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(71) Applicant: **Sercomm Corporation**
Nangkang
T'ai pei 115 (TW)

(72) Inventor: **LEE, Pei-Ju**
115 NanKang Taipei (TW)

(74) Representative: **2K Patentanwälte Blasberg**
Kewitz & Reichel
Partnerschaft mbB
Schumannstrasse 27
60325 Frankfurt am Main (DE)

(54) **ANTENNA DEVICE**

(57) An antenna device includes a first shorting element, a second shorting element, a first radiation element, a second radiation element and a third radiation element. The first shorting element and the second shorting element are electrically connected to a ground plane. The first radiation element has a feeding point and is disposed between the first shorting element and the second shorting element. The second radiation element is

electrically connected between the first radiation element and the first shorting element. The third radiation element is electrically connected between the first radiation element and the second shorting element. The first to third radiation elements, the first shorting element and the second shorting element form two antenna elements disposed in parallel, such that the antenna device operates in a first frequency band and a second frequency band.

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention is related to an antenna device, and particularly to an antenna device having wideband operation and omnidirectional radiation pattern.

2. Description of Related Art

[0002] In recent years, ceiling-type network equipment such as access point (AP) is normally installed at a high point (e.g. ceiling) in a space so as to provide broader signal coverage. In addition, in order to provide optimal signal coverage, an antenna device in the ceiling-type network equipment must have omnidirectional radiation pattern. However, in most cases, the conventional antenna device does not satisfy the need for both of wideband operation and omnidirectional radiation pattern, and thus limits the development of the ceiling-type network equipment in practical application.

SUMMARY OF THE INVENTION

[0003] The invention is defined in the independent claim. The dependent claims define preferred embodiments. The invention provides an antenna device which has good dual wideband operation and omnidirectional radiation pattern, thereby effectively increasing signal coverage of ceiling-type network equipment.

[0004] An antenna device according to an embodiment includes a first shorting element, a second shorting element, a first radiation element, a second radiation element and a third radiation element. The first shorting element and the second shorting element are electrically connected to a ground plane. The first radiation element has a feeding point and is disposed between the first shorting element and the second shorting element. The second radiation element is electrically connected between the first radiation element and the first shorting element. The third radiation element is electrically connected between the first radiation element and the second shorting element. The first radiation element to the third radiation element, the first shorting element and the second shorting element form two antenna elements disposed in parallel, such that the antenna device operates in a first frequency band and a second frequency band.

[0005] Based on the above, the antenna device uses the first radiation element to the third radiation element, the first shorting element and the second shorting element to form two antenna elements that are arranged in parallel according to the embodiments of the invention. With such configuration, the antenna device can have good dual wideband operation and omnidirectional radiation pattern, and can further be adapted for use in the ceiling-type network equipment while effectively increas-

ing signal coverage of the ceiling-type network equipment.

[0006] In order to make the aforementioned features and advantages of the invention more comprehensible, embodiments accompanying figures are described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIGs. 1 and 2 are schematic views illustrating an antenna device according to an embodiment of the invention.

FIG. 3 is a diagram illustrating return loss of an antenna device in a first frequency band according to an embodiment of the invention.

FIG. 4 is a diagram illustrating return loss of an antenna device in a second frequency band according to an embodiment of the invention.

FIG. 5 is a schematic view illustrating configuration of an antenna device relative to a ground plane according to an embodiment of the invention.

FIG. 6 is a schematic view illustrating radiation pattern of an antenna device according to an embodiment of the invention.

FIG. 7 is a schematic view illustrating configuration of an antenna device relative to a ground plane according to another embodiment of the invention.

FIG. 8 is a schematic view illustrating an antenna device according to another embodiment of the invention.

FIG. 9 is a diagram describing the radiation pattern of the antenna device illustrated in the embodiment of FIG. 8.

DESCRIPTION OF EMBODIMENTS

[0008] FIGs. 1 and 2 are schematic views illustrating an antenna device according to an embodiment of the invention. As shown in FIG. 1 and FIG. 2, an antenna device 100 includes a first radiation element 110, a second radiation element 120, a third radiation element 130, a first shorting element 140 and a second shorting element 150. Each of the first to third radiation elements 110-130, the first shorting element 140 and the second shorting element 150 may be, for example, a rectangular metal sheet.

[0009] The antenna device 100 further includes a fixing element 160. Specifically, the antenna device 100 may be tightly attached to a ground plane 101 through the fixing element 160. Accordingly, the fixing element 160 may be regarded as a part of the ground plane 101. In

another embodiment, persons skilled in the art may remove the fixing element 160 based on the need of design, and the first shorting element 140 and the second shorting element 150 in the antenna device 100 may be directly and electrically connected to the ground plane 101.

[0010] Further referring to FIGs. 1 and 2, the first radiation element 110 has a feeding point FP1, and the first radiation element 110 is disposed between the first shorting element 140 and the second shorting element 150. Specifically, the first radiation element 110 includes a first sidewall SD11 and a second sidewall SD12 opposite to each other, and the first sidewall SD11 faces the ground plane 101. The second sidewall SD12 is electrically connected to the second radiation element 120 and the third radiation element 130. Moreover, the feeding point FP1 is disposed in the center of the first sidewall SD11. In an embodiment, the first radiation element 110 is perpendicular to the ground plane 101, and may be divided into a first portion 111 and a second portion 112. For example, in an embodiment, the first portion 111 and second portion 112 may be two different elements tightly attached to each other to form the first radiation element 110. In another embodiment, the first portion 111 and second portion 112 may be formed integrally, for example.

[0011] The second radiation element 120 is electrically connected between the first radiation element 110 and the first shorting element 140. The third radiation element 130 is electrically connected between the first radiation element 110 and the second shorting element 150. Specifically, the second radiation element 120 and the third radiation element 130 are disposed symmetrically relative to the first radiation element 110. For instance, the geometric plane where the first radiation element 110 is located is used as a basis; the second radiation element 120 and third radiation element 130 are disposed symmetrically on two opposite sides of the first radiation element 110. In one embodiment, the second radiation element 120 is parallel to the ground plane 101 and electrically connected to the first portion 111 of the first radiation element 110. The third radiation element 130 is parallel to the ground plane 101 and electrically connected to the second portion 112 of the first radiation element 110. As such, the first to third radiation elements 110-130 can form a T-shaped structure.

[0012] The first shorting element 140 is electrically connected to a sidewall SD21 of the second radiation element 120, and the second shorting element 150 is electrically connected to a sidewall SD31 of the third radiation element 130. Specifically, the first shorting element 140 extends from the sidewall SD21 of the second radiation element 120 to the ground plane 101 in a direction perpendicular to the second radiation element 120. The second shorting element 150 extends from the sidewall SD31 of the third radiation element 130 to the ground plane 101 in a direction perpendicular to the third radiation element 130. In addition, in an embodiment, the first shorting element 140 and the second shorting element

150 are perpendicular to the ground plane 101.

[0013] It should be noted that the first portion 111 (or the first radiation element 110 as a whole), the second radiation element 120 and the first shorting element 140 may form a first inverted-F antenna. The second portion 112 (or the first radiation element 110 as a whole), the third radiation element 130 and the second shorting element 150 may form a second inverted-F antenna. Apart from that, the first inverted-F antenna and the second inverted-F antenna are connected in parallel. In other words, the first to third radiation elements 110-130, the first shorting element 140 and the second shorting element 150 can form two antenna elements arranged in parallel, and the two antenna elements are respectively an inverted-F antenna. As such, the antenna device 100 can operate in a first frequency band and a second frequency band and have the characteristic of dual wide-band operation.

[0014] For example, a distance D11 from the feeding point FP1 to both ends of the first sidewall SD11 may be 1/4 wavelength of the first frequency band. In other words, the length of the first radiation element 110 (i.e., the length of the first sidewall SD11) may be 1/2 wavelength of the first frequency band. As such, the antenna device 100 can operate in the first frequency band mainly through the first radiation element 110. In addition, a plurality of current paths formed by the first radiation element 110 can further effectively expand the bandwidth of the first frequency band. For instance, FIG. 3 is a diagram illustrating return loss (S11) of an antenna device in a first frequency band according to an embodiment of the invention. As shown in FIG. 3, the first frequency band of the antenna device 100 is a 5 GHz band, for example; the return loss of the antenna device 100 between 4.5 GHz ~ 6.5 GHz can be less than -11 dB.

[0015] On the other hand, the length of the second radiation element 120 and the length of the third radiation element 130 are both denoted by D12, and the length D12 is 1/4 wavelength of the second frequency band. As such, the antenna device 100 can operate in the second frequency band mainly through the second radiation element 120 and the third radiation element 130. In addition, a plurality of current paths formed by the second radiation element 120 and the third radiation element 130 can further effectively expand the bandwidth of the second frequency band. For example, FIG. 4 is a diagram illustrating return loss of an antenna device in a second frequency band according to an embodiment of the invention. As shown in FIG. 4, the second frequency band of the antenna device 100 is a 2.4 GHz band, for example; the return loss of the antenna device 100 between 2.17 GHz ~ 3 GHz can be less than -10 dB.

[0016] It should be noted that persons skilled in the art can adjust the lengths (i.e., D11 and D12) of the first to third radiation elements 110-130 and the configuration position of the two shorting elements 140 and 150 to change the current distribution of the first to third radiation elements 110-130 such that the radiation pattern of the

antenna device 100 changes correspondingly. That is to say, persons skilled in the art can slightly adjust the current of the first to third radiation elements 110-130 to control the radiation pattern of the antenna device 100 so that the antenna device 100 has omnidirectional radiation pattern.

[0017] For example, FIG. 5 is a schematic view illustrating configuration of an antenna device relative to a ground plane according to an embodiment of the invention. As shown in FIG. 5, in an embodiment, the antenna device 100 may be disposed in the center of the ground plane 101. Additionally, when the antenna device 100 is disposed in the center of the ground plane 101, the radiation pattern of the antenna device 100 is shown as illustrated in FIG. 6. The left part of FIG. 6 shows a radiation pattern of the antenna device 100 at 2.45 GHz in the XY-plane where $\theta = 60^\circ$; the right part of FIG. 6 shows a radiation pattern of the antenna device 100 at 5.5 GHz in the XY-plane where $\theta = 60^\circ$. Here, θ is the angle between the radiation direction and the Z-axis. Moreover, the solid line and dashed lines in FIG. 6 respectively represent main polarization gain and cross-polarization gain of the antenna device 100. As shown in FIG. 6, the antenna device 100 has omnidirectional radiation pattern at 2.45 GHz and 5.5 GHz.

[0018] In other words, the antenna device 100 has good dual wideband operation and omnidirectional radiation pattern. Therefore, in practical application, the antenna device 100 is adapted for ceiling-type network equipment, and can effectively increase signal coverage of the ceiling-type network equipment. Other than that, the antenna device 100 is coupled to the ground plane 101 through the shorting element 140 and shorting element 150; that is, the antenna device 100 has a dual grounding structure. As such, the current of the first to third radiation elements 110-130 can be distributed more uniformly so that the radiation pattern of the antenna device 100 can be more stable and not easily affected by external environment.

[0019] FIG. 7 is a schematic view illustrating configuration of an antenna device relative to a ground plane according to another embodiment of the invention. As shown in FIG. 7, in another embodiment, the antenna device 100 may be adjacent to an edge 710 of the ground plane 101. For example, a distance D7 between the antenna device 100 and the edge 710 can be 10 mm. It should be noted that when the antenna device 100 is adjacent to the edge 710 of the ground plane 101, the radiation pattern of the antenna device 100 in the first frequency band (i.e., high frequency band) would be affected by the ground plane 101. In this case, the effect caused by the ground plane 101 to the antenna device 100 may be reduced by slightly adjusting the lengths of the second radiation element 120 and the third radiation element 130 as well as the configuration positions of the shorting 140 and the shorting 150.

[0020] For example, FIG. 8 is a schematic view illustrating an antenna device according to another embodi-

ment of the invention. As shown in FIG. 8, when the antenna device 100 is adjacent to the edge 710 of the ground plane 101, the lengths of the second radiation element 120 and the third radiation element 130 may be adjusted to a length D82, and the length D82 is smaller than the length D12 as shown in FIG. 1. In other words, when the antenna device 100 is adjacent to the edge 710 of the ground plane 101, the effect caused by the ground plane 101 to the antenna device 100 can be reduced by decreasing the lengths of the second radiation element 120 and the third radiation element 130 as well as shifting the position of the shorting element 140 and shorting element 150 along a direction away from the edge 710. For example, FIG. 9 is a diagram describing the radiation pattern of the antenna device illustrated in the embodiment of FIG. 8. The left part of FIG. 9 shows a radiation pattern in the XY-plane ($\theta = 60^\circ$) when the antenna device 100 operates at 2.45 GHz; the right part of FIG. 9 shows a radiation pattern in the XY-plane ($\theta = 60^\circ$) when the antenna device 100 operates at 5.5 GHz. Here, θ is the angle between the radiation direction and the Z-axis. Additionally, the solid line and dashed line in FIG. 9 respectively represent the main polarization gain and cross-polarization gain of the antenna device 100. Referring to FIG. 9, by slightly adjusting the lengths of the radiation element 120 and radiation element 130 as well as shifting the positions of the shorting element 140 and shorting element 150, the antenna device 100 can still have good omnidirectional radiation pattern at 2.45 GHz and 5.5 GHz.

[0021] In view of the foregoing, the antenna device in the invention uses the first to third radiation elements, the first shorting element and the second shorting element to form two antenna elements arranged in parallel. As such, the antenna device can have good dual wideband operation and omnidirectional radiation pattern, and can further be adapted for use in the ceiling-type network equipment while effectively increasing the signal coverage of the ceiling-type network equipment. Moreover, the antenna device has a dual grounding structure so that the radiation pattern of the antenna device can be more stable and is not easily affected by external environment.

Claims

1. An antenna device (100), comprising:

- a first shorting element (140) and a second shorting element (150), electrically connected to a ground plane (101);
- a first radiation element (110), having a feeding point (FP1) and disposed between the first shorting element (140) and the second shorting element (150);
- a second radiation element (120), electrically connected between the first radiation element

- (110) and the first shorting element (140); and a third radiation element (130), electrically connected between the first radiation element (110) and the second shorting element (150), wherein the first to third radiation elements (110-130), the first shorting element (140) and the second shorting element (150) form two antenna elements disposed in parallel and the antenna device (100) operates in a first frequency band and a second frequency band. 5 10
2. The antenna device according to claim 1, wherein the first radiation element (110), the second radiation element (120) and the first shorting element (140) form a first inverted-F antenna, and the first radiation element (110), the third radiation element (130) and the second shorting element (150) form a second inverted-F antenna. 15
3. The antenna device according to claim 1, wherein a length of the first radiation element (110) is 1/2 wavelength of the first frequency band. 20
4. The antenna device according to claim 3, wherein lengths (D12) of the second radiation element (120) and the third radiation element (130) are respectively 1/4 wavelength of the second frequency band. 25
5. The antenna device according to claim 1, wherein the first radiation element (110) comprises a first sidewall (SD11) facing the ground plane (101), and the feeding point (FP1) is disposed in the center of the first sidewall (SD11). 30
6. The antenna device according to claim 5, wherein the first radiation element (110) further comprises a second sidewall (SD12) opposite to the first sidewall (SD11), and the second sidewall (SD12) is electrically connected to the second radiation element (120) and the third radiation element (130). 35 40
7. The antenna device according to claim 6, wherein the first to third radiation elements (110-130) form a T-shaped structure. 45
8. The antenna device according to claim 1, wherein the first radiation element (110) is perpendicular to the ground plane (101), and the second radiation element (120) and the third radiation element (130) are parallel to the ground plane (101). 50
9. The antenna device according to claim 8, wherein the first shorting element (140) and the second shorting element (150) are perpendicular to the ground plane (101). 55
10. The antenna device according to claim 1, wherein the first to third radiation elements (110-130), the first shorting element (140) and the second shorting element (150) are respectively a rectangular metal sheet.

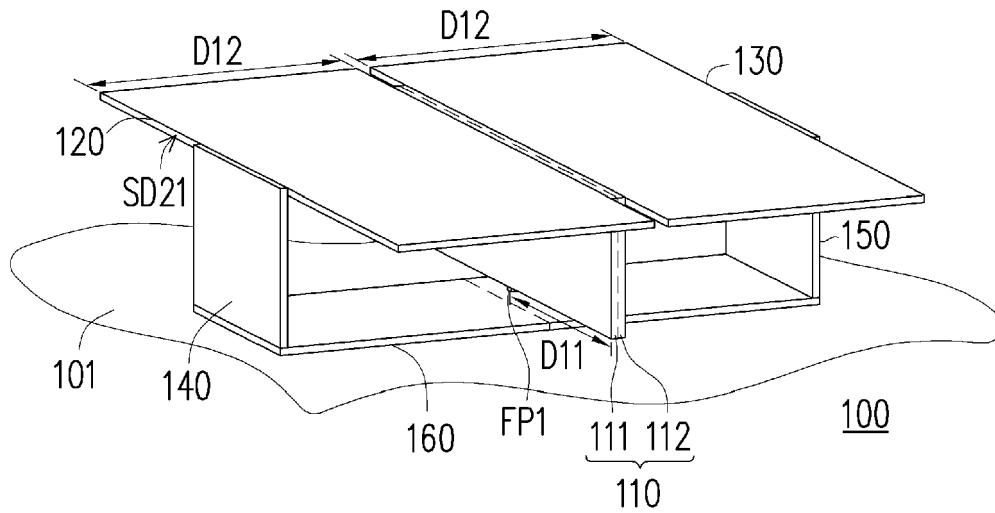


FIG. 1

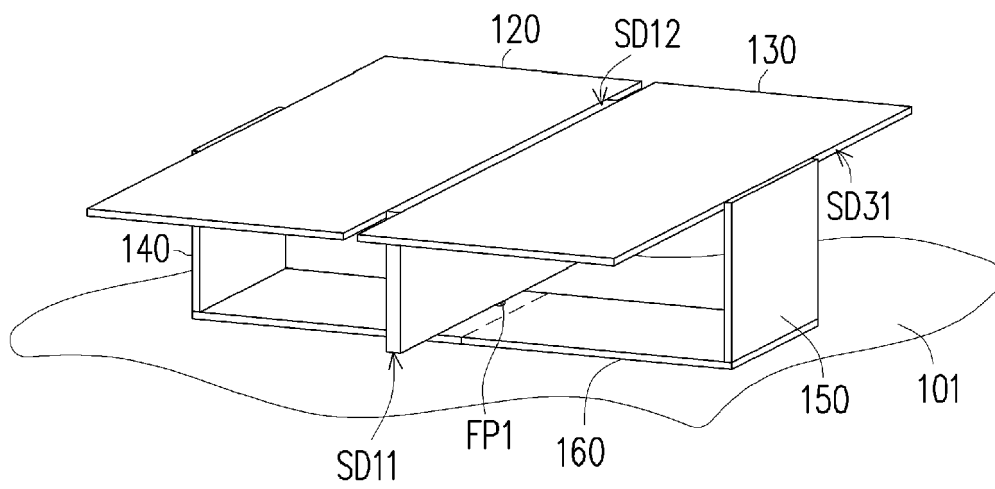


FIG. 2

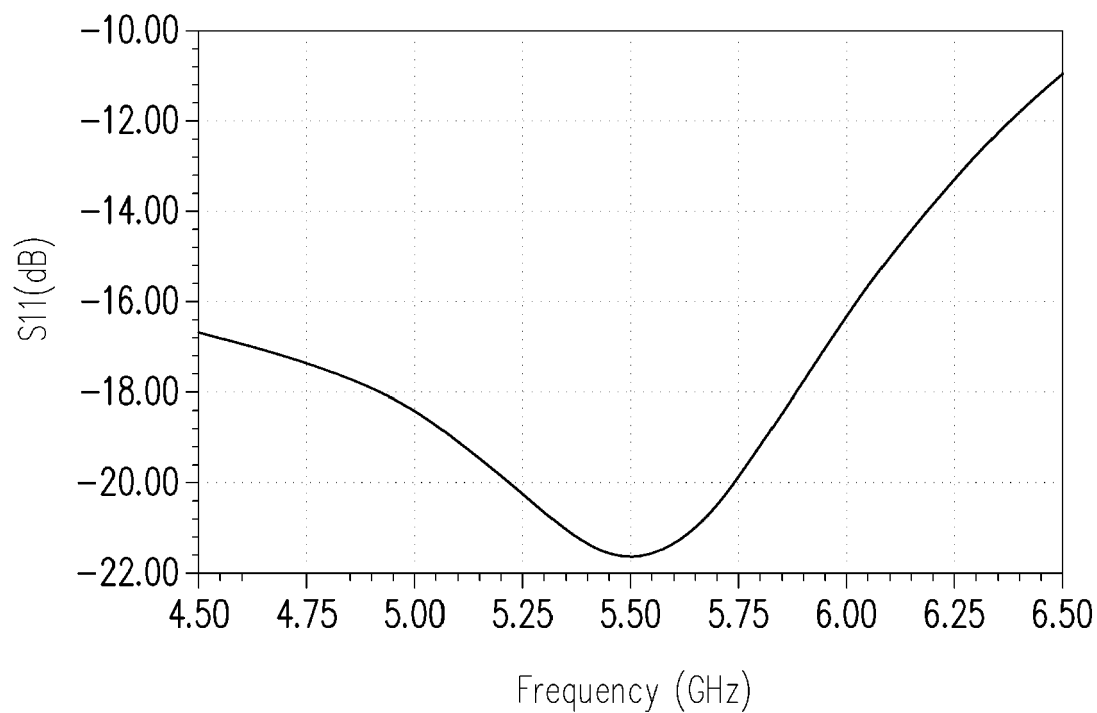


FIG. 3

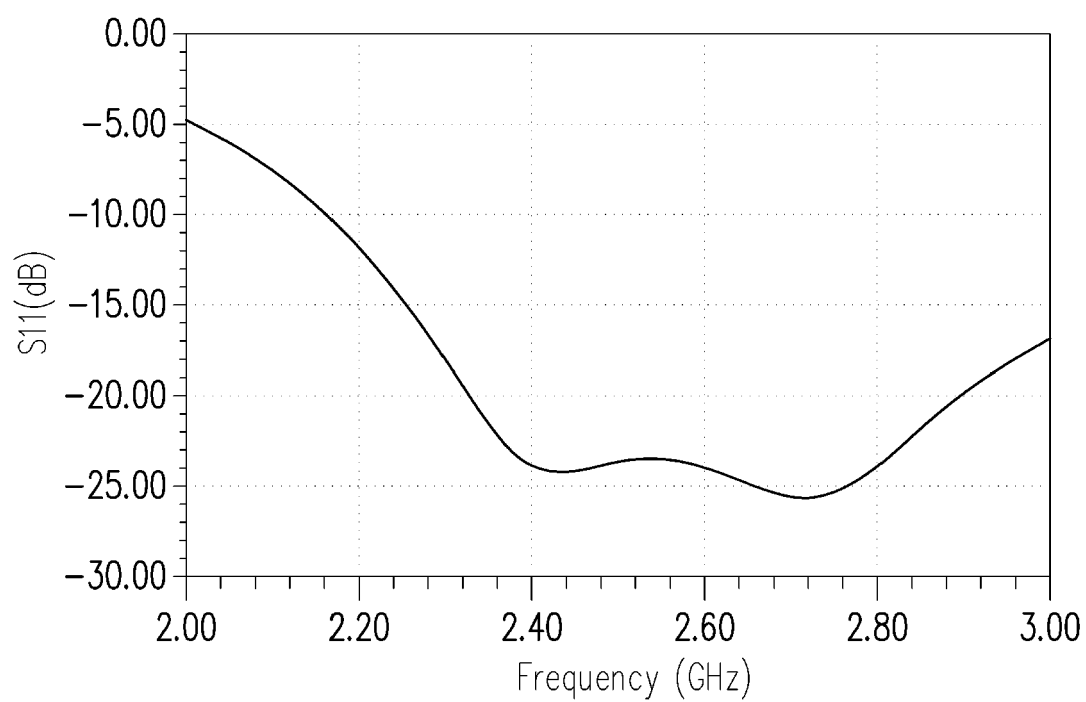


FIG. 4

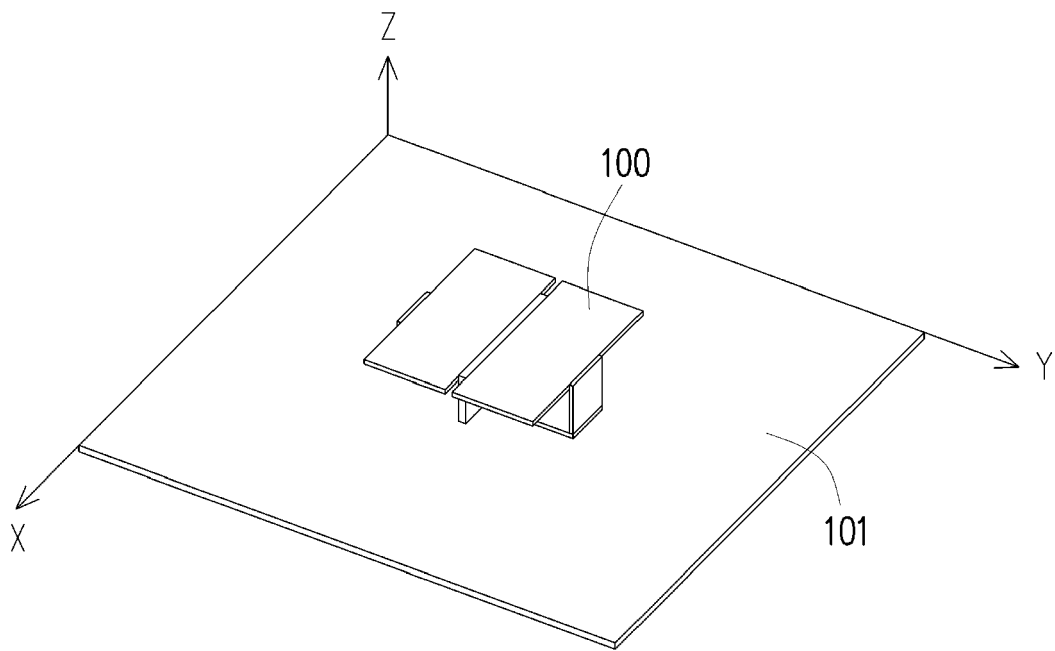


FIG. 5

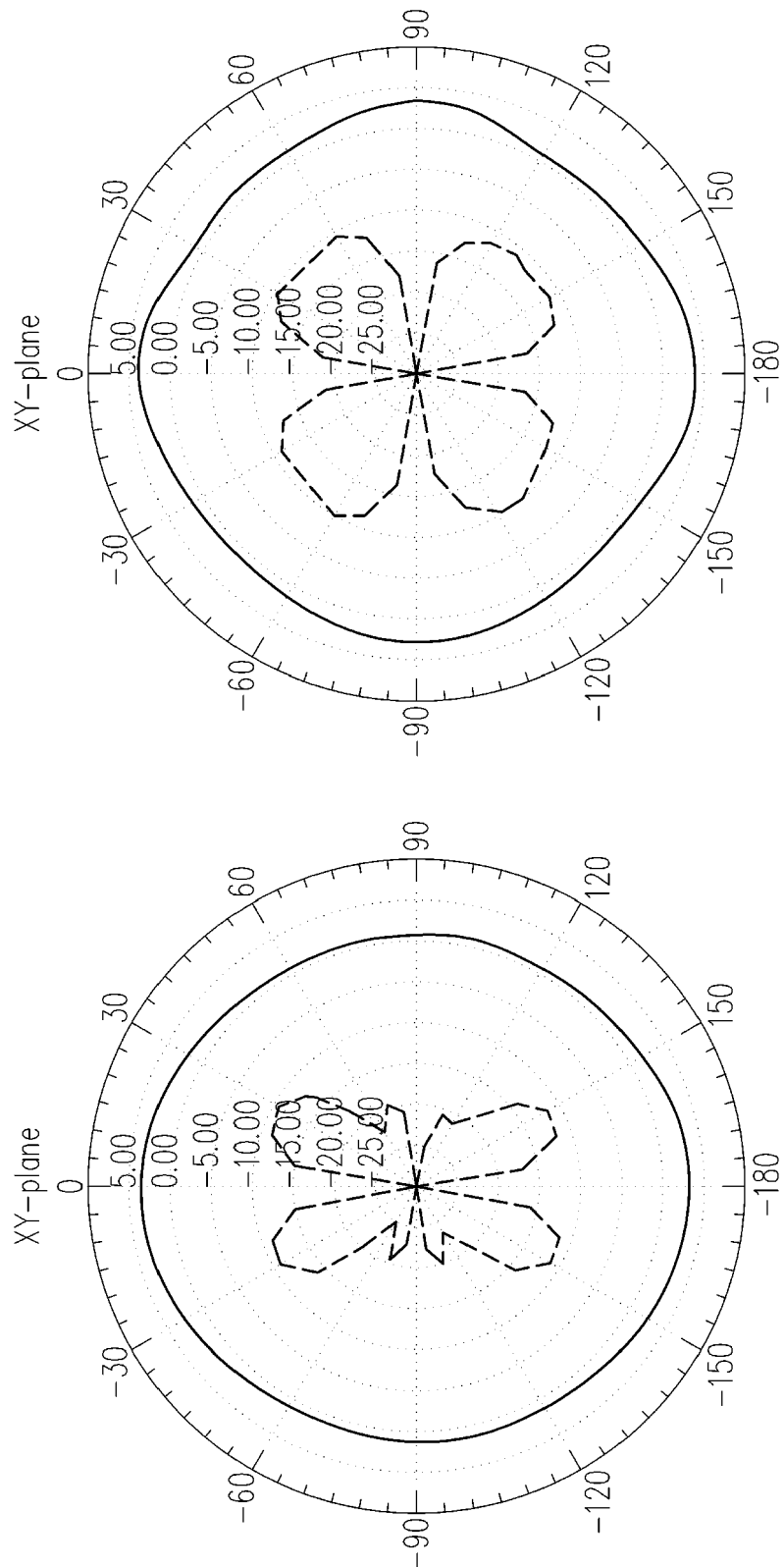


FIG. 6

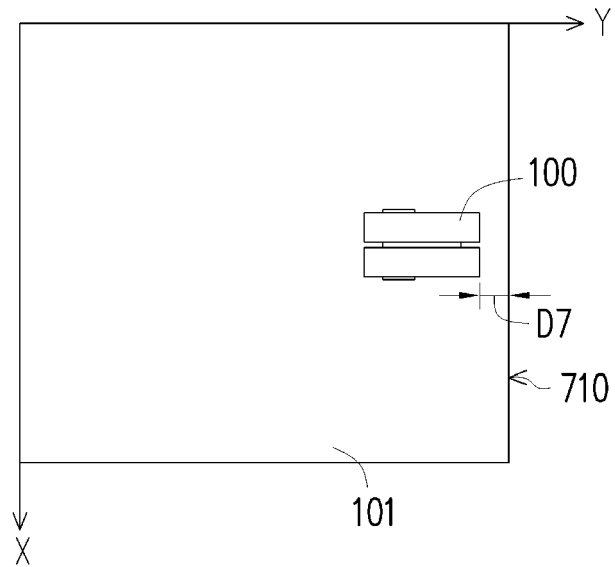


FIG. 7

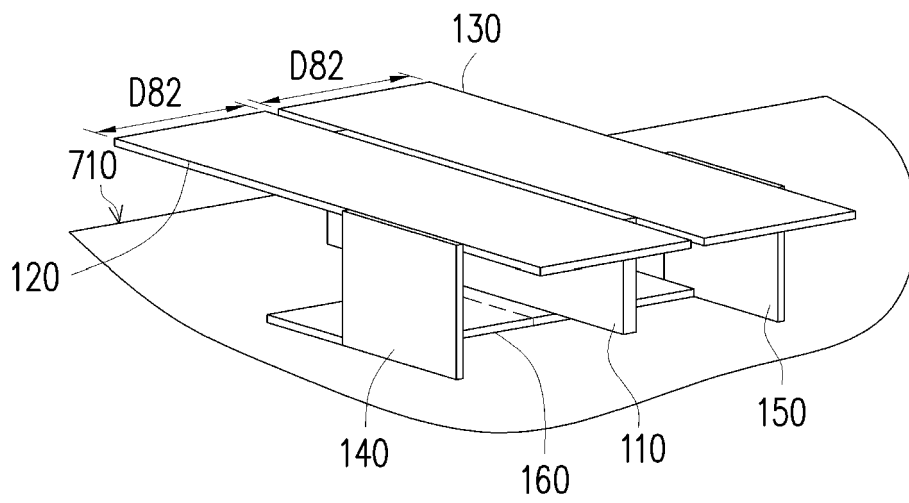


FIG. 8

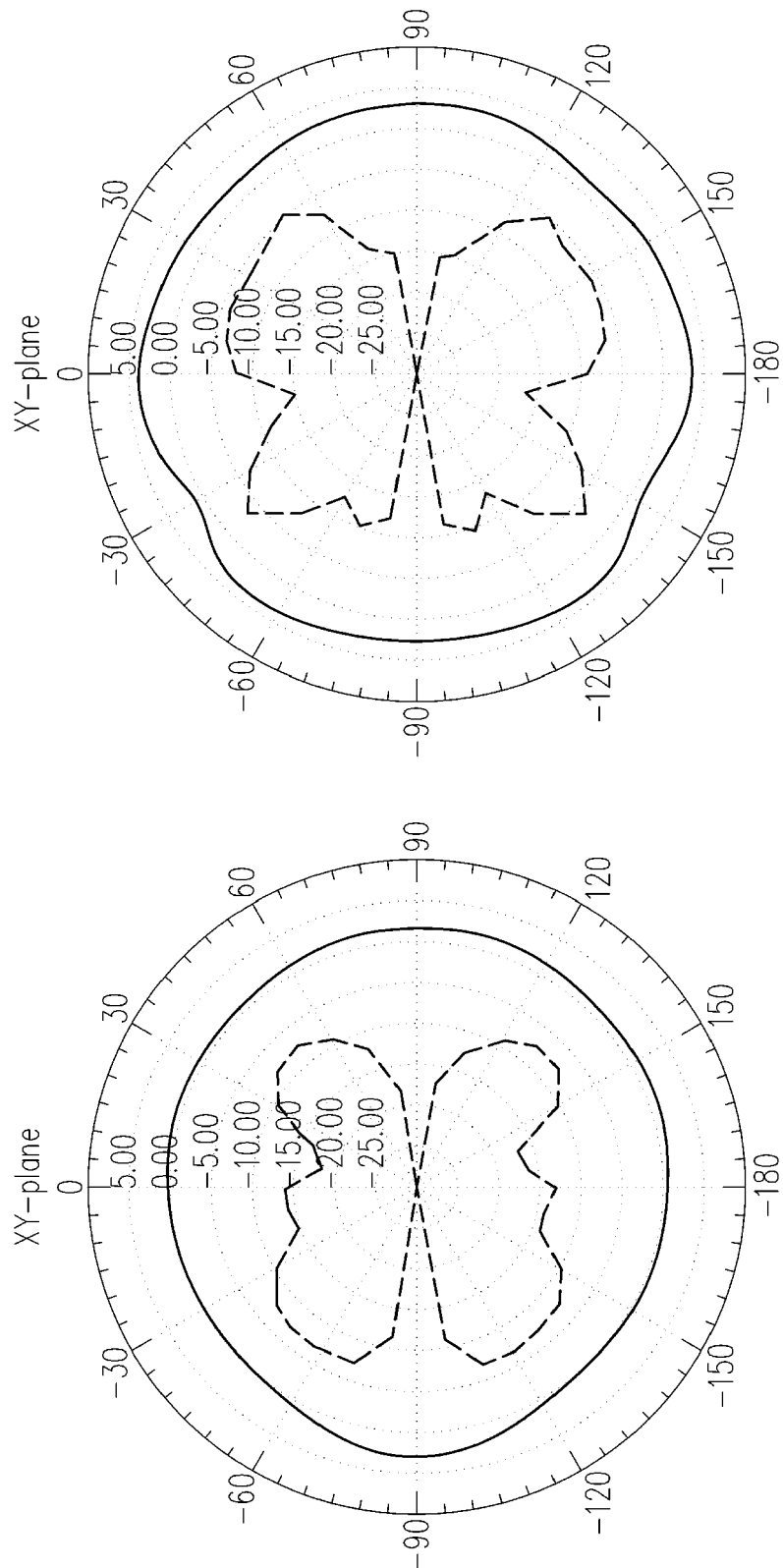


FIG. 9



EUROPEAN SEARCH REPORT

Application Number
EP 17 15 9993

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 July 2017	Examiner Yvonnet, Yannick
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82