



Ultra-wideband monopole antenna

BACKGROUND TO THE INVENTION

Field of the invention

This invention relates to an ultra-wideband monopole antenna.

- 5 Ultra-wideband (UWB) is one of the most recently developed wireless communication technologies. UWB offers communication at very high data rates and low power consumption for transmission over a short distance.

Antennas are systems including conductors used for transmitting and receiving radio waves or other electromagnetic waves by wire. UWB antennas must provide wideband input
10 impedance matching and have the ability to control the radiation patterns within the working frequency range. For a wide variety of applications, it is desirable for these antennas to have an omnidirectional response. Planar UWB antennas have been widely studied and can be easily fabricated due to their low profile, small size and low cost.

Summary of the prior art

- 15 US-A-2005/0280580 and US-A-7 132 985 are devoted to the study of new UWB antennas with simple structures having omnidirectional radiation patterns and wideband operation. They disclose planar monopole antennas that are formed on printed circuit boards by etching. The operating frequency band can cover the whole UWB bandwidth (3.1 GHz to 10.6 GHz). In Hans G. Schantz, "Bottom fed planar elliptical UWB antennas," IEEE Conference on
20 UWB systems and technologies, pp. 219-223, Nov. 2003", a bottom fed planar elliptical UWB dipole antenna is described. The antenna can provide a good omnidirectional pattern but the design can be difficult to implement as it incorporates a balun transformer to help improve matching and reduce undesired cable currents. Many other efforts have been done to continue the exploration of new antenna designs. For example, in US-A-2005/0280582 there
25 is disclosed the differential and single ended elliptical antennas. In order to increase the



impedance bandwidth or to realize frequency band rejection characteristic, narrow slits/slots may be added into the monopole patches, as disclosed in US-A-2006/0181471.

All the above antennas are planar structures which are suitable for use in single-ended or differential UWB transmitting and/or receiving systems and are easily mounted. They are
5 wideband with omnidirectional patterns in the x - z plane ($\theta=90$, $\phi=0$). However, in the y - z plane ($\theta=90$, $\phi=90$), which is also important for some applications, the radiation pattern is less controlled. (θ represents the angle with the z -axis, and ϕ represents the corresponding angle with the x -axis in the x - y plane.) For example, a null area is generated due to a reduction in a radiation gain of planar type antennas towards both edges. The signal strength
10 is low in such a null area and the effective communication may be inhibited or rendered impossible. US-A-2006/0181471 discloses a UWB antenna with 270° coverage in the main beam. The antenna includes a dielectric substrate, two Vivaldi horn radiators attached to the dielectric substrate and including central axes orthogonal to each other, and a single radiator coupled to the two Vivaldi horn radiators. The structure is quite complicated and its
15 parameters are difficult to control.

SUMMARY OF THE INVENTION

An aim of the invention is to provide a UWB monopole antenna design that has a simple structure and few adjustment parameters. In addition to omnidirectional elevation radiation in the x - z plane, it is a further aim of the present invention to provide an antenna with good
20 omnidirectional elevation radiation in the y - z plane. It has been found that use of a radiating element that has a shape resembling a guitar is advantageous. That is, it has a shape that peripherally has regions that are segments of an ellipse or of a circle.

From a first aspect, the invention provides an ultra-wideband antenna comprising: a substrate; a conductive ground plane formed on a first surface of the substrate; a radiating element
25 formed on a surface of the substrate, the radiating element having a peripheral shape that includes a plurality of regions each being a segment of an ellipse; and a feed element to transmit a signal to the radiating element.

The shape of the radiating element may have a resemblance to the body of a guitar. That is, it has two or more bulbous regions, that closer to the feed line being of a lesser width in the x -direction than that further from the feed line.

The feed element may be a 50Ω microstripline. In such embodiments, the feed element is typically formed on a surface of the substrate opposite that on which the ground plane is formed.

Alternatively, the feed element is a coplanar waveguide. In such embodiments, the feed element is formed on the same surface of the substrate. The ground plane may therefore comprise two pieces of metal separated by the feed element.

10 To improve omnidirectional performance, a slot may be formed in the radiating element extending from the periphery of the radiating element. The slot may extend in a direction generally parallel to the feed line.

There is typically a gap between the feed element and the ground plane. The size of the gap is a parameter that controls operating performance of the antenna. Advantageously, the gap is of width $0\lambda_g$ and $0.04\lambda_g$, where λ_g is the wavelength in the dielectric medium of the central frequency of the operating frequency band.

The elliptical regions of the periphery of the radiating element advantageously have different radii in one or both of their major and minor axes. One or more region of the periphery of the radiating element may be a segment of a circle. This helps to distribute resonances to different frequencies, thereby increasing bandwidth.

Most typically, the radiating element is symmetrical about an axis that passes through the feed element.

From a second aspect, the invention provides an ultra-wideband antenna comprising: a substrate; a conductive ground plane formed on a first surface of the substrate; a radiating element formed on a surface of the substrate, the radiating element having a peripheral shape that includes a plurality of regions each being curved, the regions having different radii of curvature; and a feed element to transmit a signal to the radiating element.

The curved regions include one or more of a segment of a circle, a segment of an ellipse or a segment of an ovoid.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

- 5 Fig. 1a is a front view of a planar monopole antenna of a first embodiment of the invention, which is a microstripline fed structure;

Fig. 1b is the side view of a planar monopole antenna of a first embodiment of the invention;

Fig. 2 is a diagram of the return loss of the planar monopole antenna shown in Fig. 1;

- Fig. 3 illustrates another embodiment of the invention being a modification of the
10 embodiment of Fig. 1, where a slot is on one side of the radiating element.;

Fig.4 compares the gain variation at 4GHz in the y-z plane radiation patterns of the antenna shown in Figs 1 and 3;

Fig. 5 illustrates another embodiment of a planar monopole antenna where the radiating element is a combination of several circles;

- 15 Fig. 6 illustrates another embodiment of a planar monopole antenna where the radiating element is a combination of several semicircles;

Fig. 7 illustrates another embodiment of a planar monopole antenna where a wide slot cut is on the middle of the radiating element; and

- Fig. 8 is the illustration of a planar monopole antenna of the second embodiment of the
20 invention, which is incorporates a coplanar waveguide feed element; and

Figs 9 and 10 show embodiments of the invention having alternative configurations of radiating element.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the invention will now be described in detail, by way of example, and with
5 reference to the accompanying drawings.

An omnidirectional monopole antenna being a first embodiment of the invention is shown in Figures 1a and 1b. The antenna comprises a dielectric substrate 10 that has a substantially flat, opposed first and second major surface that lie in an x - y plane. On the first major surface of the substrate 10 are formed a radiating element 12 of diameter and a feed line 14. On the
10 opposite major surface of the substrate 10 is formed a metal ground plane 16. Fig 1(a) is drawn as if the substrate 10 were transparent (i.e., such that the ground plane 16 is visible when the substrate 10 is viewed looking, opposite to the z -direction, towards the surface on which the radiation element 12 and feed line 14 are formed). Figure 1(b) shows the arrangement of the elements as viewed along the x -direction.

15 The radiating element 12 has a periphery that comprises several regions that are each a segment of an ellipse, the regions having different radii in the major and minor axis. The radiating element is generally symmetrical about an axis that passes through the feed line 14 in the y -direction. The shape of the radiating element 12 has a resemblance to the body of a guitar. That is, it has two bulbous regions, that closer to the feed line 14 being of a lesser
20 width in the x -direction than that further from the feed line 14. The aim in implementing the embodiment is to broaden the bandwidth by exciting different resonances that correspond to various planar dipole/monopole antennas. Different radii of the ellipses correspond to different resonant frequencies, so the combination of these ellipses can help to enlarge the frequency bandwidth. The radius of the major axis of the largest elliptical region is typically
25 approximately half the wavelength λ_g , where λ_g is the wavelength in the dielectric medium of the central frequency of the operating frequency band. For example, the largest radius in major axis (x -axis) of the radiating element corresponds to half the wavelength in the medium at the lowest resonant frequency.

The feed line 14 is a 50Ω microstripline that is operative to transmit a signal to the radiating element. There is a gap, indicated at 18, between the feed point (the point at which the feed line 14 joins the radiating element 12) and the ground plane 16. The size of the gap is an important parameter for control of impedance matching of the antenna. It has been found that
5 when the gap is between $0\lambda_g$ and $0.04\lambda_g$, the antenna can have better impedance matching in wide bandwidth.

As shown in Fig 1, the monopole antenna is manufactured by employing planar etching technology.

Fig 2 shows the return loss of the antenna of the first embodiment of the invention. The
10 vertical axis shows the return loss and horizontal axis shows the operating frequency.

As a modification to the above antenna structure, a slot 22 is formed extending into the radiating element 12 in a direction substantially normal to the ground plane 16, as shown in Fig 3. The purpose of the slot 22, is to obtain good omnidirectional radiation characteristics (that is to say, to reduce directional variation in gain of radiation) with elevation in the y - z
15 plane while maintaining omnidirectional performance characteristics in the x - z plane. It is found that the centre of the slot 22 is preferably placed on the radiating element close to the position of half-circular radius to the circular patch centre, and the width of the slot 22 is chosen to be the same as the width of the 50Ω microstripline on the substrate.

Fig 4 is a comparison the radiation patterns of a 4GHz signal in the y - z plane of the
20 embodiments for the situations that are with and without the slot. It will be seen from Fig 4 that the gain variation is apparently improved (around 15dB to 20dB) at the two nulls by the adding of this slot.

Fig 5 and Fig 6 illustrate further embodiments of the invention. In these embodiments, the radiating element 12 is formed as with a periphery having regions shaped as a combination of
25 several segments of circles, semicircles or being shaped as part of the outline of a water droplet.

Fig 7 shows another embodiment of the embodiment with an empty region cut from the middle of the radiating elements. The peripheral shape of the empty region resembles the

outer peripheral shape of the radiating element 12. The radiating element 12 therefore has the appearance of a strip of material of approximately constant width.

A further embodiment of the invention is shown in Fig 8. The periphery of the radiating element 12 comprises combined ellipses with different radii in the major and minor axis. The
5 feed element is a coplanar waveguide (CPW) structure. In this embodiment, the metal ground plane now is on the same surface of the substrate as the radiating element and, separated by the feed line to two sides. There are three gaps in this structure, the size of which can be selected to as a design parameter of the antenna. One is the gap between the feed point and the ground planes; the other two are gaps between the ground plane and the
10 feed line. It has been found that when the gap between the feed point and the ground plane should be between $0\lambda_g$ and $0.04\lambda_g$, while the gaps between the ground plane and the feed line form the 50Ω CPW input impedance on the substrate, the antenna can have better impedance matching over a wide bandwidth, where λ_g is the wavelength in the dielectric medium of the central frequency of the operating frequency band.

15 To obtain good omnidirectional performance from this embodiment in both the y - z plane and the x - z plane, a slot can be provided on one side of the radiating element. With this slot, the impedance matching bandwidth and the gain variation in the radiation patterns can both be improved.

Other embodiments of the CPW fed planar monopole antennas are also suitable, where the
20 radiating element can be the combination of circles, semicircles or reverse water droplets. For example, the embodiment of Fig 9 has a radiating element similar to that of Fig 5, but inverted with respect to the feed. Fig 10 illustrates an embodiment in which the radiating element has an ovoid periphery, which can be likened to an inverted water droplet.

Claims

1. An ultra-wideband antenna comprising: a substrate; a conductive ground plane formed on a first surface of the substrate; a radiating element formed on a surface of the substrate, the radiating element having a peripheral shape that includes a plurality of regions each being a segment of an ellipse; and a feed element to transmit a signal to the radiating element.
2. An ultra-wideband antenna according to claim 1 in which the feed element is a 50- Ω microstripline.
3. An ultra-wideband antenna according to claim 2 in which the feed element is on a surface of the substrate opposite that on which the ground plane is formed.
4. An ultra-wideband antenna according to claim 1 in which the feed element is a coplanar waveguide.
5. An ultra-wideband antenna according to claim 4 in which the feed element is formed on the first surface of the substrate.
6. An ultra-wideband antenna according to claim 5 in which the ground plane comprises two pieces of metal separated by the feed element.
7. An ultra-wideband antenna according to any preceding claim in which a slot is formed in the radiating element extending from the periphery of the radiating element.
8. An ultra-wideband antenna according to claim 7 in which the slot extends in a direction generally parallel to the feed line.
9. An ultra-wideband antenna according to any preceding claim in which there is a gap between the feed element and the ground plane.

10. An ultra-wideband antenna according to claim 9 in which the gap is of width $0\lambda_g$ and $0.04\lambda_g$, where λ_g is the wavelength in the dielectric medium of the central frequency of the operating frequency band.
- 5 11. An ultra-wideband antenna according to any preceding claim in which the elliptical regions of the periphery of the radiating element have different radii in one or both of their major and minor axes.
12. An ultra-wideband antenna according to any preceding claim in which one or more regions of the periphery of the radiating element is a segment of a circle.
- 10 13. An ultra-wideband antenna according to any preceding claim in which the radiating element is symmetrical about an axis that passes through the feed element.
14. An ultra-wideband antenna comprising: a substrate; a conductive ground plane formed on a first surface of the substrate; a radiating element formed on a surface of the substrate, the radiating element having a peripheral shape that includes a plurality of regions each being curved, the regions having different radii of curvature; and a
15 feed element to transmit a signal to the radiating element.
15. An ultra-wideband antenna according to claim 14 in which the curved regions include one or more of a segment of a circle, a segment of an ellipse or a segment of an ovoid.