

METAMATERIAL ANTENNA

FIELD OF THE INVENTION

[0001] The present invention relates to a multi-frequency band antenna, and more particularly to a multi-frequency band antenna with the metamaterial property while reducing the volume and increasing the bandwidth.

BACKGROUND OF THE INVENTION

[0002] Recently, with increasing development of the wireless communications industry, wireless communication devices such as mobile phones, tablet computers, notebook computers, personal digital assistants or wireless access point (AP) become indispensable products of people's lives because they create a convenient living environment. As known, antennas play important roles in these wireless communication devices. Generally, the antenna is used to transmit and receive wireless signals. Consequently, the performance and quality of the wireless communication device to receive and transmit wireless signals are highly dependent on the operation properties of the antenna.

[0003] Generally, a good antenna should have low return loss and wide bandwidth. The bandwidth of the antenna is restricted by some physical factors, including the structure, size and area of the antenna. For allowing the wireless communication device to intensively and clearly receive the wireless signals, the current wireless communication device is equipped with more antennas or the volume of the antenna is increased. Consequently, the wireless communication device can receive and transmit wireless signal in the widened bandwidth or multiple frequency bands. Recently, the general trends in designing wireless communication devices are toward small size, miniaturization and slimness. Correspondingly, the

volume of the antenna for use in the wireless communication device should be reduced. For example, the monopole antenna should have a certain length in order to comply with the requirements of the resonant frequencies. For reducing the size of the antenna, the monopole antenna is formed on the substrate in a bent and folded manner. Although this approach can reduce the overall volume of the antenna, the frequency band of the antenna is adversely affected. In other words, the bandwidth of the conventional is still unsatisfied.

[0004] Metamaterials are artificial materials engineered to have properties that may not be found in nature. In particular, the metamaterials have negative permittivity and permeability. When electromagnetic waves propagate in such materials, an anti-Snell's effect, an anti-Doppler effect or an anti-Cerenkov effect may occur. These materials are also referred as left-handed materials. Since the metamaterials have properties not found in nature, the metamaterials are usually artificial composite materials with composite structures. Typically, metamaterials gain their properties not from their composition, but from their exactly-designed structures. By specially designing the structures, such as their shape, geometry, size, orientation, or arrangement, the metamaterials have the properties of left-handed materials. Some literatures disclosed that the electromagnetic bandgap structures of the metamaterials in low-profile applications may facilitate radiation of the wireless signals. Consequently, metamaterials are gradually applied to antenna design.

[0005] Nowadays, metamaterial antennas usually adopt split ring resonators (SRR) to achieve the metamaterial properties in order to reduce the antenna size and widen the bandwidth. The manufacturers of the metamaterial antennas pay much attention to development of the structures

of the split ring resonators. For example, various split ring resonators with different shapes are researched. However, even if the structure of the split ring resonator is changed, the bandwidth of the antenna is still unsatisfied. That is, this antenna fails to be operated in multiple frequency bands or applied to a desired frequency band, and the efficacy of size reduction of this antenna is insufficient. Moreover, the performance of the antenna is adversely affected.

[0006] Therefore, there is a need of providing an improved metamaterial antenna in order to avoid the above drawbacks.

SUMMARY OF THE INVENTION

[0007] An object of the present invention provides a metamaterial antenna with reduced volume. The metamaterial antenna can be operated in multiple frequency bands or applied to a desired frequency band.

[0008] Another object of the present invention provides a metamaterial antenna for facilitating mass production and cost reduction.

[0009] In accordance with an aspect of the present invention, there is provided a metamaterial antenna. The metamaterial antenna includes a substrate, a main radiation unit, a split ring resonator, and a compensator. The substrate has a first surface and a second surface, wherein the first surface and the second surface are opposed to each other. The main radiation unit is disposed on the first surface of the substrate for generating at least one resonance frequency band. The split ring resonator is disposed on the first surface of the substrate and located near the main radiation unit. The split ring resonator has a metamaterial structure property for increasing a bandwidth of the at least one resonance frequency band. The compensator is connected with the split ring resonator and includes a main bent part for adjusting impedance match of the main radiation unit.

[0010] The above contents of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a schematic top view illustrating a metamaterial antenna according to a first embodiment of the present invention;

[0012] FIG. 2 is a schematic perspective view illustrating the metamaterial antenna of FIG. 1;

[0013] FIG. 3 is a schematic top view illustrating a metamaterial antenna according to a second embodiment of the present invention;

[0014] FIG. 4 is a schematic perspective view illustrating the metamaterial antenna of FIG. 3; and

[0015] FIG. 5 is a plot illustrating the relationship between the return loss and the frequency of the metamaterial antenna of the first embodiment and two comparison antennas.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] The present invention will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this invention are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

[0017] FIG. 1 is a schematic top view illustrating a metamaterial antenna according to a first embodiment of the present invention. FIG. 2 is a schematic perspective view illustrating the metamaterial antenna of FIG. 1. As shown in FIGS. 1 and 2, the metamaterial antenna 1 comprises a substrate 10, a main radiation unit 11, a split ring resonator 12, and a compensator 13. The substrate 10 comprises a first surface 101 and a second surface 102. The first surface 101 and the second surface 102 are

opposed to each other. The substrate 10 is made of a dielectric material. In an embodiment, the substrate 10 is made of glass fiber in order to facilitate mass production and cost reduction. The main radiation unit 11 is disposed on the first surface 101 of the substrate 10 in order to generate at least one resonance frequency band. The split ring resonator 12 is disposed on the first surface 101 of the substrate 10, and located near the main radiation unit 11. The split ring resonator 12 has a metamaterial structure property for increasing the bandwidth of the at least one resonance frequency band. The main radiation unit 11 and the split ring resonator 12 are separated from each other by a coupling gap 14. Through the coupling gap 14, the capacitive coupling action between the main radiation unit 11 and the split ring resonator 12 is generated. The compensator 13 is disposed on the second surface 102 of the substrate 10 and connected with the split ring resonator 12. The compensator 13 includes a main bent part 131. By the main bent part 131 of the compensator 13, the impedance match of the main radiation unit 11 is correspondingly adjusted.

[0018] In this embodiment, the main radiation unit 11 is a monopole antenna. The main radiation unit 11 comprises a first radiation part 111, a second radiation part 112, and a feeding part 113. The first radiation part 111 is strip-shaped. The first radiation part 111 is connected with the second radiation part 112. The second radiation part 112 comprises a first segment 1121, a second segment 1122, and an anfractuous segment 1123. A first end of the first segment 1121 is connected with the first radiation part 111. The first segment 1121 is perpendicular to the first radiation part 111. The second segment 1122 is connected between the first segment 1121 and the anfractuous segment 1123. The second segment 1122 is perpendicular to the first segment 1121. The anfractuous segment 1123 is

connected with the second segment 1122. Moreover, the anfractuous segment 1123 is arranged between the first radiation part 111, the first segment 1121 and the second segment 1122. In this embodiment, the main radiation unit 11 is used to generate a first resonance frequency band (e.g. 5.0GHz~5.9GHz) and a second resonance frequency band (e.g. 2.4GHz~2.5GHz). The first radiation part 111 is used for generating the resonance and the impedance match of the first resonance frequency band (e.g. 5.0GHz~5.9GHz). The second radiation part 112 is used for generating the resonance and the impedance match of the second resonance frequency band (e.g. 2.4GHz~2.5GHz). In some embodiments, the main radiation unit 11 is a conductive metal plate. The feeding part 113 is connected with the first radiation part 111. In some embodiments, the main radiation unit 11 further comprises a third radiation part 114. The third radiation part 114 is connected with the feeding part 113.

[0019] In an embodiment, the split ring resonator 12 comprises two split square-shaped rings, an inner ring 121 and an outer ring 122, which are split at opposite ends. The outer ring 122 is arranged around the inner ring 121 with a gap therebetween. It is noted that the split ring resonator 12 can be achieved by different shapes or types. For example, the two split ring structures can be carried out by symmetrical ring structures or omega-shaped ring structures other than the square-shaped ring structures. In some embodiments, the split ring resonator 12 is implemented by a complementary split ring resonator, split ring resonator arrays, or a conductive metal plate.

[0020] The compensator 13 comprises a main bent part 131, a first extension end 132, and a second extension end 133. The first extension end 132 and the second extension end 133 are connected with the main bent part 131. The main bent part 131 comprises a meander structure.

The first extension end 132 and the second extension end 133 of the compensator 13 are electrically connected with the split ring resonator 12 through corresponding conductive vias 15. In an embodiment, the conductive vias 15 are connected with the inner ring 121 of the split ring resonator 12. The conductive vias 15 run through the first surface 101 and the second surface 102 of the substrate 10. Moreover, the inner walls of the conductive vias 15 are electroplated with a conductive material, so that the conductive vias 15 are electrically conductive. The compensator 13 has the inductor property. In addition, the compensator 13 may be implemented by a conductive metal plate. In this embodiment, the compensator 13 is used for adjusting the impedance match of the first resonance frequency band (e.g. 5.0GHz~5.9GHz), thereby increasing the bandwidth of the resonance frequency band. It is noted that numerous modifications and alterations may be made while retaining the teachings of the invention. For example, in some other embodiments, the compensator 13 is disposed on the first surface 101 of the substrate 10, and the first extension end 132 and the second extension end 133 of the compensator are directly connected with the inner ring 121 of the split ring resonator 12.

[0021] In the metamaterial antenna 1 of this embodiment, the capacitive coupling action between the main radiation unit 11 and the split ring resonator 12 may provide the metamaterial (MTM) property. Consequently, the bandwidth of the resonance frequency band generated by the main radiation unit 11 is increased. Moreover, since the compensator 13 is connected with the split ring resonator 12 and the compensator 13 has the inductor property, the impedance match of the resonance frequency band is adjusted. Under this circumstance, the bandwidth of the resonance frequency band is further increased.

[0022] In the above embodiment, the main radiation unit of the metamaterial antenna is a monopole antenna. In another embodiment, the main radiation unit of the metamaterial antenna is a dipole antenna. The configurations of the dipole antenna will be illustrated with reference to FIGS. 3 and 4. FIG. 3 is a schematic top view illustrating a metamaterial antenna according to a second embodiment of the present invention. FIG. 4 is a schematic perspective view illustrating the metamaterial antenna of FIG. 3. As shown in FIGS. 3 and 4, the metamaterial antenna 2 comprises a substrate 20, a main radiation unit 21, a split ring resonator 22, and a compensator 23. The substrate 20 comprises a first surface 201 and a second surface 202. The split ring resonator 22 comprises two split square-shaped rings, an inner ring 221 and an outer ring 222, which are split at opposite ends. The compensator 23 comprises a main bent part 231, a first extension end 232, and a second extension end 233. The main radiation unit 21 and the split ring resonator 22 are separated from each other by a coupling gap 24. The compensator 23 may be connected with the split ring resonator 22 through corresponding conductive vias 25. The structures and functions of the substrate 20, the split ring resonator 22, the compensator 23 and the conductive vias 25 of this embodiment are similar to those of the substrate 10, the split ring resonator 12, the compensator 13 and the conductive vias 15 of the first embodiment, and are not redundantly described herein. In comparison with the first embodiment, the main radiation unit 21 is a dipole antenna. The main radiation unit 21 comprises a first radiation part 211, a second radiation part 212, and a feeding part 213. The first radiation part 211 is U-shaped. The second radiation part 212 is U-shaped. The two ends of the feeding part 213 are connected with the first radiation part 211 and the second radiation part 212, respectively.

[0023] FIG. 5 is a plot illustrating the relationship between the return loss and the frequency of the metamaterial antenna of the first embodiment and two comparison antennas. In FIG. 5, the vertical axis represents the return loss, and the horizontal axis represents the resonance frequency. Moreover, the curve “a” represents the metamaterial antenna 1 of the first embodiment; the curve “b” represents an antenna of the metamaterial antenna 1 without the compensator 13; and the curve “c” represents the metamaterial antenna 1 without the split ring resonator 12 and the compensator 13. As mentioned above, the target dual bands comprise the first resonance frequency band (e.g. 5.0GHz~5.9GHz) and the second resonance frequency band (e.g. 2.4GHz~2.5GHz). Generally, the return loss corresponding to the effective frequency band should be lower than -10dB. As shown in FIG. 5, the return losses of the curve “a” and the curve “b” in the second resonance frequency band (e.g. 2.4GHz~2.5GHz) are both lower than -10dB. Moreover, the return loss of the curve “a” in the first resonance frequency band (e.g. 5.0GHz~5.9GHz) is lower than -10dB (i.e. from X to Y). Although the return loss of the curve “b” in the frequency band L is lower than -10dB, the frequency band L is not an effective frequency band. The effective frequency band (i.e. from M to N) of the curve “b” is narrower than the effective frequency band of the curve “a”, and the effective frequency band of the curve “b” is higher than the target frequency band (e.g. 5.0GHz~5.9GHz). Moreover, as shown in FIG. 5, the antenna of the curve “c” has only one effective frequency band.

[0024] From the above discussions, the present invention provides a metamaterial antenna. The capacitive coupling action between the main radiation unit and the split ring resonator may provide the metamaterial property. Consequently, the bandwidth of the resonance frequency band generated by the main radiation unit is increased. Moreover, since the

compensator has the inductor property, the impedance match of the resonance frequency band is adjusted. Under this circumstance, the bandwidth of the resonance frequency band is further increased. Consequently, the metamaterial antenna of the present invention can be operated in dual frequency bands (e.g. 5.0GHz~5.9GHz and 2.4GHz~2.5GHz). Moreover, when compared with the conventional dual-band antenna, the size of the metamaterial antenna of the present invention is reduced. For example, the area of the metamaterial antenna of the present invention is smaller than the area of the conventional planar dual-band antenna by 40%. Moreover, in case that the substrate of the metamaterial antenna of the present invention is made of glass fiber, the benefits about mass production and cost reduction will be achieved.

[0025] While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

WHAT IS CLAIMED IS:

1. A metamaterial antenna, comprising:

a substrate having a first surface and a second surface, wherein the first surface and the second surface are opposed to each other;

a main radiation unit disposed on the first surface of the substrate for generating at least one resonance frequency band;

a split ring resonator disposed on the first surface of the substrate and located near the main radiation unit, wherein the split ring resonator has a metamaterial structure property for increasing a bandwidth of the at least one resonance frequency band; and

a compensator connected with the split ring resonator, the compensator comprising a main bent part for adjusting impedance match of the main radiation unit.

2. The metamaterial antenna according to claim 1, wherein the main radiation unit and the split ring resonator are separated from each other by a coupling gap, wherein a capacitive coupling action between the main radiation unit and the split ring resonator is generated through the coupling gap.

3. The metamaterial antenna according to claim 1, wherein the main radiation unit is a monopole antenna, and the main radiation unit comprises:

a first radiation part;

a second radiation part connected with the first radiation part, and comprising a first segment, a second segment and an anfractuous segment, wherein the first segment is connected with the first radiation part, the second segment is connected between the first segment and the anfractuous segment, and the anfractuous segment is arranged between the first radiation part, the first segment and the second segment; and

a feeding part connected with the first radiation part.

4. The metamaterial antenna according to claim 3, wherein the main radiation unit further comprises a third radiation part, wherein the third radiation part is connected with the feeding part.

5. The metamaterial antenna according to claim 1, wherein the main radiation unit is a dipole antenna, and the main radiation unit comprises a first radiation part, a second radiation part and a feeding part, wherein both of the first radiation part and the second radiation part are U-shaped, and two ends of the feeding part are connected with the first radiation part and the second radiation part, respectively.

6. The metamaterial antenna according to claim 1, wherein the at least one resonance frequency band generated by the main radiation unit includes a first resonance frequency band of 5.0GHz~5.9GHz and a second resonance frequency band of 2.4GHz~2.5GHz.

7. The metamaterial antenna according to claim 1, wherein the substrate comprises plural conductive vias, and the plural conductive vias run through the first surface and the second surface of the substrate, wherein the compensator is disposed on the second surface of the substrate, and the compensator is connected with the split ring resonator through the plural conductive vias.

8. The metamaterial antenna according to claim 1, wherein the compensator is disposed on the first surface of the substrate, and the compensator is directly connected with the split ring resonator.

9. The metamaterial antenna according to claim 1, wherein the main bent part comprises a meander structure.

10. The metamaterial antenna according to claim 1, wherein the split ring resonator comprises two split square-shaped rings, which are split at opposite ends.

11. The metamaterial antenna according to claim 10, wherein the split ring resonator comprises an inner ring and an outer ring, wherein the outer ring is arranged around the inner ring with a gap therebetween.

12. The metamaterial antenna according to claim 11, wherein the compensator is connected with the inner ring of the split ring resonator.