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(54) **MULTI-BAND ANTENNA**

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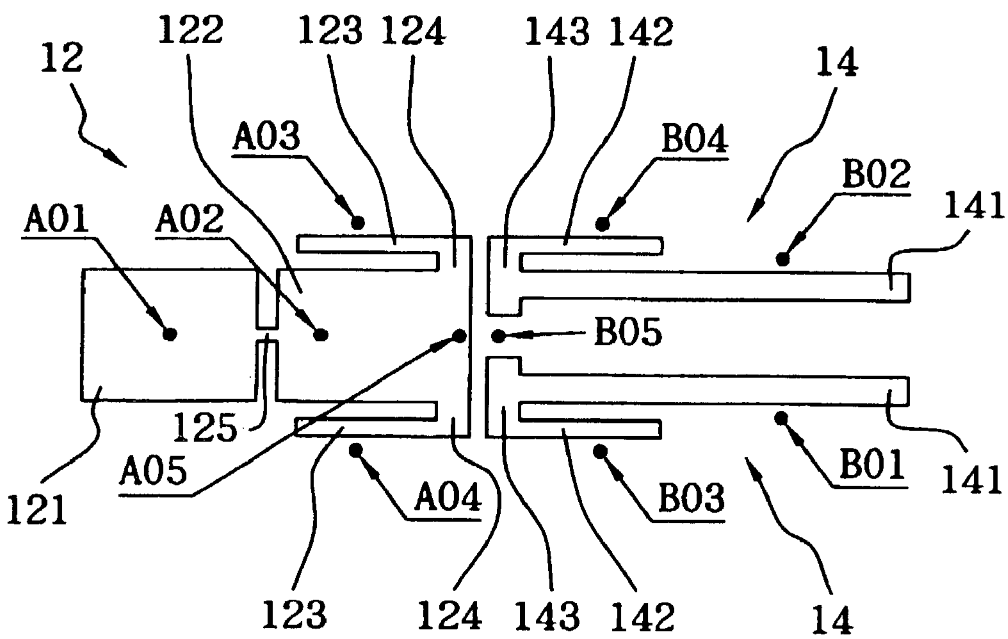
(57) **ABSTRACT**

The present invention reveals a multi-band antenna comprising a dielectric plate, a first metal foil and two second metal foils, where the first metal foil and the second metal foils are adhered to a surface of the dielectric plate. The first metal foil comprises a first plate, a second plate, two first stripes and a connecting bar, where the length of the first stripe is equivalent to one fourth wavelength of the first frequency used in the multi-band antenna, the connecting bar connects the center portions of the facing sides of the first plate and the second plate, the total length of the first plate, the second plate and the connecting bar is equivalent to one fourth wavelength of the second frequency used in the multi-band antenna. Each second metal foil comprises a second stripe and a third stripe, where the length of the second stripe is equivalent to one fourth wavelength of the second frequency used in the multi-band antenna, the length of the third stripe is equivalent to one fourth wavelength of the first frequency used in the multi-band antenna.



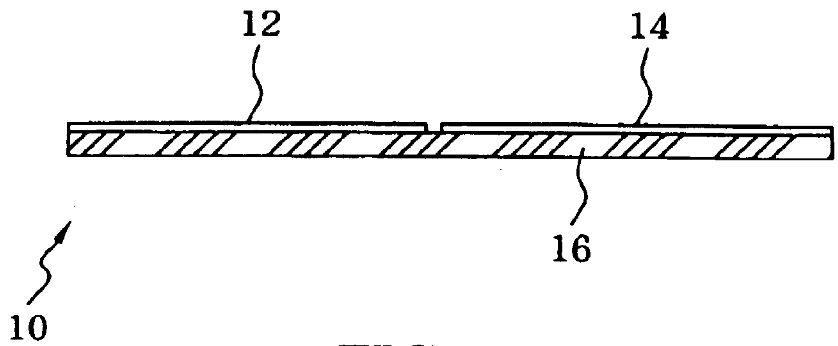

12
14
16
10

FIG. 1

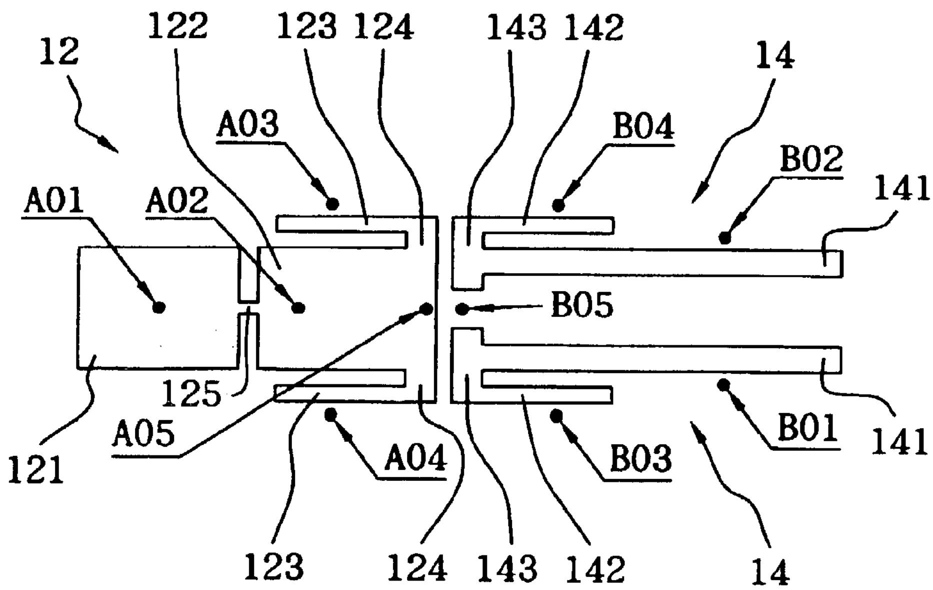

12
122
123
124
143
142
14
A03
B04
B02
141
A01
A02
B05
125
A05
121
A04
B03
B01
141
123
124
143
142
14

FIG. 2

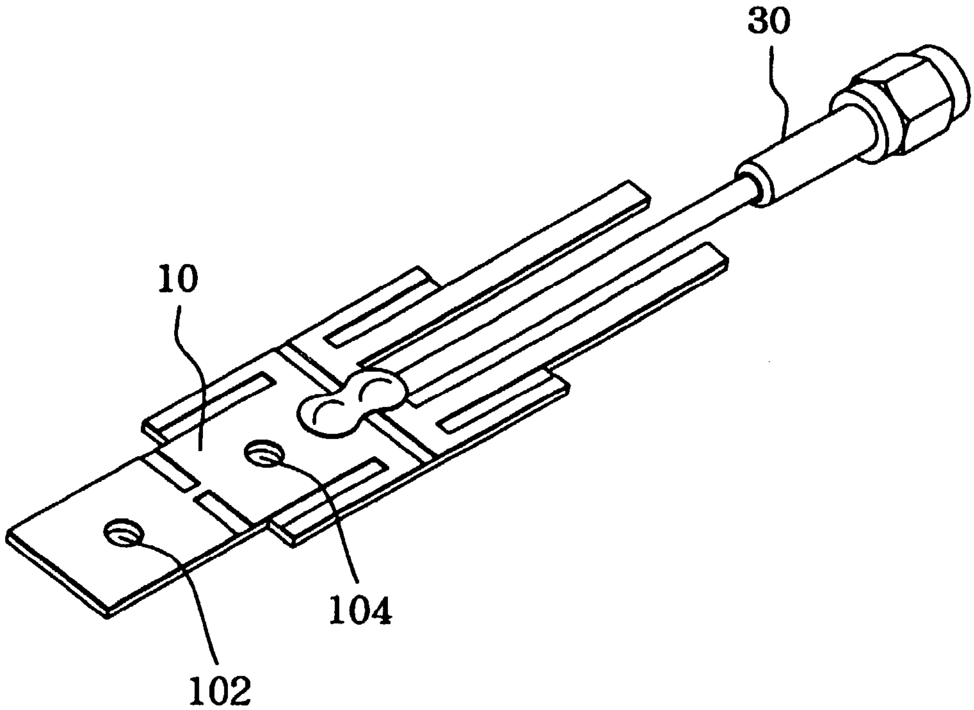


FIG. 3

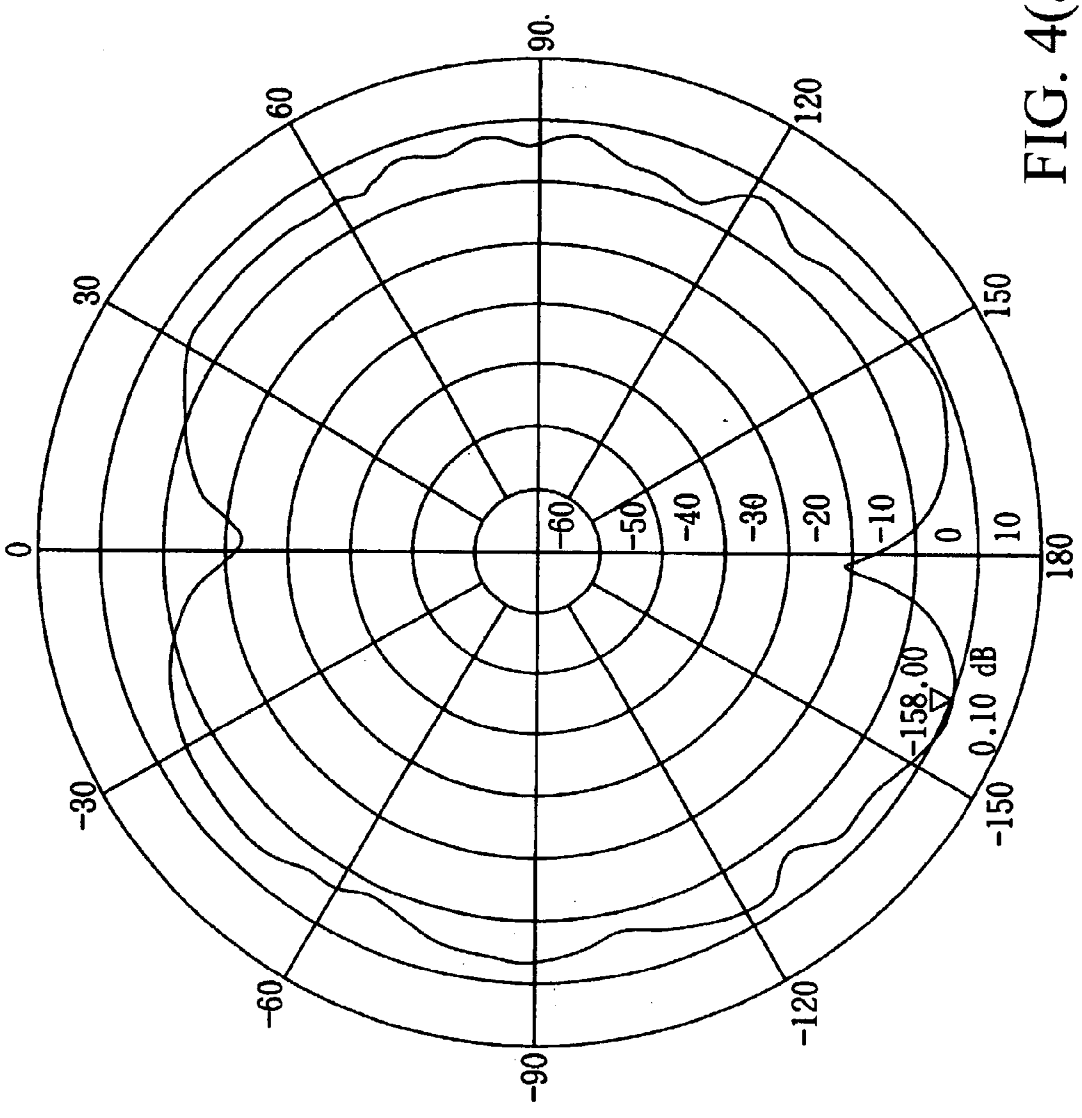

90
60
120
30
150
0
180
-30
-150
-60
-120
-90
-60
-50
-40
-30
-20
-10
0
10
-158.00
0.10 dB

FIG. 4(a)

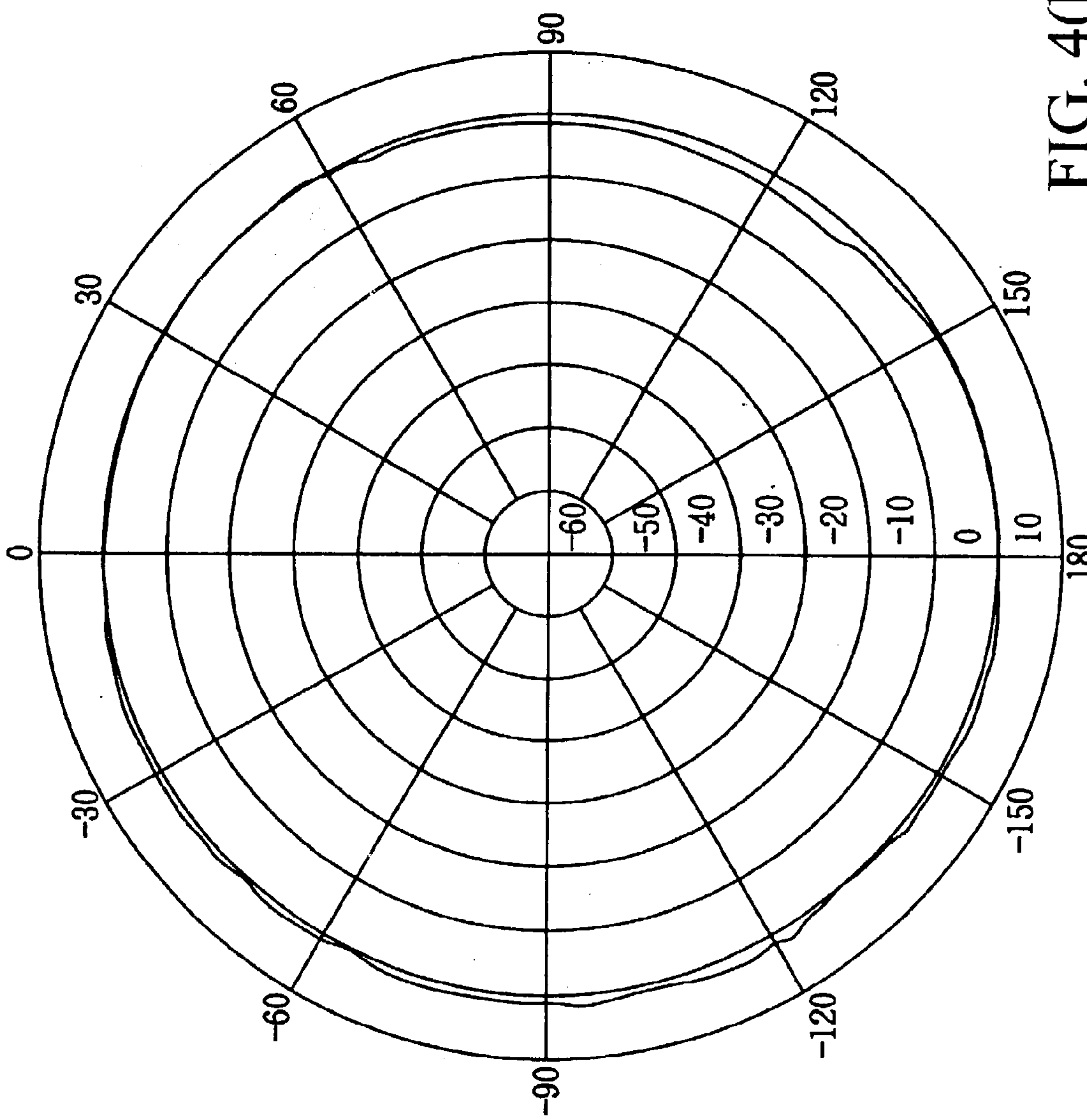


FIG. 4(b)

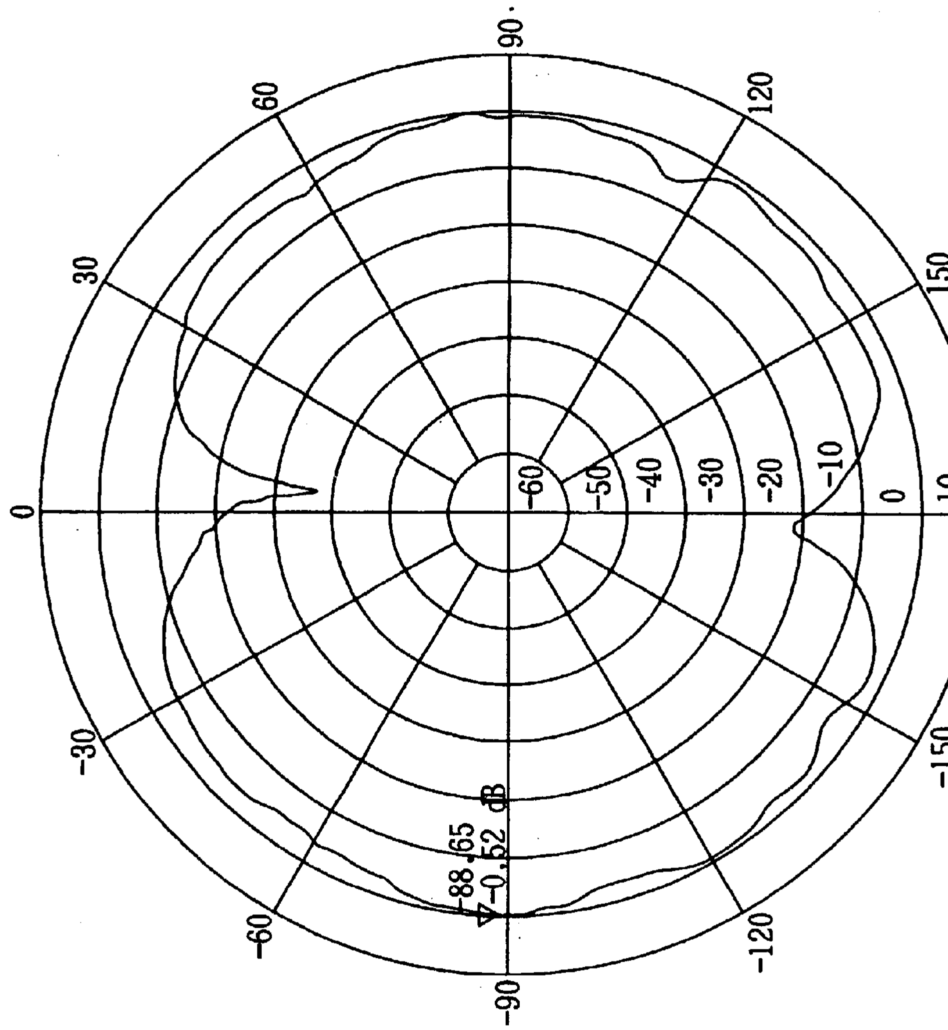

0
30
60
90
120
150
180
-30
-60
-90
-120
-150
-60
-50
-40
-30
-20
-10
0
10
-88.65
-0.52 dB

FIG. 5(a)

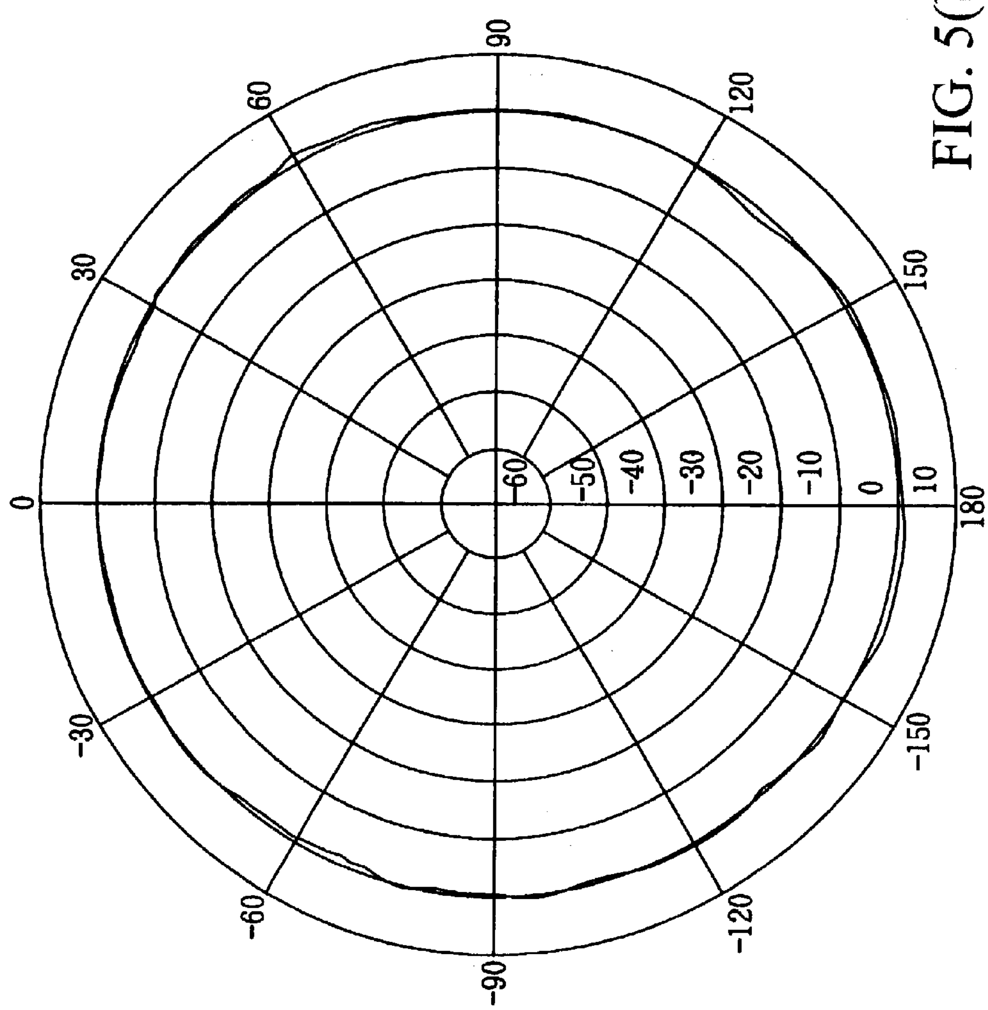


FIG. 5(b)

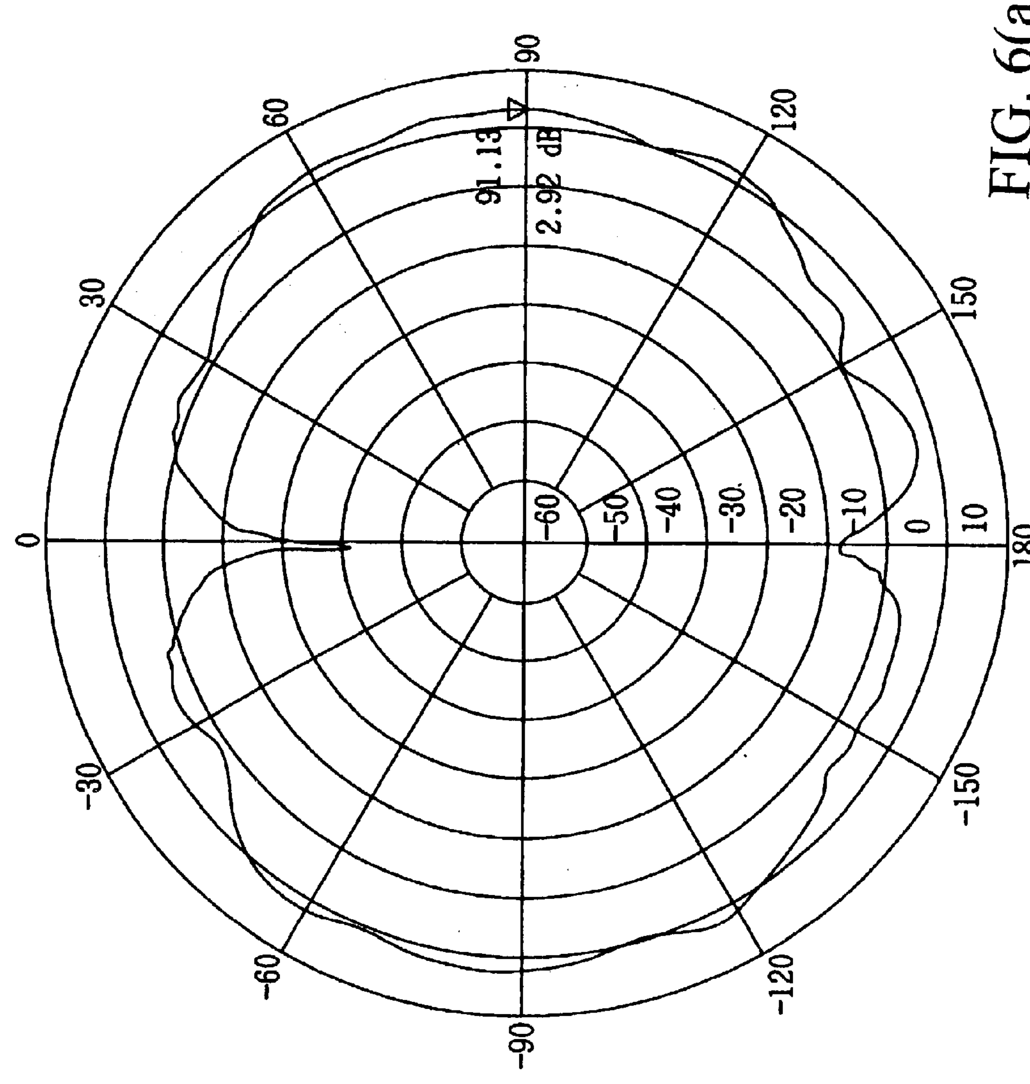

90
60
120
30
150
0
180
-30
-150
-60
-120
-90
91.13
2.92 dB
-60
-50
-40
-30
-20
-10
0
10

FIG. 6(a)

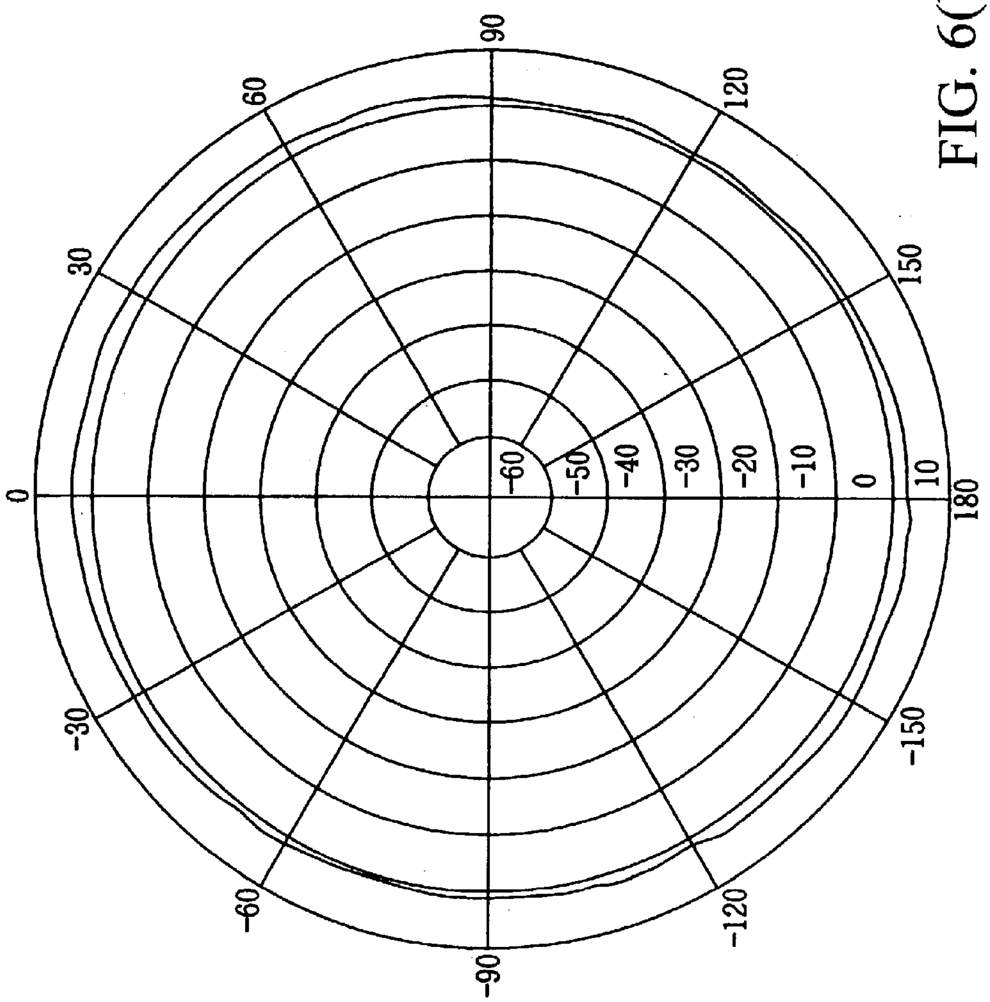


FIG. 6(b)

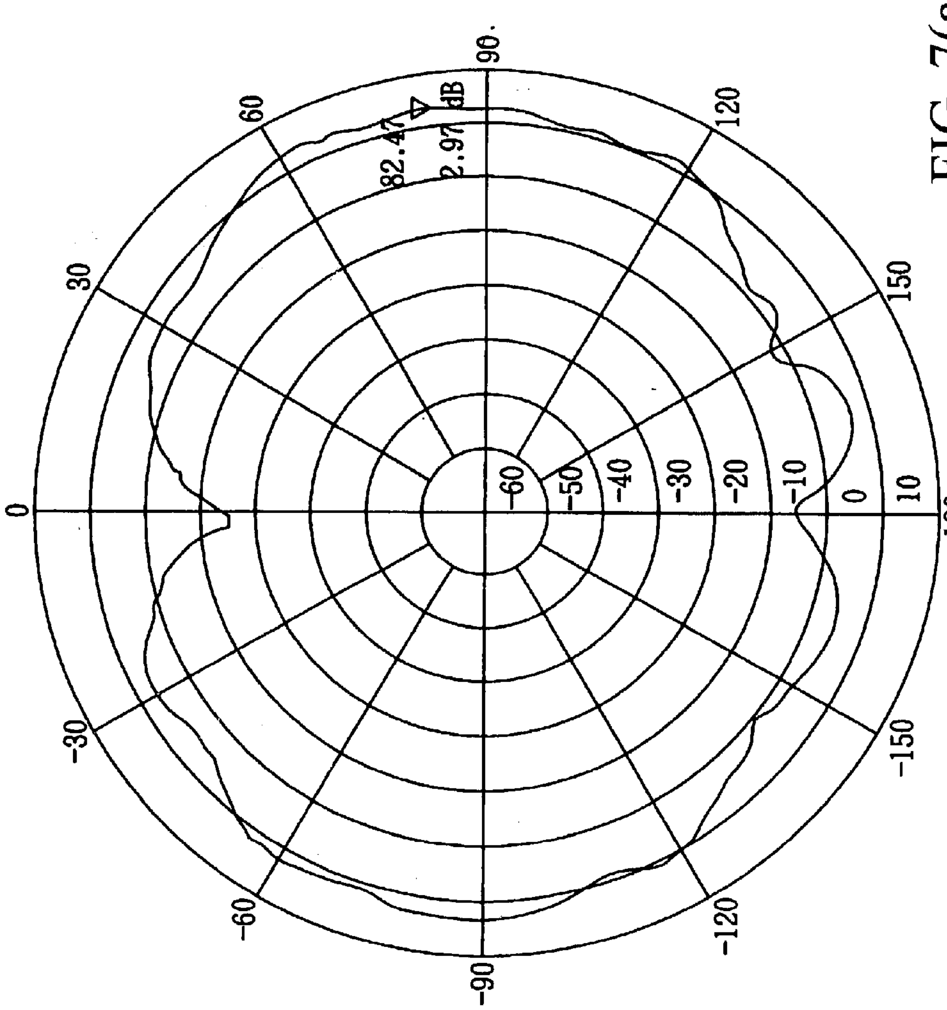

90
60
120
30
150
0
180
-30
-150
-60
-120
-90
-60
-50
-40
-30
-20
-10
0
10
82.47
2.97 dB

FIG. 7(a)

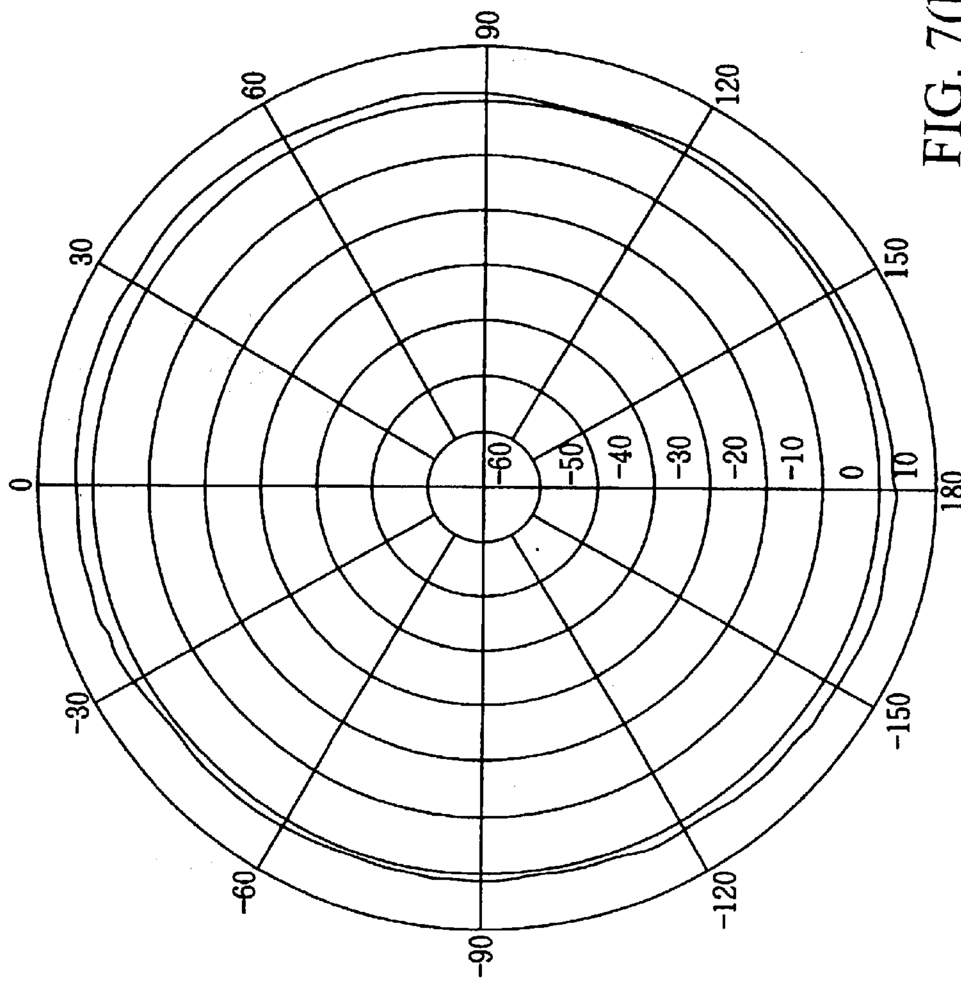


FIG. 7(b)

MULTI-BAND ANTENNA

BACKGROUND OF THE INVENTION

[0001] (A) Field of the Invention The present invention is related to an antenna, more specifically, to a multi-band antenna.

[0002] (B) Description of Related Art

[0003] With the development of wireless communication, cellular phones and WLAN (Wireless Local Area Network) are becoming necessities for current communication. Various types and categories of antennas of WLAN apparatuses and cellular phones for signal receiving and transmitting are well developed in an attempt to cover wider radiation range, achieving better signal receiving and transmitting performance. Furthermore, antennas are designed to be smaller for portable requirement and installation space concern.

[0004] ISM (Industrial, Science and Medical) band is a free worldwide public band, of which the ranges are at frequency of 900 MHz, 2.4 GHz and 5 GHz. The range of 2.4 GHz RF (Radio Frequency) band is limited between 2.4-2.8435 GHz, which is overloaded at the present.

[0005] In order to achieve superior communication quality and stability, the new wireless communication protocol U-NII of 802.11a (47CFR15.401) additionally provides a band around 5 GHz for usage, in which the band of 5.150-5.250 GHz is used for radiation power below 50 mW, the band of 5.250-5.350 GHz is used for radiation power below 250 mW, and the band of 5.725-5.825 GHz is used for radiation power below 1000 mW. Communication protocol ISM of 802.11a (47CFR15.247) designates that 5.725-5.825 GHz is used for radiation power below 1000 mW. The above described wavelengths of wireless radio wave are between 51.30-58.25 mm. Furthermore, 802.11b/g ISM (47CFR15.247) designates that the band of 2.400-2.4835 GHz is used for radiation power below 1000 mV, and the wavelengths of wireless radio wave are between 120.7-125 mm.

[0006] Because widely used bands of 2.4 GHz and 5 GHz are not in double frequency resonant relation, if an antenna uses bands of 2.4 GHz and 5 GHz, the design is more difficult than that of a dual-band cellular phone using 900 MHz and 1800 MHz.

SUMMARY OF THE INVENTIION

[0007] The object of the present invention is to provide a multi-band antenna, especially, for a WLAN apparatus, which occupies less space and has a capability of being used in various bands. By using multi-band antenna in current WLAN apparatuses, the WLAN apparatuses can be used in various bands regulated by different protocols without antenna change.

[0008] The multi-band antenna of the present invention comprises a dielectric plate, a first metal foil and two second metal foils, where the first metal foil and the second metal foils are adhered to a surface of the dielectric plate. The first metal foil comprises a first plate, a second plate, two first stripes and a connecting bar, the second plate including a first signal-fed point, the two first stripes being electrically connected to the first signal-fed point and symmetric along the second plate, the longitudinal direction of the first stripe being designated as a first direction. Each first stripe is spaced at a distance to the second plate, and the length of each first stripe is equivalent to one fourth wavelength of the first frequency used in the multi-band antenna. The connecting bar connects the centers of the facing sides of the first plate and the second plate. The longitudinal direction of the structure constituted of the first plate, the connecting bar and the second plate is along the first direction, and the total length of the first plate, the second plate and the connecting bar is equivalent to one fourth wavelength of the second frequency used in the multi-band antenna. The two second metal foils are symmetric along the first direction and are spaced according to the first metal foil along a second direction that is perpendicular to the first direction. Each second metal foil comprises a second stripe and a third stripe, where the second stripe may electrically connect to a second signal-fed point, whose longitudinal direction is in the first direction, and the length of the second stripe is equivalent to one fourth wavelength of the second frequency used in the multi-band antenna. The third stripe may electrically connect to the second signal-fed point, whose longitudinal direction is in the first direction, and the length of the third stripe is equivalent to one fourth wavelength of the first frequency used in the multi-band antenna.

[0009] For instance, the first frequency is within ISM 5 GHz band, and the second frequency is within ISM 2.4 GHz band.

[0010] The multi-band antenna can be installed in a notebook computer as a wireless signal receiving and transmitting apparatus. If an access point of a company uses ISM 2.4 GHz band, and that of another company uses ISM 5 GHz band, the multi-band antenna can be used to meet the different requirements of the different communication protocols for wireless network data transmission between these two companies.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a side view of the multi-band antenna of the present invention;

[0012] **FIG. 2** illustrates the top view of the first metal foil and the second metal foil of the present invention;

[0013] **FIG. 3** illustrates the combination of the multi-band antenna of the present invention and the wires;

[0014] **FIG. 4**(*a*) and **FIG. 4**(*b*) are the radiation diagrams of the multi-band antenna of the present invention used at 2.4 GHz;

[0015] **FIG. 5**(*a*) and **FIG. 5**(*b*) are the radiation diagrams of the multi-band antenna of the present invention used at 2.5 GHz;

[0016] **FIG. 6**(*a*) and **FIG. 6**(*b*) are the radiation diagrams of the multi-band antenna of the present invention used at 5.25 GHz; and

[0017] **FIG. 7**(*a*) and **FIG. 7**(*b*) are the radiation diagrams of the multi-band antenna of the present invention used at 5.5 GHz.

DETAILED DESCRIPTION OF THE INVENTION

[0018] **FIG. 1** is a side view of the multi-band antenna **10** of the present invention, in which a first metal foil **12** and two second metal foils **14** are adhered to a dielectric plate **16**, and a spacing is between the first metal foil **12** and the two second metal foils **14**. The thickness of the dielectric plate **16** is between 0.3-0.5 mm, and the total thickness of the first metal foil **12** and the second metal foils **14** is between 0.025-0.03 mm.

[**0019**] **FIG. 2** illustrates the top view of the first metal foil **12** and the second metal foils **14**. The first metal foil **12** comprises a first plate **121**, a second plate **122**, two first stripes **123**, two first connecting plates **124** and a connecting bar **125**, where the connecting bar **125** connects the facing sides of the first plate **121** and the second plate **122**. The longitudinal direction of the structure constituted of the first plate **121**, the connecting bar **125** and the second plate **122** is designated as a first direction for clear description below. The two first stripes **123**, whose longitudinal direction is along the first direction, are placed on the two sides of the second plate **122**, and the ends close to the second metal foils **14** are individually connected to the two sides of the end of the second plate **122**, closed to the second metal foils **14**, by the two first connecting plates **124** to form a symmetric structure. Two openings formed by the first stripes **123**, the first connecting plates **124** and the second plate **122** are the heading for the first plate **121**, and the width of the opening, i.e., the spacing between the first stripe **123** and the second plate **122**, is less than 2 mm.

[**0020**] A spacing less than 2 mm is between the first metal foil **12** and the second metal foils **14**. The two second metal foils **14** are symmetric along the first direction, and each second metal foil **14** comprises a second stripe **141**, a third stripe **142** and a second connecting plate **143**. The longitudinal directions of the second stripe **141** and the third stripe **142** are along the first direction, and their ends are connected by the second connecting plate **143**. The spacing between each second stripe **141** and each third stripe **142** is less than 2 mm.

[**0021**] The design of the multi-band antenna of the present invention is based on the half-wave dipole antenna technique, and thus the effective lengths of the first metal foil **12** and the second metal foils **14** are equivalent to one fourth wavelength of the frequency used. The horizontal dimensions of the components shown in **FIG. 2** are designated as "lengths", and the vertical dimensions of that are designated as "widths" hereinafter for clear differentiation. The connecting bar **125** will induce an equivalent inductance when a signal is being transmitted. Because the higher the frequency, the greater the inductive reactance $2\pi fL$ (f is a frequency, and L is an inductance) if the multi-band antenna **10** for both ISM 2.4 GHz and 5 GHz bands uses a frequency of 5 GHz, the higher inductive reactance of the equivalent inductance resulted from the higher frequency will induce an open resonant effect between the first plate **121** and the second plate **122**, i.e., the first plate **121** of the multi-band antenna **10** is not in use. The signal receiving and transmitting of the multi-band antenna **10** are positioned at **A03**, **A04** and B**03**, B**04** of **FIG. 2**, **i**.e., only the first stripes **123** and the third stripes **142** are in use. The width of the connecting bar **125**, compared to the first plate **121** and the second plate **122**, is limited to avoid too small equivalent inductance that may lower the open resonant effect. The width of the connecting bar **125** had better be less than one tenth of the width of the second plate **122**, e.g., less than 1 mm in this embodiment.

[**0022**] In contrast, when the multi-band antenna **10** uses a frequency of ISM 2.4 GHz band, the lower inductive reactance resulted from the lower frequency will induce a close resonant effect at the connecting bar **125**. Therefore, the effective length of the multi-band antenna **10** is equivalent to the total length of the first plate **121**, the connecting bar **125** and the second plate **122**, i.e., the entire length of the first metal foil **12**, which is approximately equivalent to the length of the second stripe **141**. The locations of signal receiving and transmitting of the multi-band antenna **10** are at **A01**, **A02** and B**01**, B**02** of **FIG. 2**. The lengths of the first metal foil **12** and the second stripe **141** can be derived by the following Eg. (1)

$$\lambda = \frac{c}{f * \sqrt{\varepsilon_r}} \tag{1}$$

[**0023**] where λ is a wavelength;

[**0024**] c is the light speed, i.e., 3×10^{11} mm;

[**0025**] f is a frequency; and

[**0026**] ϵ_r is the dielectric constant of the dielectric plate **16**.

[**0027**] If f is 2.4 GHz and the dielectric constant ϵ_r of the dielectric plate **16** is 1.69, one fourth wavelength of the frequency of 2.4 GHz calculated by Eq. (1) is approximate 24 mm, which is both the length of the second stripe **141** and the total length of the first plate **121**, the connecting bar **125** and the second plate **122**. Because the geometry of the structure of first plate **121**, the connecting bar **125** and the second plate **122** is different from that of the second stripe **141**, their ϵ_r may be different, causing slight different lengths between them.

[**0028**] If f is 5.25 GHz and the dielectric constant ϵ_r of the dielectric plate **16** is 1.69, one fourth wavelength of the frequency of 5.25 GHz calculated by Eq. (1) is approximate 11 mm, which is equivalent to the lengths of the first stripe **123** and the third stripe **142**.

[**0029**] The second plate **14** comprises a first signal-fed point A**05** for signal receiving and transmitting of the first metal foil **12**, and a second signal-fed point B**05** is interposed between the two second stripes **141** for signal receiving and transmitting of the second metal foils **14**.

[**0030**] Referring to **FIG. 3, a** lead **30** is electrically connected to both the first signal-fed point A**05** and the second signal-fed point B**05**, the spacing between the two second metal foils **14** is to accommodate the lead **30**. The first plate **121** and the second plate **122** of the multi-band antenna **10** can further comprise two fixing holes **102**, **104** for installation.

[**0031**] The first metal foil **12** and the second metal foils **14** can be composed of copper, gold or the like. The dielectric coefficient ϵ_r of the dielectric plate **16** is between 1 to 4.55, which can be made of glass fiber, e.g., FR-4.

[**0032**] **FIG. 4**(*a*), **FIG. 5**(*a*), **FIG. 6**(*a*) and **FIG. 7**(*a*) respectively show the radiation diagrams of the multi-band antenna **10** at 2.4 GHz, 2.5 GHz, 5.25 GHz and 5.5 GHz. In such cases, the multi-band antenna **10** lies on the plane of each diagram, and the radiation unit is dBi.

[0033] **FIG. 4**(*b*), **FIG. 5**(*b*), **FIG. 6**(*b*) and **FIG. 7**(*b*) respectively show the radiation diagrams of the multi-band antenna **10** at 2.4 GHz, 2.5 GHz, 5.25 GHz and 5.5 GHz. In such cases, the multi-band antenna is placed vertically to the plane of each diagram, and the radiation unit is dBi.

[0034] In view of the diagrams at different frequencies, the multi-band antenna **10** is an omni antenna that performs excellently at various frequencies.

[0035] Although the embodiment employs simple rectangular and elongated components to form the multi-band antenna, they can be made in other forms, e.g., the first stripes **123** and the third stripes **142** are in waveform so long as the effective lengths is equivalent to one fourth wavelength of the frequency used.

[0036] As described in the "Background of the Invention", ISM 5 GHz band can be divided into three sub-bands. The multi-band antenna **10** can use ISM 5 GHz band, i.e., which can meet the requirement of multi-band communication, so named "multi-band antenna."

[0037] The above-described embodiment of the present invention are intended to be illustrative only. Numerous alternative embodiments may be devised by those skilled in the art without departing from the scope of the following claims.

What is claimed is:

1. A multi-band antenna having a first frequency and a second frequency substantially lower than the first frequency, the multi-band antenna comprising:

(a) a dielectric plate;

(b) a first metal foil disposed on a surface of the dielectric plate, comprising:

a first plate;

a second plate including a first signal-fed point;

two first stripes whose length is equivalent to one fourth wavelength of the first frequency;

two first connecting plates for connecting the two first stripes and the second plate; and

a connecting bar for connecting the first plate and the second plate, and the total length of the first plate, the connecting bar and the second plate being equivalent to one fourth wavelength of the second frequency; and

(c) two second metal foils disposed on the surface of the dielectric plate and spaced at a distance to the first metal foil, each of the second metal foils comprises:

a second stripe whose length is equivalent to one fourth wavelength of the second frequency;

a third stripe whose length is equivalent to one fourth wavelength of the first frequency; and

a second connecting plate for connecting the second stripe and the third stripe.

2. The multi-band antenna of claim 1, wherein the first connecting plates are used to connect one side of the second plate and one end of the first stripe so that the periphery of the first stripe, the first connecting plates and the second plate forms an opening heading for the first plate.

3. The multi-band antenna of claim 1, wherein one end of the second connecting plate is electrically connected to a second signal-fed point.

4. The multi-band antenna of claim 1, wherein the first frequency is within ISM 5 GHz band, and the second frequency is within ISM 2.4 GHz band.

5. The multi-band antenna of claim 1, wherein one fourth wavelengths of the first and the second frequencies are calculated by the following equation

$$\lambda = \frac{c}{f * \sqrt{\varepsilon_r}},$$

where λ represents the wavelength;

c represents the light speed;

f represents one of the first and the second frequencies; and

ϵ_r represents a dielectric constant of the dielectric plate.

6. The multi-band antenna of claim 1, wherein the width of the connecting bar is less than 1 mm.

7. The multi-band antenna of claim 1, wherein the width of the connecting bar is less than one tenth of the width of the second plate.

8. The multi-band antenna of claim 1, wherein the spacing between the first stripe and the second plate is less than 2 mm.

9. The multi-band antenna of claim 1, wherein the spacing between the second stripe and the third stripe is less than 2 mm.

10. The multi-band antenna of claim 1, wherein the spacing between the first metal foil and the second metal foil is less than 2 mm.

11. The multi-band antenna of claim 1, wherein the first metal foil and the second metal foils are made of copper.

12. The multi-band antenna of claim 1, wherein the thickness of the first metal foil and the second metal foil is between 0.025-0.03 mm.

13. The multi-band antenna of claim 1, wherein the thickness of the dielectric plate is between 0.3-0.5 mm.

14. The multi-band antenna of claim 1, wherein the dielectric plate is made of glass fiber.

15. The multi-band antenna of claim 1, wherein the dielectric constant of the dielectric plate is between 1 to 4.55.

16. A multi-band antenna having a first frequency and a second frequency substantially lower than the first frequency, the multi-band antenna comprising:

a dielectric plate;

a first metal foil disposed on a surface of the dielectric plate, comprising a first plate and two first stripes, wherein the length of the two first stripe is equivalent to one fourth wavelength of the first frequency, the length from the first plate to the end of the first stripe is equivalent to one fourth wavelength of the second frequency, and the first plate and the two first stripes are in an electrically insulating state when the first frequency is in use, the first plate and the two first stripes are in an electrical connecting state when the second frequency is in use; and a second metal foil disposed on the surface of the dielectric plate and spaced at a distance to the first metal foil, the second metal foil including a second stripe and a third stripe connected to the second stripe, wherein the length of the second stripe is equivalent to one fourth wavelength of the second frequency, the length of the third stripe is equivalent to one fourth wavelength of the first frequency.

17. The multi-band antenna of claim 16, wherein the thickness of the dielectric plate is between 0.3-0.5 mm.

18. The multi-band antenna of claim 16, wherein the first frequency is within ISM 5 GHz band, and the second frequency is within ISM 2.4 GHz band.

19. The multi-band antenna of claim 16, wherein the first plate and the two first stripes are connected by a connecting bar whose width is less than 1 mm, and the connecting bar is in an electrically open state when the first frequency is in use.

* * * * *