

Printed Circular Disc Monopole Antennas with Notched Ground Plane

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Abstract

In this paper, a novel printed disc monopole antenna with a notched ground plane for UWB applications is presented. Two different shapes are proposed for the notch: a triangular one and an exponential curved one. By choosing the suitable size of the notch, wide band operation can be obtained. The proposed antenna has an omni-directional pattern in the xy -plane and the influence of the notch on the radiation pattern is very small. These features are very attractive for UWB applications.

1. INTRODUCTION

There has been much interest in developing ultra-wideband (UWB) antennas for short-range and high-speed wireless communications, since the Federal Communications Commission (FCC) allocated the frequency band from 3.1 to 10.6 GHz for UWB systems in 2002. UWB antennas are necessary for compact, nondispersive and wide impedance bandwidth properties. Various types of planar monopole antennas have been developed for UWB systems. To improve the impedance bandwidth of planar monopole antennas for UWB applications, several wide-banding enhancement techniques have been reported, such as using a bevelling technique [1], various disc shapes [2], a shorting pin [3], a trident-shaped feeding strip [4], and so on. However, strictly speaking, these are not planar structures because the radiators are perpendicular to their ground planes. It seems that the planar monopole antennas are not particularly easy to integrate into handsets or mobile terminal cases. Accordingly, a printed disc monopole antenna is considered one of good candidates owing to its light weight, low profile, relatively low cost and ease of manufacture [5-7].

In this paper, we present a new design for a printed disc monopole antenna with a notched ground plane in order to achieve wide bandwidth operation. A triangular notch and an exponential curved notch are proposed and the optimal designs of both notch shapes are shown. By adjusting the size of the notch, we can obtain wide band performance on the VSWR characteristics of the antenna. The simulation and measurement results of the VSWR characteristics and the

measurement results of the radiation pattern are presented and discussed.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed printed circular disc monopole antenna. The antenna is printed on a dielectric substrate with a relative permittivity of 2.25 and a thickness of 0.8 mm. The antenna consists of a circular disc radiator with a diameter of 17 mm and a microstrip feed line on the top side of the substrate, and a ground plane with a notch on its bottom side. The length of the substrate is 57 mm, and its width is 50 mm. The microstrip line fed by a SMA connector is designed to be 50Ω of width $w = 2.4$ mm. The size of the ground plane is chosen to be rectangular and has dimensions of 50 mm (L) x 40 mm (W). There is a triangular notch or an exponential curved notch of length l_a and width l_b at the antenna feed point in the ground plane. The feed gap between the circular radiator and the ground plane in the yz -plane is fixed at $d_f = 0$.

3. NUMERICAL AND EXPERIMENTAL RESULTS

In this section, a printed circular disc monopole antenna with a notched ground plane is characterized in detail. A triangular notch and an exponential curved notch are chosen as shape for a notch. We will begin by considering the effect of the notch length and notch width, in order to determine the

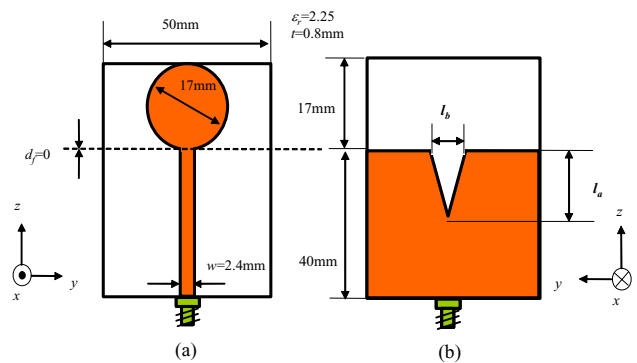


Fig. 1. Geometry of the proposed antenna, (a) Top view and (b) Bottom view.

appropriate configuration parameter of the notch. The FDTD method is used extensively in the design and analysis of the antenna, and the measured values of the VSWR are obtained by a network analyzer.

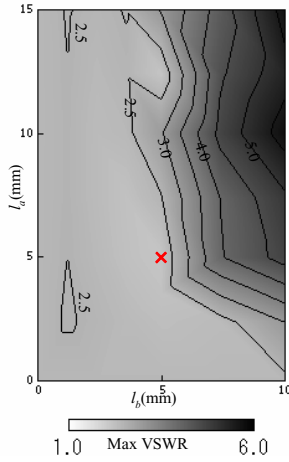


Fig. 2. 2-D contour plot of maximum value of the VSWR in the UWB band (triangular notch).

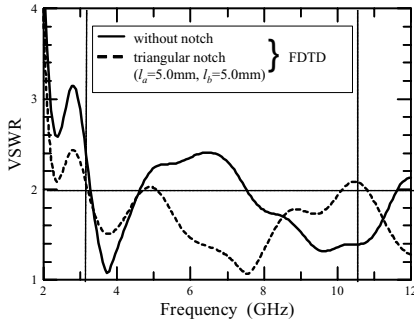


Fig. 3. Calculated VSWR of the antenna with and without triangular notch.

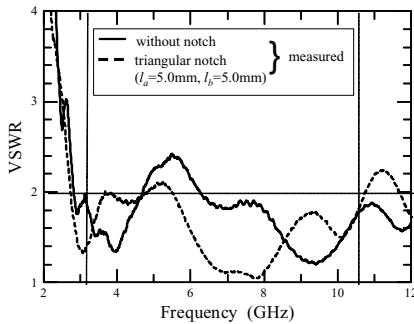


Fig. 4. Measured VSWR of the antenna with and without triangular notch.

A. Triangular notch

Figure 2 shows the 2-D contour plot with maximum value of the VSWR characteristics obtained by numerical analysis in UWB band. It can be seen that the effect of notch width l_b on VSWR is greater than the effect of notch length l_a . We can ascertain that the VSWR is less than 2.5 in the large area including the antenna without the notch ($l_a = 0$ mm and $l_b = 0$ mm). The lowest point of the VSWR is 2.14, when $l_a = 5.0$ mm and $l_b = 5.0$ mm are chosen.

The VSWR characteristics calculated as a function of frequency of the antenna with and without a triangular notch are shown in Fig. 3. The dimensions of the triangular notch are $l_a = l_b = 5.0$ mm. The maximum values of the VSWR in the UWB band with and without the notch are 2.1 at 10.5 GHz and 2.4 at 6.5 GHz, respectively. It is clearly seen that the VSWR is decreased over a frequency range of about 4 GHz to 7 GHz in the antenna with the triangular notched ground plane.

Figure 4 shows the VSWR characteristics measured as a function of frequency of the antenna with and without a triangular notch, where the length and width of the triangular notch are $l_a = l_b = 5.0$ mm. The maximum values of the VSWR in the UWB band with and without the notch are 2.1 at 5.2 GHz and 2.4 at 5.5 GHz, respectively. The measured data agree fairly well with the calculated data for both antennas with and without a notch. We can see from Fig. 3 and 4 that the VSWR of the antenna using the ground plane with triangular notch is slightly greater than 2 in the UWB band.

B. Exponential curved notch

Figure 5 shows the bottom side of the antenna with an exponential curved notch on the ground plane. The exponential curved notch is defined as

$$z = \begin{cases} -a \{ e^{b(l_b/2 - |y|)} - 1 \} & , |y| \leq l_b/2 \\ 0 & , |y| > l_b/2 \end{cases}$$

where coefficient a is fixed at 0.33 after some calculation.

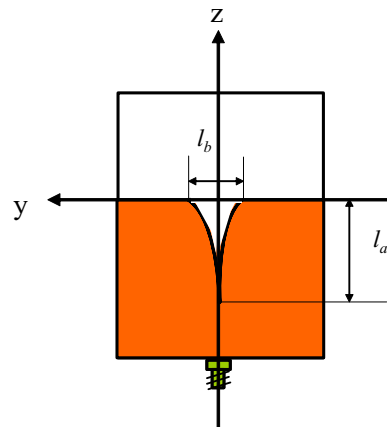


Fig. 5. Bottom view of the antenna with an exponential curved notch on the ground plane

Figure 6 shows the 2-D contour plot of maximum value of the calculated VSWR in UWB band, when the dimensions of the exponential curved notch are varied. It is observed that the VSWR is generally smaller and the changes of the VSWR are gentler than the contour plot of the triangular notch shown in Fig. 2. It seems that the cause of this is that the exponential curved notch can provide a match between the impedance of the microstrip line and that of the circular disc radiator more gradually than that of the triangular notch. The lowest point of the VSWR is 1.99, when $l_a = 7.4$ mm and $l_b = 5.0$ mm.

The VSWR characteristics calculated as a function of frequency are shown in Fig. 7. The dimensions of the exponential curved notch are $l_a = 7.4$ mm and $l_b = 5.0$ mm. The maximum value of the VSWR of the antenna with the exponential curved notch in the UWB band is 1.99 at 4.9 GHz. It is observed that the result of the exponential curved notch is almost same as that of the triangular notch shown in Fig. 3.

Figure 8 shows the VSWR characteristics measured as a function of frequency, when the dimensions of the exponential curved notch are $l_a = 7.4$ mm and $l_b = 5.0$ mm. The maximum value of the VSWR in the UWB band with the notch is 2.0 at 4.1 GHz.

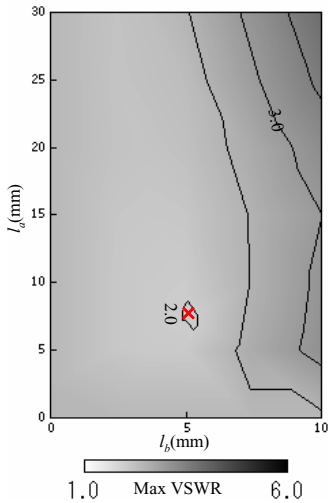


Fig. 6. 2-D contour plot of maximum value of the VSWR in the UWB band (exponential curved notch).

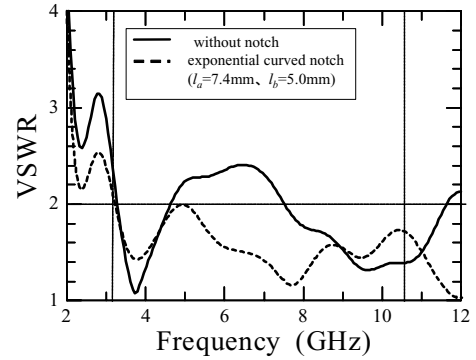


Fig. 7. Calculated VSWR of the antenna with and without exponential curved notch.

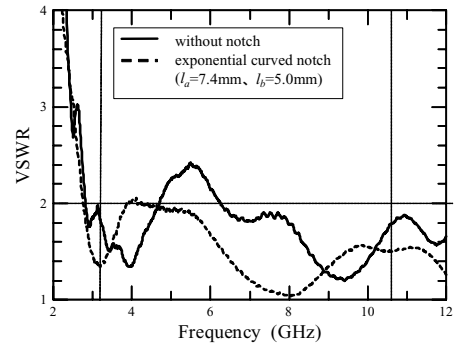


Fig. 8. Measured VSWR of the antenna with and without exponential curved notch.

C. Radiation Patterns

The radiation pattern is measured with a network analyzer in an anechoic chamber. Figures 9–11 illustrate the measured radiation patterns of the proposed antenna in the xy -plane, xz -plane and yz -plane, where (a) and (b) show at 3 GHz and 10 GHz, respectively. It is noticed that the patterns in the xy -plane are close to omni-directional at both frequencies and therefore suitable for UWB applications. There are very few differences among patterns of the antenna without a notch, those with the triangular notch and those with the exponential notch, mainly because the dimension of each notch is much smaller than the wavelength.

- without notch
- - - triangular notch ($l_a=5.0\text{mm}$, $l_b=5.0\text{mm}$)
- · - exponential curved notch ($l_a=7.4\text{mm}$, $l_b=5.0\text{mm}$)

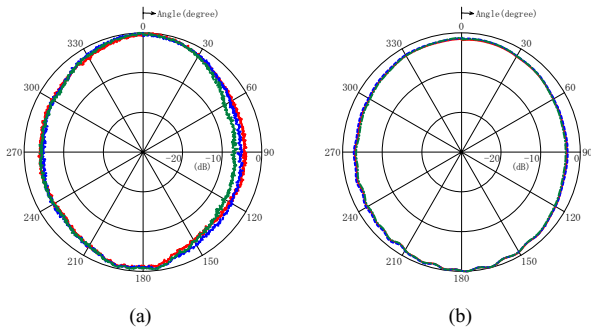


Fig. 8. Measured radiation patterns of the proposed antenna in the xy -plane, (a) 3 GHz and (b) 10 GHz.

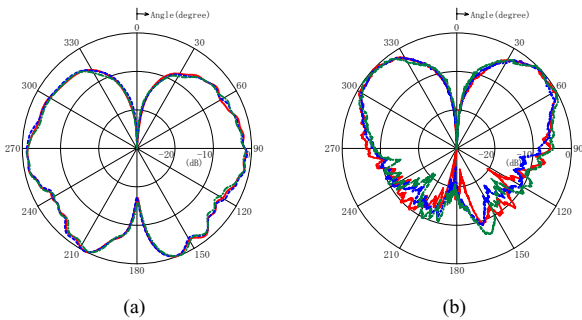


Fig. 9. Measured radiation patterns of the proposed antenna in the yz -plane, (a) 3 GHz and (b) 10 GHz.

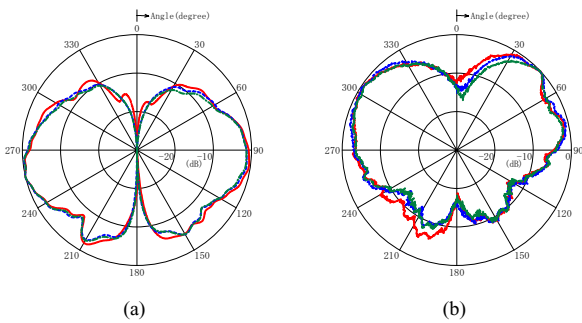


Fig. 10. Measured radiation patterns of the proposed antenna in the xz -plane, (a) 3 GHz and (b) 10 GHz.

4. CONCLUSION

An improved design of the printed disc monopole antenna with a notched ground plane for wide-banding of the impedance is proposed. A triangular notch and an exponential curved notch are proposed, and the optimal design of each shape of notch is verified. By appropriately adjusting the size of the notch, the VSWR characteristics of the antenna can be clearly improved. The antenna shows monopole radiation patterns with omni-directional patterns in the xy -plane. The influence of the notch on the radiation pattern is very small.

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