

DIPOLE ANTENNA

Field of the Invention

The present invention generally relates antennae in radio frequency communications and, more specifically, to dipole antennae.

5 Background of the Invention

Antennae are essential components in wireless applications. To provide an antenna that can fit into a compact or handheld device such as cell phones, remote controllers, compact global positioning system (GPS) receivers, walkie-talkies, etc., it is common to manufacture antennae as part of a printed circuit board (PCB). Technically, such an antenna tends to be
10 fed by a 'microstrip', which is PCB structure comprised of a ground plate located under a signal trace with the width of the ground plate being about ten times the width of signal trace. Such an antenna is typically a monopole antenna, an inverted F antenna, (IFA), or a planar inverted F antenna (PIFA), in which the ground plate on PCB is an integral part of the radio frequency (RF) radiation mechanism.

15 The RF transmission of such an antenna is affected by the RF ground plate parameters. Therefore, a user's hand covering the RF ground element of a handheld device may significantly affect the RF transmission efficiency of the device. Such effect is sometimes referred to as ground effect, ground element effect, or hand effect in RF transmission.
20 Specifically, the RF radiation of the device may be partially absorbed by the hand holding the device, thereby reducing the RF transmission efficiency of the device.

Feeding the RF signal via a co-axial cable to an antenna would reduce the ground element effect, thereby improving the RF transmission performance. However, a co-axial cable is
25 bulky and cannot easily fit into a compact device with a PCB antenna. In addition, attaching

the co-axial cable to the antenna requires soldering that is also susceptible to reliability problems.

Accordingly, it would be advantageous to have an RF device with stable RF transmission efficiency. It is desirable for the device to have an antenna with high RF transmission efficiency and small ground element effect. It would also be desirable for the antenna to be compact. It would be of further advantage for the antenna structure to be easy to manufacture and reliable.

10 Summary of the Embodiments

The present invention proposes a dipole antenna with high efficiency and low ground element effect. The fabrication of the dipole antenna is simple and cost efficient. Furthermore, a dipole antenna in accordance with the present invention is compact and can easily fit into a handheld device such as, for example, cell phone, remote controller, compact global positioning system (GPS) receiver, walkie-talkie, etc.

In accordance with one embodiment of the present invention, a dipole antenna includes a dielectric substrate having first surface and a second surface opposite to each other, a first conductive strip formed on the first surface of said dielectric substrate and having a first linear trace near a first end and a bend forming a first radiation arm near a second end; wherein the first linear trace has a width, a second conductive strip formed on the second surface of said dielectric substrate and having a second linear trace near a first end and a bend forming a second radiation arm extending substantially opposite to the first radiation arm near a second end; wherein the second linear trace has a width substantially equal to or greater than the width of the first linear trace, and a ground element formed on the second surface of said dielectric substrate.

In accordance with a preferred embodiment of the present invention, the first linear trace in said first conductive strip has a length equal to or greater than about one eighth of a wavelength of a radio frequency signal to be transmitted by the dipole antenna and the second

linear trace in said second conductive strip has a length substantially equal to the length of the first linear trace in said first conductive strip.

5 In accordance with another preferred embodiment of the present invention, the length of the first linear trace in said first conductive strip is equal to or greater than about one fourth of the wavelength of the radio frequency signal to be transmitted by the dipole antenna.

10 In accordance with another preferred embodiment of the present invention that incorporate the features of the above mentioned embodiments, the width of the second linear trace in said second conductive strip is approximately equal to or greater than two times of the width of the first linear trace in said first conductive strip.

15 In accordance with another preferred embodiment of the present invention that incorporate the features of the above mentioned embodiments, the ground element of the dipole antenna has a width greater than the width of the second linear trace.

Brief Description of the Drawings

Figure 1 illustrates an antenna in accordance with an embodiment of the present invention;

Figure 2 illustrates an isometric view of the antenna shown in Fig. 1;

Figure 3 illustrates an exploded view of the antenna shown in Fig. 1;

20 Figure 4 illustrates a radiation pattern of an antenna in accordance with one embodiment of the present invention;

Figure 5 illustrates a radiation pattern of an antenna in accordance with another embodiment of the present invention;

25 Figure 6 illustrates an antenna in accordance with an additional embodiment of the present invention;

Figure 7 illustrates an antenna in accordance with a further embodiment of the present invention;

Figure 8 illustrates an antenna in accordance with yet another embodiment of the present invention; and

Figure 9 illustrates an antenna in accordance with yet another embodiment of the present invention.

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Detailed Description of Various Embodiments

Various embodiments of the present invention are described herein below with reference to the figures, in which elements of similar structures or functions are represented by like reference numerals throughout the figures. It should be noted that the figures are only intended to facilitate the description of the preferred embodiments of the present invention.

10 They are not intended as an exhaustive description of the present invention or as a limitation on the scope of the present invention. Furthermore, the figures are not necessarily drawn to scales.

Figures 1, 2, and 3 illustrate an antenna 100 in accordance with an embodiment of the present invention. Antenna 100 is formed on a printed circuit board (PCB). Specifically, antenna 100 is formed from conductive layers on a PCB substrate 101. In accordance with a preferred embodiment of the present invention, antenna 100 includes a first conductive element 103 formed on a top surface of substrate 101 and a second conductive element 105 formed on a bottom surface of substrate 101.

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One end of the conductive element 103 on the top surface of substrate 101 is connected to a signal feed, i.e., an input/output port, of a radio frequency integrated circuit (RFIC) 107 for sending and receiving wireless signals. Thus, conductive element 103 functions as a signal trace of the antenna 100. Another end of the conductive element 103 extends linearly from the RFIC 107 for a distance and bends to form a first radiation arm 109. In accordance with one specific embodiment of the present invention, radiation arm 109 extends sidewise and backward. This results in the shape of a hook in the first conductive element 103, as shown in

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Figs. 1, 2, and 3. An elongated portion of the conductive element 103 extending linearly from the RFIC 107 to the bend of the radiation arm 109 forms a linear trace 111 of antenna 100.

Conductive element 105 on the bottom surface of substrate 101 has an RF ground element 113 connected to a ground terminal of RFIC 107. Conductive element 105 functions as ground trace of antenna 100. An elongated and linear portion or linear trace 117 of the conductive element 105 extends from RF ground element 113 and bends to form a second radiation arm 115 of antenna 100. In accordance with a specific embodiment, second radiation arm 115 bends sidewise and backwards in a manner similar to first radiation arm 109, thereby resulting in the shape of a hook as shown in Figs. 1-3.

Radiation arms 109 and 115 bend in directions generally opposite to each other as shown in Figs. 1-3, thereby forming dipole antenna 100. Generally opposite extending arms 109 and 115 function as two radiation arms of dipole antenna 100.

In accordance with a preferred embodiment of the present invention, radiation arms 109 and 115 of dipole antenna 100 have a combined length of no greater than one half of the wavelength of the RF signal to be transmitted by antenna 100. In accordance with a specific embodiment, radiation arm 109 and 115 have equal lengths, which is equal to or less than one fourth or one quarter of the wavelength of the RF signal to be transmitted by dipole antenna 100. For example, if dipole antenna 100 is to transmit an RF signal having a frequency of 2.5 giga-Hertz, (GHz), the combined length of radiation arms 109 and 115 preferably have a length of 6 centimeter (cm) or less. More specifically, the length of each of radiation arm 109 and 115 is equal to or less than about 3 cm. In accordance with an embodiment of the present invention, the effective length of radiation arms 109 and 115 may be adjusted by turning on a vector network analyzer to achieve an optimal performance for antenna 100.

Linear traces 111 and 117 extend from RFIC 107 and RF ground element 113, respectively, substantially parallel to each other and for about the same distance. Linear traces 111 and 117 form a finite ground microstrip structure in antenna 100 and function to as a transmission line

for electromagnetic signals. In accordance with an embodiment of the present invention, substrate 101 functions as a dielectric substance separating signal strip 111 from ground strip 117. In accordance with a preferred embodiment of the present invention, the finite ground microstrip structure formed by strips 111 and 117 has a length equal to or greater than one eighth of the wavelength of the RF signal transmitted through antenna 100 for efficient energy transfer from RFIC 107 to radiation arms 109 and 115. Preferably, the length of strips 111 and 117 is equal to or greater than about one fourth or one quarter of the wavelength of the RF signal. For example, if antenna 100 is to transmit an RF signal of 2.4 GHz to 2.5 GHz, and industrial, scientific, and medical (ISM) band reserved internationally for the use of RF energy for industrial, scientific and medical purposes other than communications, the length of linear strips 111 and 117 is preferably equal to about 1.5 cm or longer. In a preferred embodiment, the length of linear strips or traces 111 and 117 is about 3 cm or longer when antenna 100 is used for transmitting the RF signal with a frequency about 2.5 GHz.

In accordance with a preferred embodiment of the present invention, the width of first linear trace or signal strip 111 is not significantly greater than the width of second linear trace or ground strip 117. In other words, the width of signal strip 111 is preferably approximately equal to or less than that of ground strip 117. In a preferred embodiment, the width of ground strip 117 is equal to or greater than about 2 times of the width of signal strip 111.

In accordance with an embodiment of the present invention, ground strip 117 is an elongated conductive strip narrower than a dimension of RF ground element 113 in a direction substantially perpendicular to ground strip 117. Long and narrow strips 111 and 117 significantly reduce the interference of ground element 113 on radiation arms 109 and 115 and improve the efficiency of dipole antenna 100. In other words, the long and narrow shapes of strips 111 and 117 effectively reduce the ground effect or ground element effect on the performance of antenna 100.

In accordance with a preferred embodiment of the present invention, the dimensions of strips 111 and 117 are determined according to the microstrip design principle to achieve

desirable impedance, e.g., 50 ohms (Ω). If other impedance is desired, the dimensions of strips 111 and 117 can be adjusted accordingly. Designing the dimensions of strips 111 and 117 according to the microstrip design principle to achieve desired impedance eliminates the need for impedance conversion and matching, thereby simplifying the structure and improving the efficiency and performance of dipole antenna 100.

The geometry of radiation arms 109 and 115, and finite ground microstrips 111 and 117 describe above with reference to Figs. 1-3 effectively reduces or substantially eliminates the RF ground element effect of ground element 113 on the radiation efficiency of antenna 100.

Thus, the hand of a user covering the RF ground element 113 in a handheld device is unlikely to affect the radiation efficiency of antenna 100 in the device. To achieve this effective isolation of RF ground element 113 from radiation arms 109 and 115, thereby reducing or eliminating the ground element effect, the lengths of linear strips 111 and 117 is preferably greater than one eighth of the wavelength of the RF signal transmitted by antenna 100. For more enhanced isolation, the length of linear strips 111 and 117 is preferably equal to or greater than about one fourth of the wavelength of the RF signal transmitted by antenna 100. Long strips 111 and 117 isolate RF ground element 113 under RRIC 107 from radiation arms 109 and 115, thereby substantially eliminating the ground effect and enhancing the efficiency of dipole antenna 100.

In accordance with an embodiment of the present invention, radiation arms 109 and 115 are not limited to having a hooked shape as shown in Figs. 1-3. In accordance with various embodiments of the present invention, radiation arms 109 and 115 may have different shapes such as, for example, bent, folded, straight as shown in Fig. 8, curved as shown in Fig. 9, etc.

In accordance with an embodiment of the present invention, radiation arms 109 and 115 are preferably so shaped that they are sufficiently far from ground element 113 to substantially eliminate ground element effect. By way of example, radiation arms 109 and 115 are bent to fit in a space with a linear dimension less than about one half of the wavelength of the RF signal to be transmitted by antenna 100 while maintaining its actual length of greater than one half of the wavelength in accordance with a specific embodiment of the present invention. In other words, antenna 100 for transmitting the RF signal at the frequency of 2.5 GHz would fit

in a space with a linear dimension less than 6 cm. Therefore, antenna 100 in accordance with an embodiment of the present invention can be easily fabricated using a PCB and fit in a compact handheld device. Fabricating antenna 100 on a PCB is simple and cost efficient.

5 While RF ground element 113 has little influence on the radiation efficiency of antenna 100, the geometry or shape of RF ground element 113 may affect the radiation pattern to certain extent. By way of example, in antenna 100 shown in Fig. 1, a width 119 of ground
10 element 113 is about one half of the wavelength of the RF signal to be transmitted by antenna 100. With such a dimension, ground element 113 functions as a mild signal reflector, thereby resulting in a slightly directional radiation pattern for antenna 100 as shown in Fig. 4. Specifically, the radiation pattern has strong gain towards the front of antenna 100 along the Z direction shown in Figs. 1 and 4. This radiation pattern with gain toward the front is desirable for a handheld remote control device where a user tends to point the remote control device in the direction of an apparatus, e.g., a television set, to be controlled.

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In a preferred embodiment shown in Fig. 6, width 119 of ground element 113 is less than one fourth or one quarter of the wavelength of the RF signal to be transmitted by antenna 100. In this embodiment, the ground effect of ground element 113 on the radiation pattern of antenna 100 is substantially diminished and the radiation pattern of antenna 100 is
20 substantially omni-directional as illustrated in Fig. 5. Figure 5 shows that the radiation of antenna 100 in accordance with an embodiment of the present invention illustrated in Fig. 6 is generally evenly distributed in all directions. The top diagram in Fig. 5 shows the radiation pattern as slightly elongated in the vertical direction, when viewed from the X direction. The bottom diagram in Fig. 5, however, shows an omni-directional distribution of radiation when
25 viewed from the Y direction.

Figure 7 illustrates antenna 100 in accordance with another embodiment of the present invention. Specifically, width 119 of ground element 113 at its rear end is about one half of the wavelength of the RF signal like the embodiment described above with reference to Fig. 1.
30 However, ground element 113 is tapered toward the front end where ground element 113 joins strip 117, so that an angle of less than about 100 degrees ($^{\circ}$) is formed by two sides of

ground element 113 near front end. This configuration is like removing the tow front corners of ground element 113 shown in Fig. 1. This configuration further reduces the proximity of ground element 113 to radiation arms 109 and 115, thereby resulting in a more omni-directional radiation pattern like that shown in Fig. 5.

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Figure 8 illustrates antenna 100 in accordance with yet another embodiment of the present invention, in which radiation arms 109 and 115 are two substantially straight strips perpendicular to signal strip 111 and ground strip 117 and extending in opposite direction from each other. This configuration keeps radiation arms 109 and 115 far away from ground 113 to effectively reduce the ground element effect. However, this configuration needs a wide PCB to accommodate the full lengths of radiation arms 109 and 115. Figure 9 illustrates antenna 100 in accordance with another embodiment of the present invention, in which radiation arms 109 and 115 are in the form of gentle curves or arches. In accordance with an embodiment of the present invention, radiation arms 109 and 115 may have other shapes. For example, radiation arms 109 and 115 may be conformed to the outlines of different products and PCBs.

In accordance with an embodiment of the present invention, antenna 100 is not limited to having signal strip 111 directly connected to RRIC 107. In accordance with yet another embodiment, signal strip 111 of the finite ground microstrip is coupled to RRIC 107 via by a matching network. By way of example, Figs. 6, 7, and 9 shows a contact 121 to the matching network. Matching network may perform impedance matching thereby providing more flexibility in the geometry, dimension, and design of different components in antenna 100.

In accordance with an embodiment of the present invention, RF ground element 113 is preferably large enough to provide sufficient coverage to all RF related elements on the PCB. The widths of strips 111 and 117 are determined with the above mentioned criteria and may be adjusted for optimal performance of antenna 100 taking such parameters as the thickness and dielectric constant of PCB substrate 101 into consideration.

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By now it should be appreciated that a compact dipole antenna has been provided. In accordance with an embodiment of the present invention, a dipole antenna may be fabricated on a PCB to provide high space efficiency, design and manufacturing simplicity, and durability. A finite ground strip of longer than one eighth or one quarter of the wavelength of the RF signal would significantly reduce the ground effect on the RF transmission. The width of signal strip being no greater than that of the ground strip would further reduce the ground effect. To achieve better performance, the width of the signal strip may be between one half and one fifth of the width of the ground strip. The geometries of different components of the dipole components describe above significantly reduce the ground effect and enhance the performance of the dipole antenna. The dipole antenna in accordance with an embodiment of the present invention may be compact and easily fabricated on a PCB. Therefore it is simple, reliable, and cost efficient. A dipole antenna in accordance with an embodiment of the present invention can easily fit into a compact device. In addition, the finite ground microstrip in accordance with an embodiment of the present invention may reduce energy loss during the RF transmission in comparison to other coupling technologies, such as coupling feeding and microstrip balun feeding.

While specific embodiments of the present invention have been described herein above, they are not intended as limitations on the scope of the invention. The present invention encompasses those modifications and variations of the described embodiments that are obvious to those skilled in the art. For example, although it has been described that the antenna is printed onto a PCB, those skilled in the art would understand that the principles as disclosed are not confined to be used only with PCB antennae. Other forms of antennae employing the same principles are within the scope of the present invention. By way of example, a dipole antenna in accordance with the present invention may be a non-miniature antenna which can be mechanically fabricated or an antenna which are etched into semiconductor integrated circuits.

CLAIMS

1. A dipole antenna, comprising:
a dielectric substrate having first surface and a second surface opposite to each other;
a first conductive strip formed on the first surface of said dielectric substrate and
5 having a first linear trace near a first end and a bend forming a first radiation arm near a second end; wherein the first linear trace has a width;
a second conductive strip formed on the second surface of said dielectric substrate and having a second linear trace near a first end and a bend forming a second radiation arm extending substantially opposite to the first radiation
10 arm near a second end; wherein the second linear trace has a width substantially equal to or greater than the width of the first linear trace; and
a ground element formed on the second surface of said dielectric substrate.
2. The dipole antenna of claim 1, wherein:
the first linear trace in said first conductive strip has a length equal to or greater than
15 about one eighth of a wavelength of a radio frequency signal to be transmitted by the dipole antenna; and
the second linear trace in said second conductive strip has a length substantially equal to the length of the first linear trace in said first conductive strip.
3. The dipole antenna of claim 2, wherein the length of the first linear trace in said first
20 conductive strip is equal to or greater than about one fourth of the wavelength of the radio frequency signal to be transmitted by the dipole antenna.
4. The dipole antenna of claim 1, 2, or 3, wherein the width of the second linear trace in said second conductive strip is approximately equal to two times of the width of the first linear trace in said first conductive strip.
- 25 5. The dipole antenna of claim 1, 2, or 3, wherein the width of the second linear trace in said second conductive strip is greater than about two times of the width of the first linear trace in said first conductive strip.

6. The dipole antenna of claim 1, 2, or 3, wherein the first linear trace and the second linear trace have a dimension determined via a microstrip design principle to achieve a predetermine impedance.
- 5 7. The dipole antenna of claim 6, wherein the first linear trace and the second linear trace have a dimension determined via the microstrip design principle to achieve an impedance of fifty ohms.
8. The dipole antenna of claim 1, 2, or 3, wherein said ground element has a width greater than the width of the second linear trace.
- 10 9. The dipole antenna of claim 8, wherein said ground element has a width of about one fourth of a wavelength of a radio frequency signal to be transmitted by the dipole antenna.
10. The dipole antenna of claim 8, wherein said ground element has a width of about one half of a wavelength of a radio frequency signal to be transmitted by the dipole antenna.
- 15 11. The dipole antenna of claim 8, wherein said ground element has a tapered portion adjacent the second linear trace.
12. The dipole antenna of claim 1, 2, or 3, wherein the first radiation arm and the second radiation arm have a combined length equal to or less than about one half of a wavelength of a radio frequency signal to be transmitted by the dipole antenna.
- 20 13. The dipole antenna of claim 1, 2, or 3, wherein:
the first radiation arm has a length equal to or less than about one fourth of a
wavelength of a radio frequency signal o be transmitted by the dipole
antenna; and
the second radiation arm has a length substantially equal to the length of the first
25 radiation arm.

14. The dipole antenna of claim 1, 2, or 3, wherein:
the first radiation arm is formed in a shape of a first hook; and
the second radiation arm is formed in a shape of a second hook opposite to the first hook.
- 5 15. The dipole antenna of claim 1, 2, or 3, wherein:
the first radiation arm is formed in a shape of a first arch; and
the second radiation arm is formed in a shape of a second arch opposite to the first arch.
- 10 16. The dipole antenna of claim 1, 2, or 3, wherein:
the first radiation arm is formed in a straight line substantially perpendicular to the first linear trace; and
the second radiation arm is formed in a straight line substantially perpendicular to the second linear trace and opposite to the first radiation arm.
- 15 17. A dipole antenna substantially as described and illustrated in the description and the accompanying drawings.