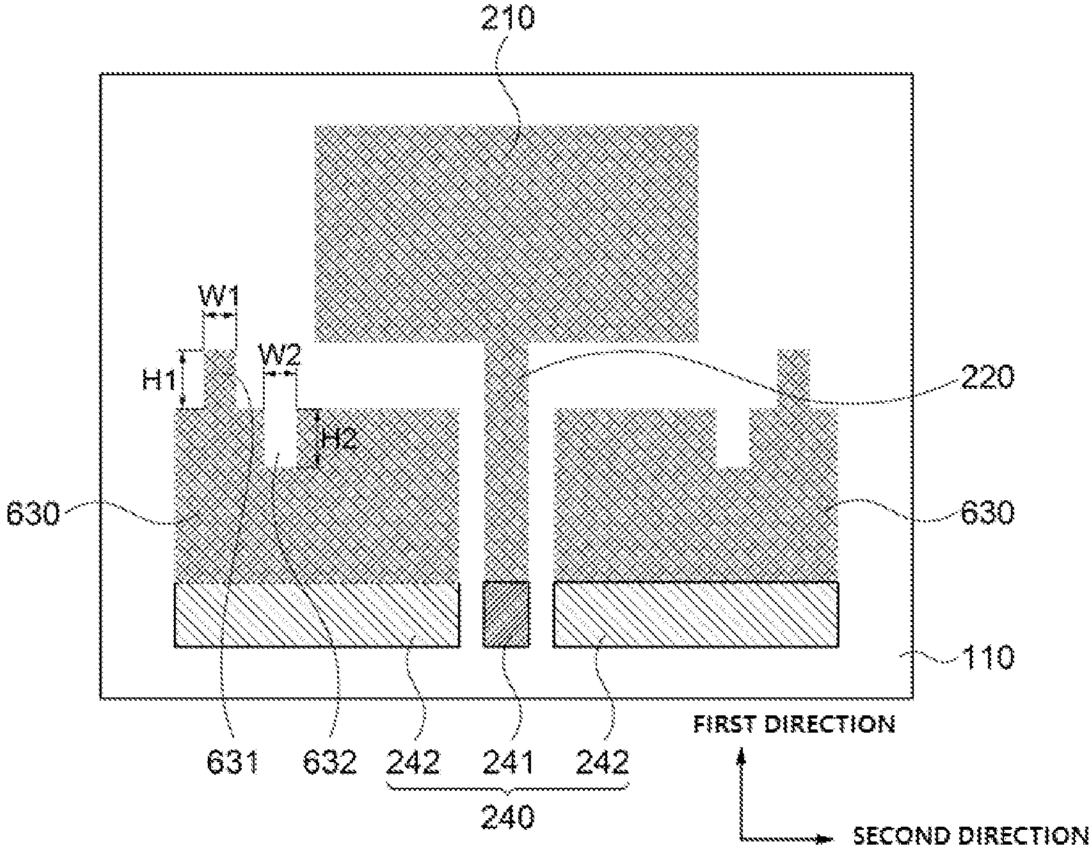

210
W1
W2
H1
H2
220
630
630
110
631
632
242
241
242
240
FIRST DIRECTION
SECOND DIRECTION

FIG. 7

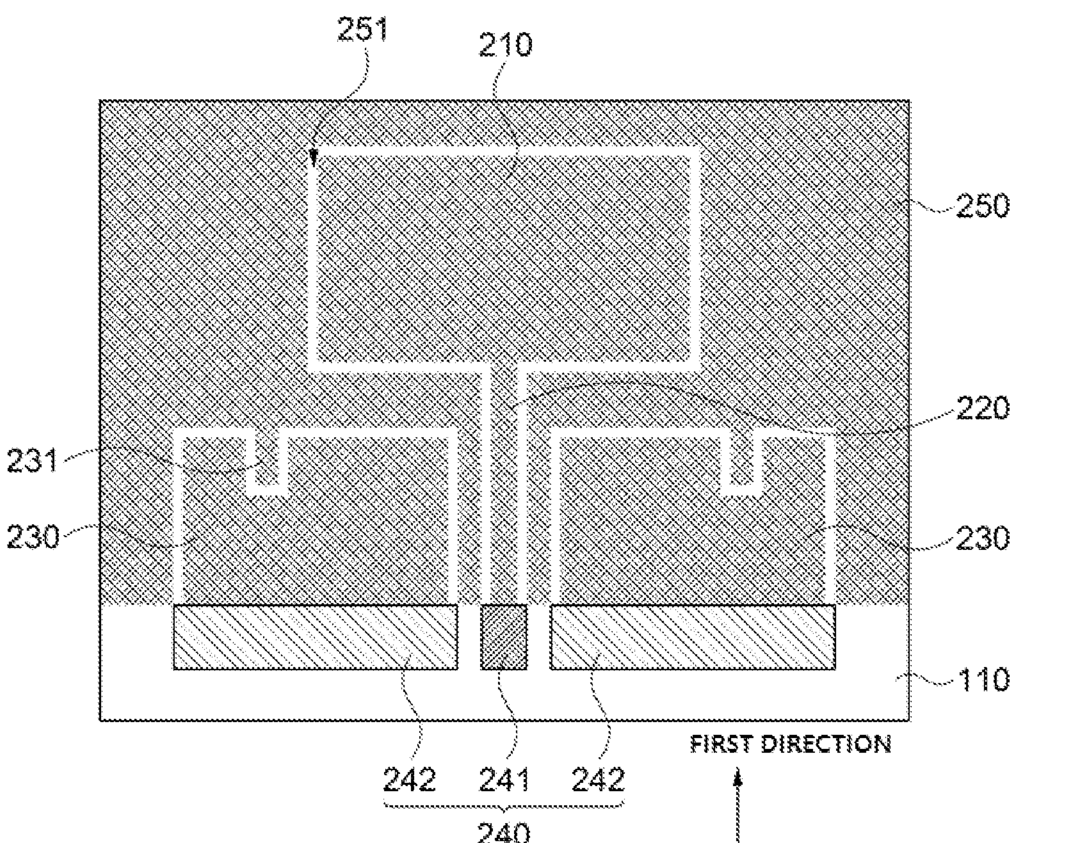
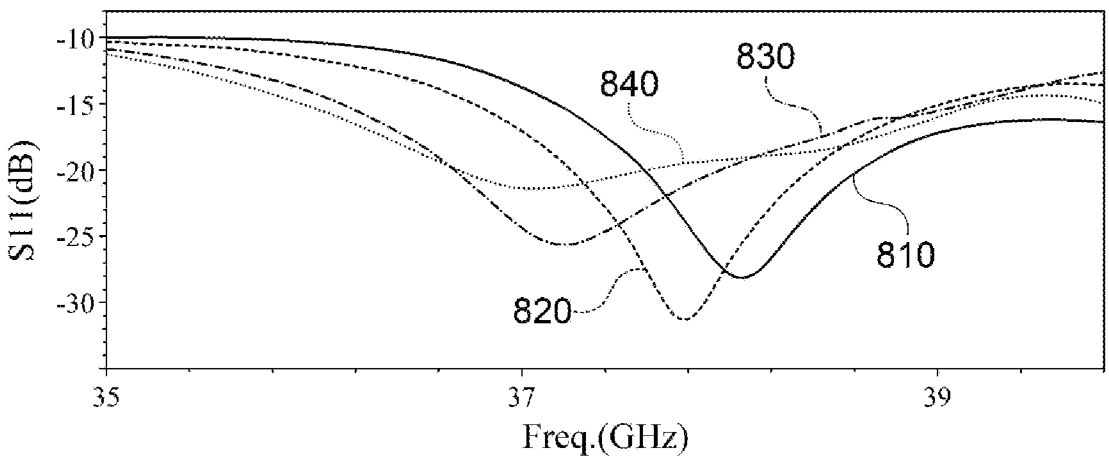
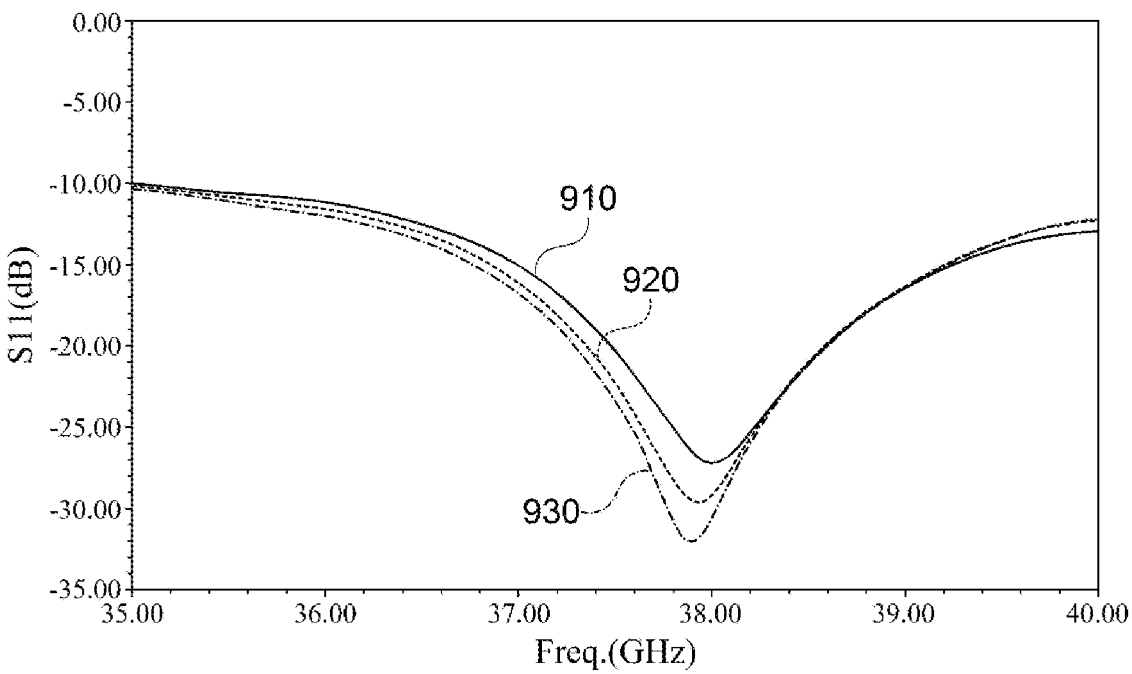

251
210
250
220
231
230
230
110
FIRST DIRECTION
242
241
242
240
SECOND DIRECTION

FIG. 8



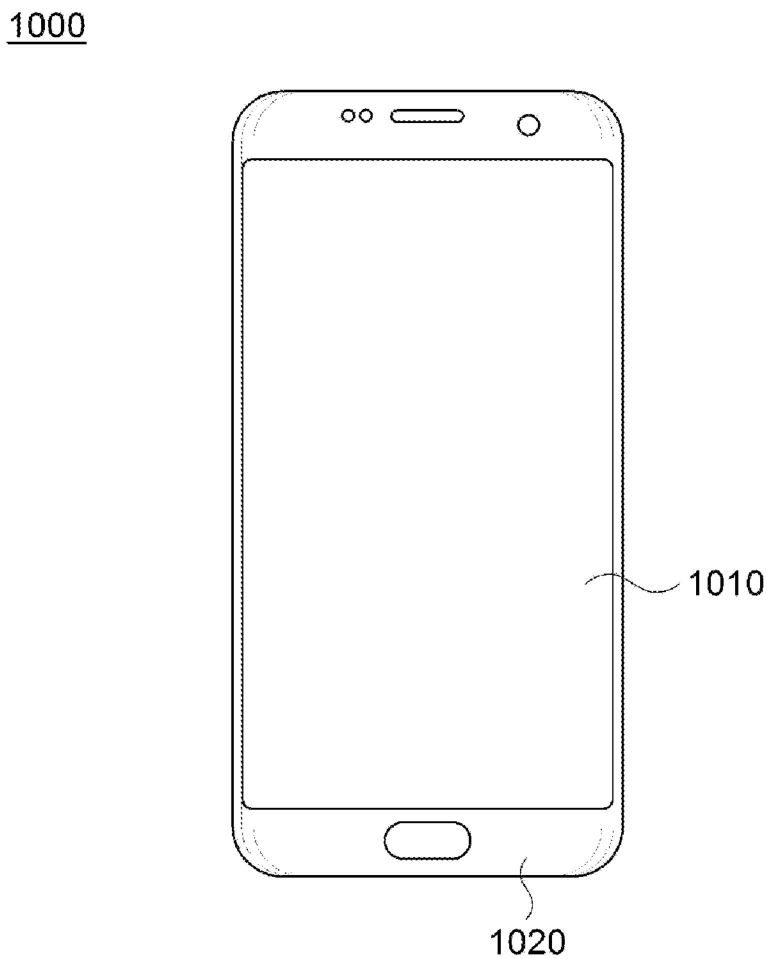
-10
-15
-20
-25
-30
S11(dB)
35
37
39
Freq.(GHz)
810
820
830
840

FIG. 9



0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
S11(dB)
35.00
36.00
37.00
38.00
39.00
40.00
Freq.(GHz)
910
920
930

FIG. 10



ANTENNA DEVICE AND DISPLAY DEVICE INCLUDING THE SAME

CROSS REFERENCE TO RELATED APPLICATIONS AND CLAIM OF PRIORITY

[0001] The present application is a continuation application to International Application No. PCT/KR2021/007594 filed on Jun. 17, 2021, which claims the benefit of Korean Patent Applications No. 10-2020-0076855 filed on Jun. 24, 2020 at the Korean Intellectual Property Office, the disclosures of which are incorporated by reference herein in their entirety.

BACKGROUND

1. Field

[0002] The present invention relates to an antenna device and a display device including the same.

2. Description of the Related Art

[0003] Recently, according to development of the information-oriented society, wireless communication techniques such as Wi-Fi, Bluetooth, and the like are implemented, for example, in a form of smartphones by combining with display devices. In this case, an antenna may be coupled to the display device to perform a communication function.

[0004] Recently, with mobile communication techniques becoming more advanced, it is necessary for an antenna for performing communication in ultra-high frequency bands to be coupled to the display device.

[0005] In addition, as the display device on which the antenna is mounted becomes thinner and lighter, a space occupied by the antenna may also be reduced. Accordingly, it is not easy to simultaneously implement the transmission and reception of high frequency and wideband signals within a limited space.

[0006] For example, in the case of recent 5G mobile communication in high frequency bands, as the wavelength is shorter, a case in which signal transmission and reception may be blocked occurs, and it may be necessary to implement the transmission and reception of multi-band signals.

[0007] Therefore, it is necessary to apply an antenna to a display device in a form of a film or a patch, and in order to implement the above-described high frequency communication, a structural design of the antenna to secure the reliability of radiation characteristics is required despite a thin structure.

[0008] For example, Korean Patent Laid-Open Publication No. 2010-0114091 discloses a dual patch antenna module, but it may not be sufficient to be applied to a small device because the antenna module is manufactured in a thin shape within a limited space.

SUMMARY

[0009] It is an object of the present invention to provide an antenna device and a display device including the same.

[0010] To achieve the above objects, the following technical solutions are adopted in the present invention.

[0011] 1. An antenna device including: a dielectric layer; a first radiator disposed on an upper surface of the dielectric layer; a transmission line whose one end is connected with the first radiator on the upper surface of the dielectric layer; a signal pad connected to the other end of the transmission line; ground pads disposed around the signal pad; and a second radiator extending from the ground pad parallel to the transmission line and including one or more uneven parts.

[0012] 2. The antenna device according to the above 1, wherein the one or more uneven parts are formed on one side of the second radiator facing the first radiator.

[0013] 3. The antenna device according to the above 1, wherein a height and a width of each of the one or more uneven parts are determined depending on a desired resonance frequency of the second radiator.

[0014] 4. The antenna device according to the above 1, wherein the second radiator is electrically and physically spaced apart from the first radiator and the transmission line.

[0015] 5. The antenna device according to the above 1, wherein the second radiator and the ground pad are formed as a single member.

[0016] 6. The antenna device according to the above 1, wherein the second radiator is formed in a mesh structure, and the ground pad is formed in a solid structure.

[0017] 7. The antenna device according to the above 1, wherein the resonance frequency of the second radiator is higher than the resonance frequency of the first radiator.

[0018] 8. The antenna device according to the above 1, wherein the second radiator includes a pair of second radiators disposed so as to face each other with the transmission line interposed therebetween on the upper surface of the dielectric layer.

[0019] 9. The antenna device according to the above 1, wherein at least one of the first radiator, the transmission line and the second radiator is formed in a mesh structure.

[0020] 10. The antenna device according to the above 1, further including a ground layer disposed on a lower surface of the dielectric layer.

[0021] 11. A display device including the antenna device according to the above 1.

[0022] According to the present invention, by disposing the first radiator and the second radiator on the upper surface of the dielectric layer, it is possible to implement a dual band antenna.

[0023] In addition, by forming one or more uneven parts in the second radiator, the second radiator may be finely tuned to a desired resonance frequency, and thereby improving the radiation effect of the second radiator.

[0024] Further, by forming at least a portion of the antenna conductive layer of the antenna device in a mesh structure, it is possible to improve a transmittance of the antenna device, and suppress the antenna device from being viewed by a user when mounting it on the display device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0026] FIG. **1** is a schematic cross-sectional view illustrating an antenna device according to an embodiment;

[0027] FIG. **2** is a schematic plan view illustrating the antenna device according to an embodiment;

[0028] FIG. **3** is a schematic plan view illustrating an antenna device according to another embodiment;

[0029] FIG. **4** is a schematic plan view illustrating an antenna device according to another embodiment;

[0030] FIG. **5** is a schematic plan view illustrating an antenna device according to another embodiment;

[0031] FIG. **6** is a schematic plan view illustrating an antenna device according to another embodiment;

[0032] FIG. **7** is a schematic plan view illustrating an antenna device according to another embodiment;

[0033] FIG. **8** is a diagram for describing a change in a resonance frequency of the second radiator depending on heights of the uneven part;

[0034] FIG. **9** is a diagram for describing a change in the resonance frequency of the second radiator depending on widths of the uneven part; and

[0035] FIG. **10** is a schematic plan view for describing a display device according to an embodiment.

DETAILED DESCRIPTION

[0036] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. However, since the drawings attached to the present disclosure are only given for illustrating one of preferable various embodiments of present invention to easily understand the technical spirit of the present invention with the above-described invention, it should not be construed as limited to such a description illustrated in the drawings.

[0037] An antenna device described in the present disclosure may be a patch antenna or a microstrip antenna manufactured in a form of a transparent film. For example, the antenna device may be applied to electronic devices for high frequency or ultra-high frequency (e.g., 3G, 4G, 5G or more) mobile communication, Wi-Fi, Bluetooth, near field communication (NFC), global positioning system (GPS), and the like, but it is not limited thereto. In addition, the antenna device may be applied to various target structures such as an automobile, a building and the like.

[0038] In the following drawings, two directions which are parallel to an upper surface of a dielectric layer and cross each other are defined as a first direction and a second direction. In this case, the first direction and the second direction may cross each other perpendicularly. In addition, a direction perpendicular to the upper surface of the dielectric layer is defined as a third direction. For example, the first direction may correspond to a length direction of the antenna device, the second direction may correspond to a width direction of the antenna device, and the third direction may correspond to a thickness direction of the antenna device.

[0039] FIG. **1** is a schematic cross-sectional view illustrating an antenna device according to an embodiment.

[0040] Referring to FIG. **1**, an antenna device **100** may include a dielectric layer **110** and an antenna conductive layer **120**.

[0041] The dielectric layer **110** may include an insulation material having a predetermined dielectric constant. According to an embodiment, the dielectric layer **110** may include an inorganic insulation material such as glass, silicon oxide, silicon nitride, or metal oxide, or an organic insulation material such as an epoxy resin, an acrylic resin, or an imide resin. The dielectric layer **110** may function as a film substrate of the antenna device on which the antenna conductive layer **120** is formed.

[0042] According to an embodiment, a transparent film may be provided as the dielectric layer **110**. In this case, the transparent film may include a polyester resin such as polyethylene terephthalate, polyethylene isophthalate, polyethylene naphthalate, polybutylene terephthalate, etc.; a cellulose resin such as diacetyl cellulose, triacetyl cellulose, etc.; a polycarbonate resin; an acrylic resin such as polymethyl (meth)acrylate, polyethyl (meth)acrylate, etc.; a styrene resin such as polystyrene, acrylonitrile-styrene copolymer, etc.; a polyolefm resin such as polyethylene, polypropylene, cyclic polyolefin or polyolefin having a norbomene structure, ethylene-propylene copolymer, etc.; a vinyl chloride resin; an amide resin such as nylon, aromatic polyamide; an imide resin; a polyether sulfonic resin; a sulfonic resin; a polyether ether ketone resin; a polyphenylene sulfide resin; a vinylalcohol resin; a vinylidene chloride resin; a vinylbutyral resin; an allylate resin; a polyoxymethylene resin; a thermoplastic resin such as an epoxy resin and the like. These compounds may be used alone or in combination of two or more thereof. In addition, a transparent film made of a thermosetting resin or an ultraviolet curable resin such as (meth)acrylate, urethane, acrylic urethane, epoxy, silicone, and the like may be used as the dielectric layer **110**.

[0043] According to an embodiment, an adhesive film such as an optically clear adhesive (OCA), an optically clear resin (OCR), and the like may also be included in the dielectric layer **110**.

[0044] According to an embodiment, the dielectric layer **110** may be formed in a substantial single layer, or may be formed in a multilayer structure of two or more layers.

[0045] Capacitance or inductance may be generated by the dielectric layer **110**, thus to adjust a frequency band which can be driven or sensed by the antenna device **100**. When the dielectric constant of the dielectric layer **110** exceeds about 12, a driving frequency is excessively reduced, such that driving of the antenna in a desired high frequency band may not be implemented. Therefore, according to an embodiment, the dielectric constant of the dielectric layer **110** may be adjusted in a range of about 1.5 to 12, and preferably about 2 to 12.

[0046] According to an embodiment, an insulation layer (e.g., an encapsulation layer, a passivation layer, etc. of a display panel) inside the display device on which the antenna device **100** is mounted may be provided as the dielectric layer **110**.

[0047] The antenna conductive layer **120** may be disposed on the upper surface of the dielectric layer **110**. The antenna conductive layer **120** may include one or more antenna units including a first radiator and a second radiator.

[0048] The antenna conductive layer **120** may include a low resistance metal such as silver (Ag), gold (Au), copper (Cu), aluminum (Al), platinum (Pt), palladium (Pd), chromium (Cr), titanium (Ti), tungsten (W), niobium (Nb), tantalum (Ta), vanadium (V), iron (Fe), manganese (Mn), cobalt (Co), nickel (Ni), zinc (Zn), tin (Sn), molybdenum (Mo), calcium (Ca), or an alloy including at least one thereof. These may be used alone or in combination of two or more thereof. For example, the antenna conductive layer **120** may include silver (Ag) or a silver alloy (e.g., a silver-palladium-copper (APC) alloy) to implement a low resistance. As another example, the antenna conductive layer **120** may include copper (Cu) or a copper alloy (e.g., a copper-calcium (CuCa) alloy) in consideration of low resistance and fine line width patterning.

[0049] According to an embodiment, the antenna conductive layer **120** may include a transparent conductive oxide such as indium tin oxide (ITO), indium zinc oxide (IZO), indium zinc tin oxide (IZTO), or zinc oxide (ZnOx).

[0050] According to an embodiment, the antenna conductive layer **120** may include a lamination structure of a transparent conductive oxide layer and a metal layer, for example, may have a two-layer structure of transparent conductive oxide layer-metal layer or a three-layer structure of transparent conductive oxide layer-metal layer-transparent conductive oxide layer. In this case, resistance may be reduced to improve signal transmission speed while improving flexible properties by the metal layer, and corrosion resistance and transparency may be improved by the transparent conductive oxide layer.

[0051] According to an exemplary embodiment, the antenna conductive layer **120** may include a blackening processing part. Accordingly, reflectance on a surface of the antenna conductive layer **120** may be decreased, thereby reducing the pattern from being viewed due to light reflection.

[0052] According to an embodiment, the surface of the metal layer included in the antenna conductive layer **120** is converted into metal oxide or metal sulfide to form a blackened layer. According to an embodiment, the blackened layer such as a black material coating layer or a plating layer may be formed on the antenna conductive layer **120** or the metal layer. Herein, the black material coating layer or plating layer may include silicon, carbon, copper, molybdenum, tin, chromium, molybdenum, nickel, cobalt, or oxide, sulfide, or an alloy containing at least one of them.

[0053] The composition and thickness of the blackened layer may be adjusted in consideration of an effect of reducing reflectance.

[0054] Specific details of the antenna conductive layer **120** will be described below with reference to FIGS. **2** and **7**.

[0055] According to an embodiment, the antenna device **100** may further include a ground layer **130**. Since the antenna device **100** includes the ground layer **130**, vertical radiation characteristics may be implemented.

[0056] The ground layer **130** may be formed on a lower surface of the dielectric layer **110**. The ground layer **130** may be disposed so as to be at least partially overlapped with the antenna conductive layer **120** with the dielectric layer **110** interposed therebetween. For example, the ground layer **130** may be overlapped with the radiator (see **210** and **230** in FIG. **2**) of the antenna conductive layer **120**.

[0057] According to an embodiment, a conductive member of the display device or display panel on which the antenna device **100** is mounted may be provided as the ground layer **130**. For example, the conductive member may include electrodes or wirings such as a gate electrode, source/drain electrodes, pixel electrode, common electrode, data line, scan line, etc. of a thin film transistor (TFT) included in the display panel; and a stainless steel (SUS) plate, heat radiation sheet, digitizer, electromagnetic shielding layer, pressure sensor, fingerprint sensor, etc. of the display device.

[0058] FIG. **2** is a schematic plan view illustrating the antenna device according to an embodiment.

[0059] Referring to FIGS. **1** and **2**, the antenna device **100** according to an embodiment may include the antenna conductive layer **120** formed on the upper surface of the dielectric layer **110**. Herein, the antenna conductive layer **120** may include an antenna unit including a first radiator **210** and second radiators **230**, a transmission line **220** and a pad electrode **240**.

[0060] The first radiator **210** may be formed in a mesh structure. Thereby, transmittance of the first radiator **210** may be increased, and flexibility of the antenna device **100** may be improved. Therefore, the antenna device **100** may be effectively applied to a flexible display device.

[0061] A length of the first radiator **210** in the first direction may be determined depending on a desired first resonance frequency, and a width of the first radiator **210** in the second direction may be determined depending on a desired radiation resistance and gain. According to an embodiment, the first resonance frequency may belong to a band of 28 GHz, but it is not limited thereto.

[0062] The first radiator **210** may be electrically connected to the transmission line **220** to be supplied with a power through the transmission line **220**.

[0063] According to one embodiment, as shown in FIG. **2**, the first radiator **210** may be implemented in a rectangular shape. However, this is only an example and there is no particular limitation on the shape of the first radiator **210**. That is, the first radiator **210** may be implemented in various shapes such as a rhombus, circle and the like.

[0064] The transmission line **220** is disposed between the first radiator **210** and a signal pad **241** of the pad electrode **240**, and may be branched from a central portion of the first radiator **210** to electrically connect the first radiator **210** and the signal pad **241**.

[0065] According to an embodiment, the transmission line **220** may include substantially the same conductive material as the first radiator **210**. Further, the transmission line **220** may be formed as a substantial single member by integrally connecting with the first radiator **210**, or may be formed as a separate member from the first radiator **210**.

[0066] According to an embodiment, the transmission line **220** may be formed in a mesh structure having substantially the same shape (e.g., having the same line width, the same interval, etc.) as the first radiator **210**.

[0067] The second radiator **230** may be electrically and physically spaced apart from the first radiator **210** and the transmission line **220**, and may be coupled to the first radiator **210** and the transmission line **220** to be supplied with a power. The second radiator **230** may extend from ground pads **242** of the pad electrode **240** to the first radiator **210** in parallel to the transmission line **220**. For example, a pair of second radiators **230** may be formed in a coplanar waveguide with ground (CPW ground) structure disposed to face each other with the transmission line **220** interposed therebetween on the upper surface of the dielectric layer **110** having the ground layer **130** disposed on a lower surface thereof.

[0068] According to an embodiment, the second radiator **230** may be formed as a substantial single member by integrally connecting with the ground pad **242**, or may be formed as a separate member from the ground pad **242**. In addition, the second radiator **230** may have a width which is formed smaller than, equal to, or larger than the width of the ground pad **242**.

[0069] The second radiator **230** may include an uneven part **231** recessed into an inside the second radiator **230**.

[0070] The uneven part **231** may be formed on one side of the second radiator **230** facing the first radiator **210**. At this time, one side of the second radiator **230** facing the first radiator **210** is a side of the second radiator **230** positioned in the first direction, and may include both a region which is overlapped with the first radiator **210** and a region which is not overlapped therewith in the first direction. A location, height H, and width W of the uneven part **231** may be determined depending on the desired resonance frequency, radiation resistance, and gain of the second radiator **230** in consideration of the length in the first direction and the width in the second direction of the second radiator **230**. According to an embodiment, the second resonance frequency may be higher than the first resonance frequency. For example, the second resonance frequency may belong to a band of 38 GHz, but it is not limited thereto.

[0071] According to an embodiment, the second radiator **230** may be formed in a mesh structure having substantially the same shape (e.g., having the same line width, the same interval, etc.) as the first radiator **210**. Thereby, it is possible to improve a transmittance of the antenna unit, and suppress the antenna device from being viewed by a user when the antenna device **100** is mounted on the display device. The second radiator **230** may include substantially the same conductive material as the first radiator **210**.

[0072] As shown in FIG. **2**, the second radiator **230** may be formed in a coplanar waveguide with ground (CPW ground) structure, and it may be difficult to finely tune the resonance frequency of the second radiator **230** having the CPW ground structure. In the antenna device according to an embodiment, the uneven part **231** is formed in the second radiator **230**, and the height H and/or the width W of the uneven part **231** are/is adjusted, thereby it may be implemented so that the resonance frequency of the second radiator **230** having the CPW ground structure is more accurately matched with the desired second resonance frequency. That is, according to an embodiment, the length and width of the second radiator **230** may be determined to coarsely tune the resonance frequency of the second radiator **230** to the desired second resonance frequency, and the height and/or width of the uneven part **231** may be determined to finely tune the resonance frequency of the second radiator **230** to the desired second resonance frequency. Thereby, it is possible to improve a radiation effect of the second radiator **230**.

[0073] The pad electrode **240** may include a signal pad **241** and ground pads **242**.

[0074] The signal pad **241** may be connected to an end of the transmission line **220**, thus to be electrically connected with the first radiator **210** through the transmission line **220**. Thereby, the signal pad **241** may electrically connect a driving circuit unit (e.g., an IC chip, etc.) and the first radiator **210**. For example, a circuit board such as a flexible printed circuit board (FPCB) may be bonded to the signal pad **241**, and a driving circuit unit may be mounted on the flexible printed circuit board. Accordingly, the first radiator **210** and the driving circuit unit may be electrically connected with each other.

[0075] The ground pads **242** may be disposed around the signal pad **241** so as to be electrically and physically separated from the signal pad **241**. For example, a pair of ground pads **242** may be disposed to face each other with the signal pad **241** interposed therebetween.

[0076] According to an embodiment, the signal pad **241** and the ground pad **242** may be formed in a solid structure including the above-described metal or alloy to reduce signal resistance.

[0077] Meanwhile, for convenience of description, FIG. **2** illustrates only one antenna unit, but a plurality of antenna units may be arranged on the upper surface of the dielectric layer **110** in an array form. In this case, a separation distance between the antenna units may be greater than half of a wavelength corresponding to the resonance frequency (e.g., the first resonance frequency or the second resonance frequency) of the antenna unit in order to minimize radiation interference from each antenna unit.

[0078] FIG. **3** is a schematic plan view illustrating an antenna device according to another embodiment.

[0079] Referring to FIGS. **1** and **3**, the antenna conductive layer **120** may include an antenna unit including a first radiator **210** and second radiators **330**, a transmission line **220**, and a pad electrode **240**. Herein, the first radiator **210**, the transmission line **220** and the pad electrode **240** are the same as those of the configuration described with reference to FIG. **2**, therefore the same configuration will not be described in detail. In addition, the second radiator **330** is similar to the second radiator **230** shown in FIG. **2**, therefore it will not be described in detail within the overlapping range.

[0080] The second radiator **330** may include two or more uneven parts **331** and **332** recessed into an inside the second radiator **330** at an interval.

[0081] The two or more uneven parts **331** and **332** may be formed on one side of the second radiator **330** facing the first radiator **210**. In other words, the uneven parts **331** and **332** may be formed on an opposite side of the side connected with the ground pad **242** in the second radiator **230**. Positions, heights H**1** and H**2**, and widths W**1** and W**2** of the uneven parts **331** and **332** may be determined depending on the desired resonance frequency, radiation resistance, and gain of the second radiator **330** in consideration of the length in the first direction and the width in the second direction of the second radiator **330**. According to an embodiment, the heights H**1** and H**2** and widths W**1** and W**2** of the respective uneven parts **331** and **332** may be the same as or different from each other.

[0082] As shown in FIG. **3**, the second radiator **330** may be formed in a coplanar waveguide with ground (CPW ground) structure, and it may be difficult to finely tune the resonance frequency of the second radiator **330** having the CPW ground structure. In the antenna device according to an embodiment, the two or more uneven parts **331** and **332** are formed in the second radiator **330**, and the heights H**1** and H**2** and/or widths W**1** and W**2** of the uneven parts **331** and **332** are adjusted respectively, thereby it may be implemented so that the resonance frequency of the second radiator **330** having the CPW ground structure is more accurately matched with the desired second resonance frequency. That is, according to an embodiment, the length and width of the second radiator **330** may be determined to coarsely tune the resonance frequency of the second radiator **330** to the desired second resonance frequency, and the heights and/or widths of the respective uneven parts **331** and **332** may be determined to finely tune the resonance frequency of the second radiator **330** to the desired second resonance frequency. Thereby, it is possible to improve the radiation effect of the second radiator **330**.

[0083] Meanwhile, for convenience of description, FIG. **3** illustrates only one antenna unit, a plurality of antenna units may be arranged on the upper surface of the dielectric layer **110** in an array form. In this case, the separation distance between the antenna units may be greater than half of a wavelength corresponding to the resonance frequency (e.g., the first resonance frequency or the second resonance frequency) of the antenna unit in order to minimize radiation interference from each antenna unit.

[0084] FIG. **4** is a schematic plan view illustrating an antenna device according to another embodiment.

[0085] Referring to FIGS. **1** and **4**, the antenna conductive layer **120** may include an antenna unit including a first radiator **210** and second radiators **430**, a transmission line **220**, and a pad electrode **240**. Herein, the first radiator **210**, the transmission line **220** and the pad electrode **240** are the same as those of the configuration described with reference to FIG. **2**, therefore the same configuration will not be described in detail. In addition, the second radiator **430** is similar to the second radiator **230** shown in FIG. **2**, therefore it will not be described in detail within the overlapping range.

[0086] The second radiator **430** may include an uneven part **431** protruding to an outside of the second radiator **430**.

[0087] The uneven part **431** may be formed on one side of the second radiator **430** facing the first radiator **210**. A position, height H, and width W of the uneven part **431** may be determined depending on the desired resonance frequency, radiation resistance, and gain of the second radiator **430** in consideration of the length in the first direction and the width in the second direction of the second radiator **430**.

[0088] As shown in FIG. **4**, the second radiator **430** may be formed in a coplanar waveguide with ground (CPW ground) structure, and it may be difficult to finely tune the resonance frequency of the second radiator **430** having the CPW ground structure. In the antenna device according to an embodiment, the uneven part **431** is formed in the second radiator **430**, and the height H and/or the width W of the uneven part **431** are/is adjusted, thereby it may be implemented so that the resonance frequency of the second radiator **430** having the CPW ground structure is more accurately matched with the desired second resonance frequency. That is, according to an embodiment, the length and width of the second radiator **430** may be determined to coarsely tune the resonance frequency of the second radiator **430** to the desired second resonance frequency, and the height and/or width of the uneven part **431** may be determined to finely tune the resonance frequency of the second radiator **430** to the desired second resonance frequency. Thereby, it is possible to improve a radiation effect of the second radiator **430**.

[0089] Meanwhile, for convenience of description, FIG. **4** illustrates only one antenna unit, but a plurality of antenna units may be arranged on the upper surface of the dielectric layer **110** in an array form. In this case, a separation distance between the antenna units may be greater than half of a wavelength corresponding to the resonance frequency (e.g., the first resonance frequency or the second resonance frequency) of the antenna unit in order to minimize radiation interference from each antenna unit.

[0090] FIG. **5** is a schematic plan view illustrating an antenna device according to another embodiment.

[0091] Referring to FIGS. **1** and **5**, the antenna conductive layer **120** may include an antenna unit including a first radiator **210** and second radiators **530**, a transmission line **220**, and a pad electrode **240**. Herein, the first radiator **210**, the transmission line **220** and the pad electrode **240** are the same as those of the configuration described with reference to FIG. **2**, therefore the same configuration will not be described in detail. In addition, the second radiator **530** is similar to the second radiator **230** shown in FIG. **2**, therefore it will not be described in detail within the overlapping range.

[0092] The second radiator **530** may include two or more uneven parts **531** and **532** protruding to an outside of the second radiator **530**.

[0093] The two or more uneven parts **531** and **532** may be formed on one side of the second radiator **530** facing the first radiator **210**. Positions, heights H**1** and H**2**, and widths W**1** and W**2** of the uneven parts **531** and **532** may be determined depending on the desired resonance frequency, radiation resistance, and gain of the second radiator **530** in consideration of the length in the first direction and the width in the second direction of the second radiator **530**. According to an embodiment, the heights H**1** and H**2** and widths W**1** and W**2** of the respective uneven parts **531** and **532** may be the same as or different from each other.

[0094] As shown in FIG. **5**, the second radiator **530** may be formed in a coplanar waveguide with ground (CPW ground) structure, and it may be difficult to finely tune the resonance frequency of the second radiator **530** having the CPW ground structure. In the antenna device according to an embodiment, the two or more uneven parts **531** and **532** are formed in the second radiator **530**, and the heights H**1** and H**2** and/or widths W**1** and W**2** of the uneven parts **531** and **532** are adjusted respectively, thereby it may be implemented so that the resonance frequency of the second radiator **530** having the CPW ground structure is more accurately matched with the desired second resonance frequency. That is, according to an embodiment, the length and width of the second radiator **530** may be determined to coarsely tune the resonance frequency of the second radiator **530** to the desired second resonance frequency, and the heights and/or widths of the respective uneven parts **531** and **532** may be determined to finely tune the resonance frequency of the second radiator **530** to the desired second resonance frequency. Thereby, it is possible to improve the radiation effect of the second radiator **530**.

[0095] Meanwhile, for convenience of description, FIG. **5** illustrates only one antenna unit, a plurality of antenna units may be arranged on the upper surface of the dielectric layer **110** in an array form. In this case, the separation distance between the antenna units may be greater than half of a wavelength corresponding to the resonance frequency (e.g., the first resonance frequency or the second resonance frequency) of the antenna unit in order to minimize radiation interference from each antenna unit.

[0096] FIG. **6** is a schematic plan view illustrating an antenna device according to another embodiment.

[0097] Referring to FIGS. **1** and **6**, the antenna conductive layer **120** may include an antenna unit including a first radiator **210** and second radiators **630**, a transmission line **220**, and a pad electrode **240**. Herein, the first radiator **210**, the transmission line **220** and the pad electrode **240** are the same as those of the configuration described with reference to FIG. **2**, therefore the same configuration will not be described in detail. In addition, the second radiator **630** is similar to the second radiator **230** shown in FIG. **2**, therefore it will not be described in detail within the overlapping range.

[0098] The second radiator **630** may include two or more uneven parts **631** and **632**. The first uneven part **631** may be recessed into an inside of the second radiator **630**, and the second uneven part **632** may protrude to an outside of the second radiator **630**.

[0099] The two or more uneven parts **631** and **632** may be formed on one side of the second radiator **630** facing the first radiator **210**. Positions, heights H**1** and H**2**, and widths W**1** and W**2** of the uneven parts **631** and **632** may be determined depending on the desired resonance frequency, radiation resistance, and gain of the second radiator **630** in consideration of the length in the first direction and the width in the second direction of the second radiator **630**. According to an embodiment, the heights H**1** and H**2** and widths W**1** and W**2** of the respective uneven parts **631** and **632** may be the same as or different from each other.

[0100] As shown in FIG. **6**, the second radiator **630** may be formed in a coplanar waveguide with ground (CPW ground) structure, and it may be difficult to finely tune the resonance frequency of the second radiator **630** having the CPW ground structure. In the antenna device according to an embodiment, the two or more uneven parts **631** and **632** are formed in the second radiator **630**, and the heights H**1** and H**2** and/or widths W**1** and W**2** of the uneven parts **631** and **632** are adjusted respectively, thereby it may be implemented so that the resonance frequency of the second radiator **630** having the CPW ground structure is more accurately matched with the desired second resonance frequency. That is, according to an embodiment, the length and width of the second radiator **630** may be determined to coarsely tune the resonance frequency of the second radiator **630** to the desired second resonance frequency, and the heights and/or widths of the respective uneven parts **631** and **632** may be determined to finely tune the resonance frequency of the second radiator **630** to the desired second resonance frequency. Thereby, it is possible to improve the radiation effect of the second radiator **630**.

[0101] Meanwhile, for convenience of description, FIG. **6** illustrates only one antenna unit, a plurality of antenna units may be arranged on the upper surface of the dielectric layer in an array form. In this case, the separation distance between the antenna units may be greater than half of a wavelength corresponding to the resonance frequency (e.g., the first resonance frequency or the second resonance frequency) of the antenna unit in order to minimize radiation interference from each antenna unit.

[0102] FIG. **7** is a schematic plan view illustrating an antenna device according to another embodiment.

[0103] Referring to FIGS. **1** and **7**, the antenna conductive layer **120** may include an antenna unit including a first radiator **210** and second radiators **230**, a transmission line **220**, a pad electrode **240**, and a dummy pattern **250**. Herein, the first radiator **210**, the second radiator **230**, the transmission line **220** and the pad electrode **240** are the same as those of the configuration described with reference to FIG. **2**, therefore the same configuration will not be described in detail.

[0104] The dummy pattern **250** may be arranged around the first radiator **210**, the transmission line **220**, and the second radiators **230**.

[0105] The dummy pattern **250** is formed in a mesh structure having substantially the same shape as at least one of the first radiator **210**, the second radiator **230**, and the transmission line **220**, and may include the same metal as at least one of the first radiator **210**, the second radiator **230** and the transmission line **220**. According to an embodiment, the dummy pattern **250** may be formed in a segmented mesh structure.

[0106] The dummy pattern **250** may be disposed so as to be electrically and physically separated from the first radiator **210**, the second radiators **230**, the transmission line **220**, and the pad electrode **240**. For example, a separation region **251** may be formed along side lines or profiles of the first radiator **210**, the second radiators **230** and the transmission line **220** to separate the dummy pattern **250** from the first radiator **210**, the second radiators **230** and the transmission line **220**.

[0107] As described above, by arranging the dummy pattern **250** having a mesh structure substantially the same as at least one of the first radiator **210**, the second radiator **230** and the transmission line **220** around the first radiator **210**, the second radiator **230**, and the transmission line **220**, it is possible to prevent the antenna unit from being viewed by the user of the display device on which the antenna device is mounted due to a difference in the electrode arrangement for each position.

[0108] FIG. **8** is a diagram for describing a change in the resonance frequency of the second radiator depending on the height of the uneven part. More specifically, FIG. **8** is a graph illustrating S**11** characteristics of the second radiator **230**, when the width W of the uneven part **231** is fixed to 0.25 mm and the height H of the uneven part **231** is formed as 0 mm, 0.5 mm, 1 mm, and 1.5 mm in the embodiment of FIG. **2**. In FIG. **8**, a solid line **810** may denote an S**11** characteristic of the second radiator when the uneven part has a height of 0 mm, a bold dotted line **820** may denote an S**11** characteristic of the second radiator when the uneven part has a height of 0.5 mm, a dash-single dotted line **830** may denote an S**11** characteristic of the second radiator when the uneven part has a height of 1 mm, and a fine dotted line **840** may denote an S**11** characteristic of the second radiator when the uneven part has a height of 1.5 mm.

[0109] Referring to FIG. **8**, it can be seen that, when the heights of the uneven part are 0 mm, 0.5 mm, 1 mm, and 1.5 mm, the second radiator resonates at frequencies of 38.044 GHz, 37.778 GHz, 37.200 GHz, and 37.022 GHz, respectively. That is, it can be seen that the resonance frequency of the second radiator varies depending on the height of the uneven part, and the resonance frequency of the second radiator may be finely tuned by adjusting the height of the uneven part.

[0110] FIG. **9** is a diagram for describing a change in the resonance frequency of the second radiator depending on the width of the uneven part. More specifically, FIG. **9** is a graph illustrating S**11** characteristics of the second radiator **230**, when the height H of the uneven part **231** is fixed to 0.5 mm and the width W of the uneven part **231** is formed as 125 μm, 375 μm, and 500 μm in the embodiment of FIG. **2**. In FIG. **9**, a solid line **910** may denote an S**11** characteristic of the second radiator when the uneven part has a width of 125 μm, a dotted line **920** may denote an S**11** characteristic of the second radiator when the uneven part has a width of 375 μm, and a dash-single dotted line **930** may denote an S**11** characteristic of the second radiator when the uneven part has a width of 1 mm.

[0111] Referring to FIG. **9**, it can be seen that, when the widths of the uneven part are 125 μm, 375 μm, and 500 μm, the second radiator resonates at frequencies of 38.000 GHz, 37.956 GHz, and 373.911 GHz, respectively. That is, it can be seen that the resonance frequency of the second radiator varies depending on the width of the uneven part, and the resonance frequency of the second radiator may be finely tuned by adjusting the width of the uneven part.

[0112] Therefore, as described above, by forming the uneven part in the second radiator and adjusting the height and/or width of the uneven part, it may be implemented so that the resonance frequency of the second radiator of the CPW ground structure is more accurately matched with the desired second resonance frequency. That is, the length and width of the second radiator may be determined to coarsely tune the resonance frequency of the second radiator to the desired second resonance frequency, and the height and/or width of the uneven part may be determined to finely tune resonance frequency of the second radiator to the desired second resonance frequency. Thereby, it is possible to improve the radiation effect of the second radiator.

[0113] FIG. **10** is a schematic plan view illustrating an image display device according to exemplary embodiments. For example, FIG. **10** shows an external shape including a window of the display device.

[0114] Referring to FIG. **10**, a display device **1000** may include a display region **1010** and a peripheral region **1020**. The peripheral region **1020** may be disposed on both sides and/or both ends of the display region **1010**, for example.

[0115] According to an embodiment, the above-described antenna device may be inserted into the display device **1000** in a form of a film or a patch. For example, the first radiator **210**, the second radiators **230**, **330**, **430**, **530**, and **630** of the antenna device and the transmission line **220** may be disposed so as to at least partially correspond to the display region **1010** of the display device **1000**, and the pad electrode **240** may be disposed to correspond to the peripheral region **1020** of the display device **1000**.

[0116] The peripheral region **1020** may correspond to a light-shielding part or a bezel part of the image display device **1000**, for example. A driving circuit such as an integrated circuit (IC) chip of the image display device **1000** and/or the antenna device may be disposed in the peripheral region **1020**.

[0117] By arranging the pad electrode **240** of the antenna device so as to be adjacent to the driving circuit, signal loss may be suppressed by shortening a path for transmitting and receiving signals.

[0118] When the antenna device includes the dummy pattern **250**, the dummy pattern **250** may be disposed so as to at least partially correspond to the display region **1010** of the display device **1000**.

[0119] The antenna device includes the antenna unit and/or the dummy pattern, which are formed in a mesh structure, such that it is possible to significantly reduce or suppress the patterns from being viewed while improving the transmittance. Accordingly, image quality in the display region **1010** may also be improved while maintaining or improving desired communication reliability.

[0120] The present invention has been described with reference to the preferred embodiments above, and it will be understood by those skilled in the art that various modifications may be made within the scope without departing from essential characteristics of the present invention. Accordingly, it should be interpreted that the scope of the present invention is not limited to the above-described embodiments, and other various embodiments within the scope equivalent to those described in the claims are included within the present invention.

What is claimed is:

1. An antenna device comprising:
a dielectric layer;
a first radiator disposed on an upper surface of the dielectric layer;
a transmission line whose one end is connected with the first radiator on the upper surface of the dielectric layer;
a signal pad connected to the other end of the transmission line;
ground pads disposed around the signal pad; and
a second radiator extending from the ground pad parallel to the transmission line and including one or more uneven parts.

2. The antenna device according to claim **1**, wherein the one or more uneven parts are formed on one side of the second radiator facing the first radiator.

3. The antenna device according to claim **1**, wherein a height and a width of each of the one or more uneven parts are determined depending on a desired resonance frequency of the second radiator.

4. The antenna device according to claim **1**, wherein the second radiator is electrically **0** and physically spaced apart from the first radiator and the transmission line.

5. The antenna device according to claim **1**, wherein the second radiator and the ground pad are formed as a single member.

6. The antenna device according to claim **1**, wherein the second radiator is formed in a mesh structure, and the ground pad is formed in a solid structure.

7. The antenna device according to claim **1**, wherein the resonance frequency of the second radiator is higher than the resonance frequency of the first radiator.

8. The antenna device according to claim **1**, wherein the second radiator includes a pair of second radiators disposed so as to face each other with the transmission line interposed therebetween on the upper surface of the dielectric layer.

9. The antenna device according to claim **1**, wherein at least one of the first radiator, the transmission line and the second radiator is formed in a mesh structure.

10. The antenna device according to claim **1**, further comprising a ground layer disposed on a lower surface of the dielectric layer.

11. A display device comprising the antenna device according to claim **1**.

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