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A Novel Ultra-Wideband Rotated Cross Monopole Antenna for Wireless Communication

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Abstract—A novel broadband planar rotated cross monopole antenna, which consists of a vertical patch (area A) and a rotated horizontal patch (area B), is proposed. By rotating the horizontal patch, the bandwidth of the proposed antenna can be significantly enhanced. The effect of the rotated angle of the horizontal patch on the bandwidth has been deeply studied. The measured results show that the proposed antenna with compact size of $50 \times 50\,\mathrm{mm}^2$ can achieve a wide impedance bandwidth (10-dB reflection coefficient) as large as 8.76 GHz (2.33–11.09 GHz) or about 130%, which is nearly two times of what the corresponding conventional cross monopole antenna was.

1. INTRODUCTION

In last few years, the multiband and wideband antenna has attracted more and more interest with the rapid development of wireless communication. Various methods have been presented for achieving antennas that can cover multi-bands by using only one antenna [1–11]. Printed planar monopoles are promising wideband antennas and can be easily integrated in communication systems by fabrication onto printed circuit boards. Recently these elements have become popular for wireless communications due to their broad bandwidth and appropriate radiation pattern [12]. In order to further enhance the bandwidth of the printed monopole, some novel methods have been proposed. In [12], the genetic algorithm was employed to design a wideband printed monopole. The bandwidth of the proposed antenna achieved by this method can reach 1.9–10 GHz, which can cover higher cellular, WLAN, and UWB bands. The authors in [13] presented a method for bandwidth enhancement by utilizing fractal-shape technology. The planar monopole antenna using the Penta-Gasket-Koch shape can achieve a good input impedance match and linear phase of throughout the passband (1.5–20 GHz and 5 dB criterion for impedance bandwidth). Utilizing multi radiation elements or parasitic elements to improve the bandwidth of the antenna is another often used method [14, 15]. Recently a wideband antenna called planar cross monopole antenna was investigated in [16]. The cross-shaped patch comprises vertical microstrip and two rectangular patches. By adding the two rectangular patches in the planar monopole antenna, the proposed antenna exhibited a wide impedance bandwidth of over 70%. However, the bandwidth of the antenna is not yet enough for some wireless communication systems, such as the UWB applications.

In this letter, a novel ultra-wideband rotated monopole antenna is proposed. The antenna consists of a vertical patch (area A) and a rectangular patch (area B). Different from the conventional cross monopole antenna, the horizontal patch of the proposed antenna here is rotated with a definite angle. Using this method, the impedance bandwidth of the proposed cross monopole antenna can be drastically enhanced. The measured results show that the bandwidth of the proposed antenna can reach 8.76 GHz (2.33–11.09 GHz) or about 130% for return loss $< 10\,\mathrm{dB}$. The antenna can cover the 2.45-GHz/5.2-GHz/5.8-GHz ISM bands (WLAN, IEEE-802.11b and g)/2.5-GHz/3.5-GHz/WiMAX and UWB (3.1–10.6 GHz) bands. In addition, the antenna has a compact size which makes it suitable for the wireless communication systems.

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2. ANTENNA DESIGN

The geometry of the proposed rotated cross monopole antenna is shown in Fig. 1. The rotated cross monopole antenna can be easily printed on a dielectric substrate. It is constituted of rotated cross-shaped planar monopole fed by $50\,\Omega$-microstrip line and a ground plane. The rotated cross patch consists of two parts: the vertical rectangular patch (A) and rotated rectangular patch (B) which has a rotated angle of α. The vertical rectangular patch (A) acts as a radiator as well as feed for the cross patch antenna. The rotated monopole radiator (B) and $50\,\Omega$-microstrip feed line are printed on the same side of the dielectric substrate while the ground plane locates on the other side. The sizes of vertical patch (A) and rotated patch (B) are $b \times d$ and $a \times c$, respectively. The whole antenna is fed by a 50-microstrip line with a width of W_f. The dimension of ground plane for the proposed antenna is $W \times L_1$. The feed gap width between the ground plane and the feed point is g. The proposed antenna is printed on a FR4 substrate with a thickness of 1.6 mm and a relative permittivity of 4.4, which has a dimension of $W \times L$.

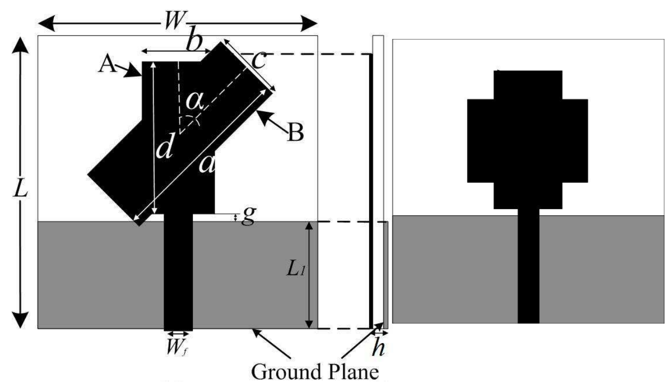

Figure 1. Geometry of the proposed antenna: (a) top view, (b) side view, (c) geometry of the reference antenna.

3. SIMULATED AND MEASURED RESULTS

In order to understand the effects of various parameters and to optimize the performance of the final design, a parameter study is carried out in this section. The whole simulation is carried out by using CST, a commercial electromagnetic simulator based on Finite Integration Technique (FIT).

In this antenna, the most critical parameter is the rotated angle of the horizontal patch. It has a significant effect on the return loss of the proposed antenna. Fig. 2 shows the simulated reflection coefficient for the presented antenna with different α. It is shown that the return loss varied significantly as different α. The return loss decreases to 10 dB gradually as α increasing. When α is larger than $50°$, the return loss becomes large. To get a wider operation band, α was chosen as $45°$. The bandwidth of simulated impedance bandwidth (10-dB reflection coefficient) is as wide as 8.76 GHz (2.33–11.09 GHz). In order to further analyze the effect of the rotated angle of the horizontal patch, Fig. 3 gives the simulated input impedance in comparison with that of the reference antenna. It can be seen that by rotating the patch of the proposed antenna, the imaginary part of the input impedance becomes flat and fluctuates around zero while the real part of the input impedance becomes close to 50 Ohms.

Beside the angle of the rotated patch, the coupling effects between the ground plane and the feed point is another important factor to influence the impedance matching of the proposed antenna. For this, the effects of the feed gap height $g = 0$, 0.5, 1, 1.5, 2 and 2.5 mm on the performance of the proposed antenna were further studied and presented. Fig. 4 shows the return loss of the antenna with different g. The obtained results clearly show that the resonant frequency of the proposed design moves towards lower frequency band and forms with increasing the feed gap height. This is because increasing the feed gap height g considerably increases the total capacitive effect, thus lowering the resonant frequency [11].

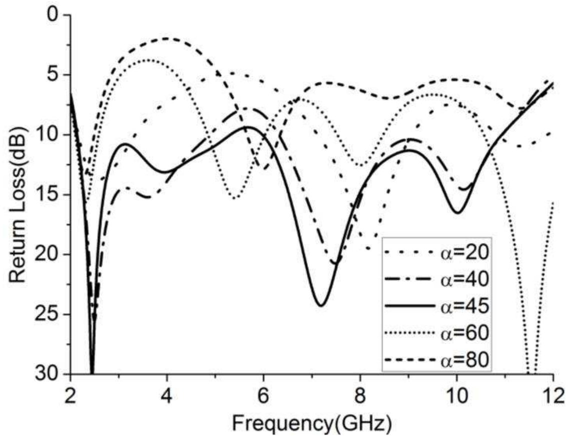

Figure 2. Simulated return losses against frequency for the proposed antenna with various α, $W = L = 50\,\mathrm{mm}$, $L_1 = 15\,\mathrm{mm}$, $a = 30\,\mathrm{mm}$, $b = 10\,\mathrm{mm}$, $c = 12\,\mathrm{mm}$, $d = 24\,\mathrm{mm}$, $g = 1\,\mathrm{mm}$.

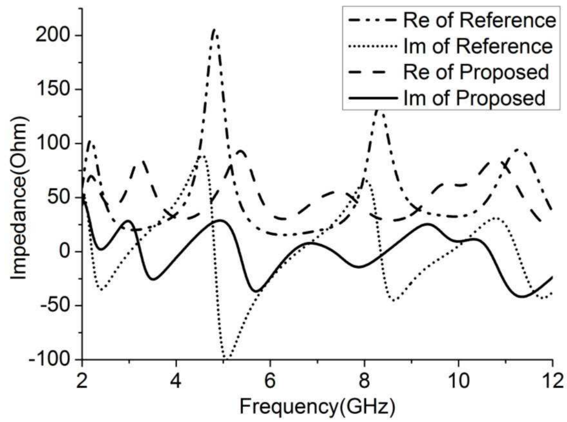

Figure 3. Simulated input impedance of the proposed antenna and the reference antenna.

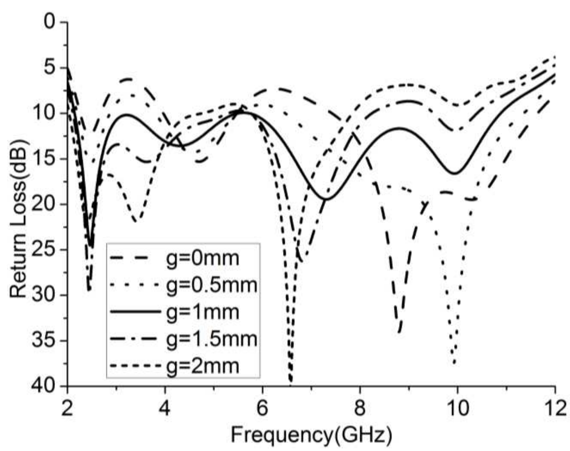

Figure 4. Simulated return losses against frequency for the proposed antenna with various g, $W = L = 50\,\mathrm{mm}$, $L_1 = 15\,\mathrm{mm}$, $a = 30\,\mathrm{mm}$, $b = 10\,\mathrm{mm}$, $c = 12\,\mathrm{mm}$, $d = 24\,\mathrm{mm}$, $\alpha = 45°$.

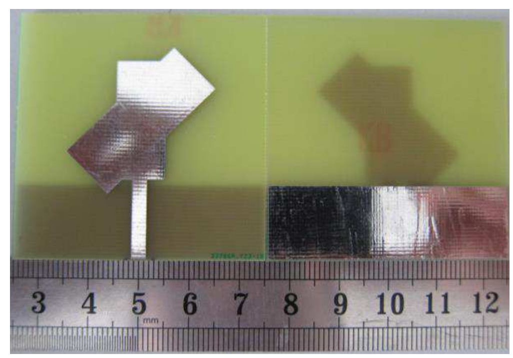

Figure 5. The prototype of the proposed antenna.

The prototype of the proposed antenna with optimal geometrical parameters as shown in Fig. 1 is constructed and measured. The geometric dimensions of the proposed antenna are as follows: $W = L = 50\,\mathrm{mm}$, $L_1 = 15\,\mathrm{mm}$, $a = 30\,\mathrm{mm}$, $b = 10\,\mathrm{mm}$, $c = 12\,\mathrm{mm}$, $d = 24\,\mathrm{mm}$, $g = 1\,\mathrm{mm}$, $\alpha = 45°$. The antenna was fabricated and the photograph of it is shown in Fig. 5. The return-loss performance was measured by using Andritsu 37269A vector network analyzer. Fig. 6 shows the simulated and measured return losses of the proposed antenna. The measured results show that the bandwidth of impedance bandwidth (10-dB reflection coefficient) is as large as 8.76 GHz (2.33–11.09 GHz) or about 130.6%. A minor difference between the simulated and measured results can be observed. The measured resonant frequency of the antenna shifts to high frequency. This may be explained by the fact that the substrate that we used is commercially available and that the permittivity is not strictly accurate.

Figure 7 gives the measured radiation patterns at 2.5 GHz, 7 GHz and 10 GHz. It can be seen that at low band, the proposed antenna has a monopole-like patterns. A approximately circular radiation pattern is obtained in xoz-plane. It is also noted that in the xoy-plane, the maxim gain directions rotate to 45° off the y-axis which is with respect to the rotated patch since the rotated patch is the

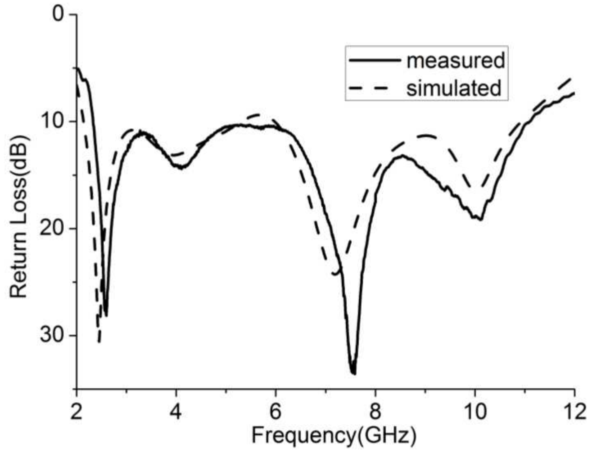

Figure 6. Measured and simulated return losses of the proposed monopole antenna.

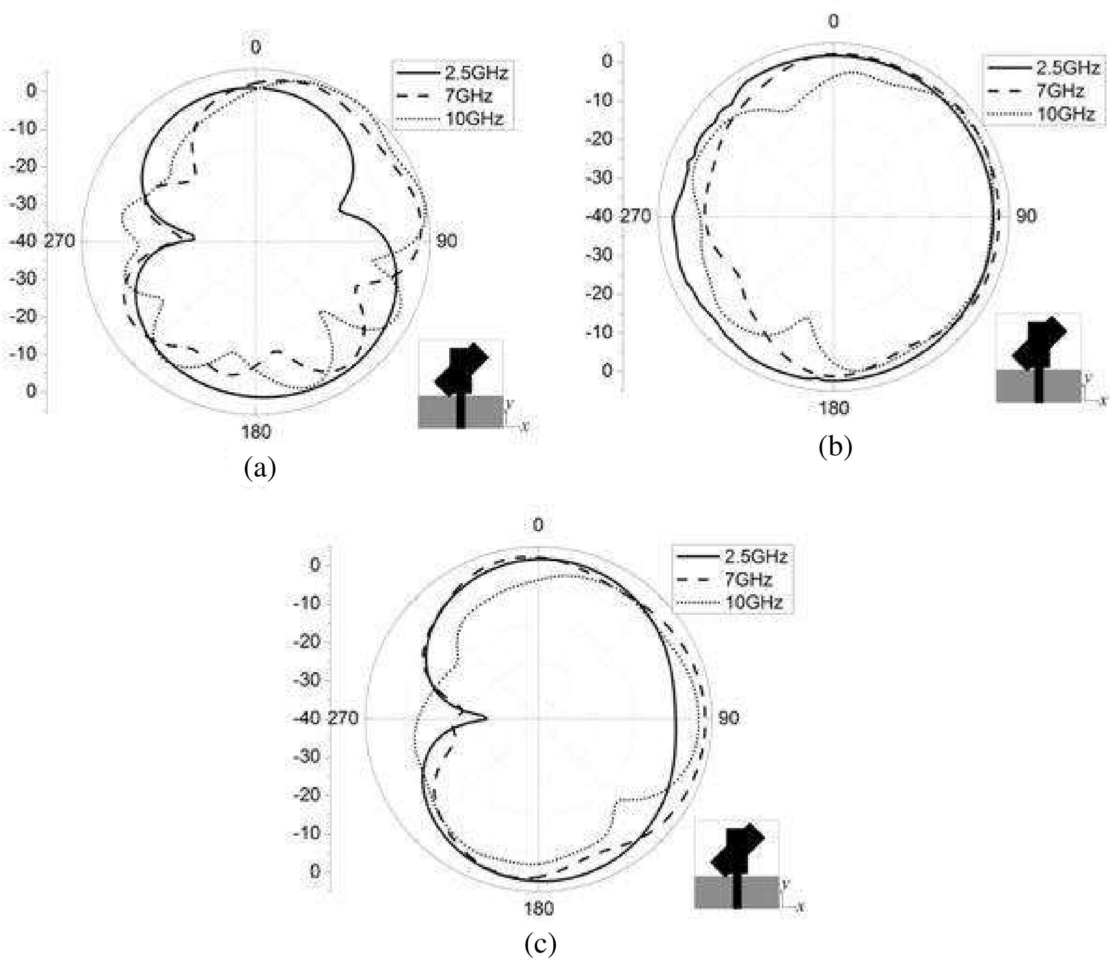

Figure 7. Radiation gain patterns of the proposed antenna in (a) *xoy*-plane, (b) *xoz*-plane, (c) *yoz*-plane at 2.5 GHz, 7 GHz and 10 GHz.

main radiator. With frequency increasing, some distortions have occurred, which because of higher-order resonant modes. To further explain the radiation pattern of the proposed antenna, the current distributions of the proposed antenna at 2.5 GHz, 7 GHz and 10 GHz are shown in Fig. 8. From the Fig. 8, it can be seen that at the low frequency, the current distribution is similar with the monopole. The radiation pattern in the *xoy*-plane is dumbbell shaped. At the high frequency band, such as the 7 GHz and 10 GHz, the current distribution at the left bottom corner of the rotated path is strong, which make the radiation pattern has a rotated angle to the top right of the antenna. This can be proved by Fig. 7(a).

Figure 9 shows the measured peak gain of the proposed antenna throughout the entire operation band. It can be seen that at the low frequency band (below 5 GHz), the measured peak gain increases with the frequency which can reach about 5.5 dB at 5 GHz. At the high band, the peak gain of the proposed antenna is over 4 dB cross the whole high band. Over the whole operation band, on average a 4.5 dB gain can be achieved.

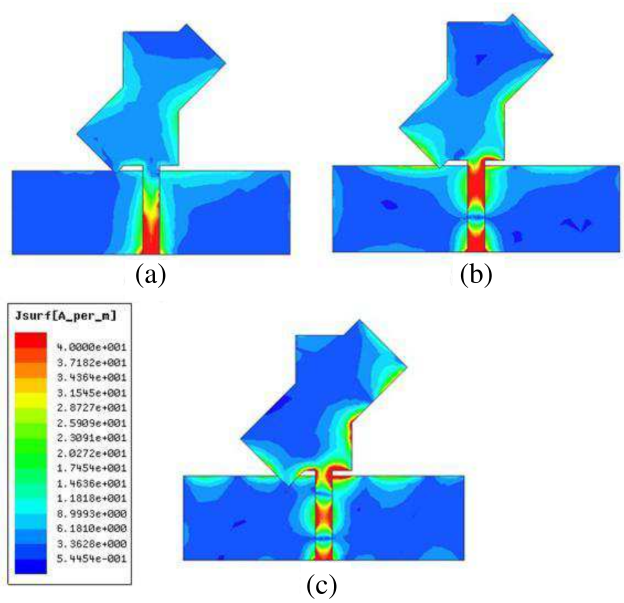

Figure 8. The current distribution of the antenna at (a) 2.5 GHz, (b) 7 GHz and (c) 10 GHz.

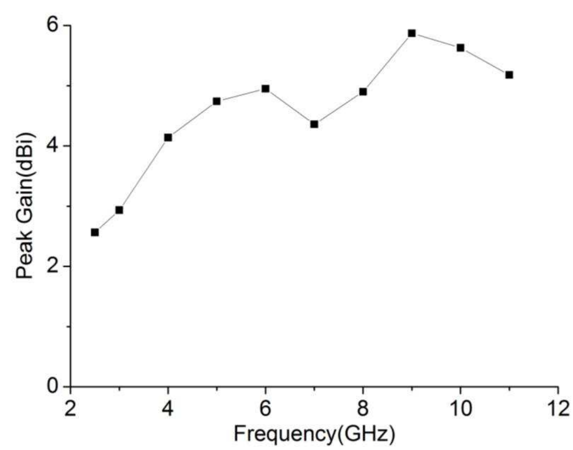

Figure 9. Measured peak gain of the proposed antenna.

4. CONCLUSION

In this paper, we present a novel planar rotated cross monopole antenna, which consists of a vertical microstrip and two rectangular patches. By rotating the horizontal patch of the regular cross monopole, the bandwidth of the antenna can be significantly enhanced. The simulated and measured results show that the proposed antenna with compact size of $50 \times 50\,\mathrm{mm}^2$ can achieve a wide impedance bandwidth (10-dB reflection coefficient) as large as 8.76 GHz (2.33–11.09 GHz) or about 130%. The antenna can cover the 2.45-GHz/5.2-GHz/5.8-GHz ISM band (WLAN, IEEE-802.11b and g)/2.5-GHz/3.5-GHz/WiMAX and UWB (3.1–10.6 GHz) bands. In addition, the effects of the critical parameters on the impedance matching of the proposed antenna are discussed in detail.

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