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Design of an UWB Antenna with Adjustable Rejection Bandwidth Using Novel Dual-T Square Resonator

Xueliang Min*, Hou Zhang, Tao Zhong, and Qiang Chen

Abstract—A novel UWB antenna with adjustable rejection bandwidth is proposed and fabricated. The proposed antenna consists of a monopole and a novel dual-T square resonator. The results demonstrate that a wide rejection bandwidth from 10.4 to 11.5 GHz can be achieved, and the rejection bandwidth can be adjusted by transforming the dimensions of dual-T square resonator. Moreover, reflection coefficient curve with two poles at one rejected bandwidth is also obtained which is induced by the proposed novel square resonator. In addition, to explain the mechanism of adjustable rejection bandwidth, the analysis of parametric study and electric field distributions of the design are given. The total volume of the antenna is $27\,\mathrm{mm} \times 19\,\mathrm{mm} \times 1\,\mathrm{mm}$. Compared to other recent works, a simpler structure, wider rejection bandwidth and more compact size are the key features of the proposed antenna. Owing to its adjustable bandwidth and simple structure, the proposed antenna can be used in UWB communications applications to suppress the radio-frequency interference.

1. INTRODUCTION

Owing to its strong point in low-power dissipation and great bandwidth, ultra-wideband (UWB) antenna has been used widely to communications applications. However, ultra-wide operating bandwidth of antenna will disturb other devices whose operating bandwidth is contained in antenna's. To suppress the interference, some methods can be used [1–5]. A U-shaped stub embedded in a rectangular slot of the radiation patch and a coupled open-/shorted-circuit stub resonator are adopted in [1]. A Q-shaped stub and an n-shaped stub in [2] are inserted to the UWB antenna for playing a role as resonator structure to obtain band-rejection characteristics. Simulated and measured results show that two obvious band-notched functions occur. Coupling a resonator beside the microstrip feedline, a UWB antenna with rejection bandwidth is proposed in [3]. From simulated results, the designed antenna shows omnidirectional radiation patterns. Tri-band-notched UWB antenna using CLL resonators [4] is reported. In [5], a method to obtain band-rejection characteristics on a UWB antenna is proposed. High notch-band-edge selectivity using embedded bandstop filter [6] is also proposed. Meander T-shaped patch and stepped impedance structure [7, 8] can also be used for band-rejection applications. Additionally, embedding slots in radiating patch or in ground plane [9–14] is a effective method to obtain band-rejection characteristic. Bandwidth enhanced antennas [15, 16] are also be researched. In [15], wider impedance bandwidth is obtained by using the tridentshaped feed line. By increasing the number of fractal iterations to three wider bandwidth is achieved [16]. However, most of the structures in these UWB antennas have been designed with one pole at one rejection bandwidth, and the band-rejection is not adjustable. Moreover, there are few reports about employing simple resonators with UWB antenna to obtain a wide adjustable rejection bandwidth in recent literatures.

In this letter, a novel UWB antenna with adjustable wide rejection bandwidth is proposed. Compared with previous work, our work has a wider rejection bandwidth and more compact size.

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* Corresponding author: Xue-Liang Min (MinXL08@163.com).
The authors are with the Missile Institute of Airforce Engineering University, Xi'an, Shaanxi Province 710051, China.

Additionally, it has two poles at one rejection bandwidth in the reflection coefficient curve, and the rejection bandwidth of the antenna can be adjusted by adjusting the dimensions of the T-stub. Compared with the UWB antenna without the introduced resonator, the proposed antenna obtains obvious wide band-rejection properties. Loading novel dual-T square resonators besides feedline has a little influence on antenna's radiation pattern, but the proposed antenna has omnidirectional radiation patterns, which indicates that it can work in all directions. Moreover, the adoption is simple and convenient, and it will not add any extra space. The total volume of design is $27\,\text{mm} \times 19\,\text{mm} \times 1\,\text{mm}$.

2. STRUCTURE OF ANTENNA

The geometries of the proposed band-rejection UWB antenna are shown in Figure 1. The antenna consists of a planar monopole antenna and two novel dual-T square resonators. The dimensions of the fundamental planar monopole antenna are $l_1 = 13.3\,\text{mm}$, $l_2 = 12\,\text{mm}$, $w = 6.2\,\text{mm}$, $w_1 = 2.6\,\text{mm}$, $r_1 = 2\,\text{mm}$, $r_2 = 3.8\,\text{mm}$. The substrate is a 1 mm thick F4B with relative permittivity of 2.65 and dissipation factor of 0.003. The metal thickness is 0.036 mm. The feedline and radiating patch are printed on the top side, and the ground plane is on the bottom side. Compared with the fundamental planar monopole antenna, the transformation is not complicated. The proposed band-rejection UWB antenna is practical and easy to fabricate. The dimensions of the structure are shown in Table 1.

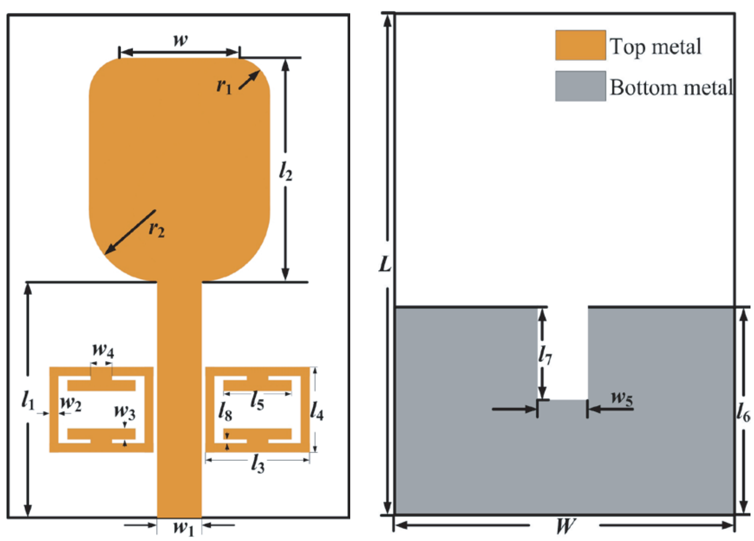


Figure 1. Structure of proposed antenna (units: mm).

Table 1. Dimensions of proposed antenna (units: mm).

Dimension	Size (mm)	Dimension	Size (mm)	Dimension	Size (mm)
l_1	13.3	l_8	0.1	r_2	3.8
l_2	12	w_1	2.6	L	27
l_3	5.8	w_2	0.5	W	19
l_4	4.6	w_3	0.6	w	6.2
l_5	3.8	w_4	1		
l_6	11.3	w_5	2.8		
l_7	5	r_1	2		

3. ANALYSIS OF ANTENNAS

Simulated reflection coefficients of fundamental UWB antenna and proposed UWB antenna are shown in the Figure 2. Comparing the effect with and without the introduced resonator, it is obvious that fundamental UWB antenna without the introduced resonator possesses an impedance bandwidth from 3.7 to 13.3 GHz for reflection coefficient less than -10 dB while the proposed antenna with the introduced resonator has an impedance bandwidth from 3.9 to 14.6 GHz except in stop band (10.4–11.5 GHz). It indicates that adding novel square resonators near the monopole antenna's transmission line induces a rejection bandwidth and extra 1.5 GHz impedance bandwidth from 13.3 to 14.8 GHz.

Variations of rejection bandwidth via the dimensions of the dual-T square resonators are investigated in Figure 3 and Figure 4. Figure 3 shows reflection coefficient variations according to the value of l_5. In this case, l_5 varies from 3.8 to 4.6 mm, while the other parameters are fixed. Simulated results display that rejection bandwidth is affected by value of l_5. When l_5 varies from 3.8 mm to 4.6 mm, the location of point B is almost fixed while the location of point A approaches lower frequency.

Figure 4 exhibits comparison of the reflection coefficients via changing the value of l_8. Simulated results indicate that rejection bandwidth becomes wider when l_8 increases from 0.1 to 0.7 mm. Similarly, it is indicated that the location of point C is effectively controlled by adjusting value of l_8 while the location of point D is almost fixed.

These results show that parameters of the novel dual-T square resonator are critical to control the proposed UWB antenna's rejection bandwidth. Being a practical band-rejection UWB antenna, it is necessary to control the rejection bandwidth. The proposed antenna meets the requirement.

Effects of changing value of l_4 is also analyzed, and simulated reflection coefficient results are shown in Figure 5. As value of l_4 increases, the total rejection bandwidth shifts toward lower frequency. In other words, adjusting value of l_4 can control the location of rejection bandwidth. It is meaningful to apply the proposed antenna in UWB systems.

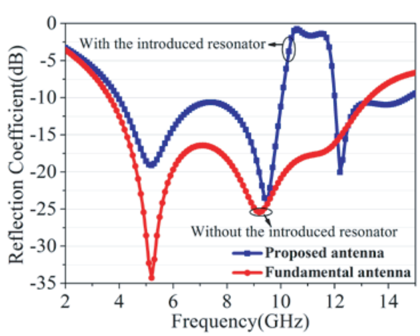


Figure 2. Simulated reflection coefficient of fundamental and proposed antennas.

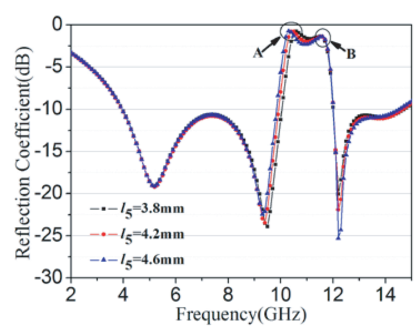


Figure 3. Reflection coefficient variations according to the value of l_5.

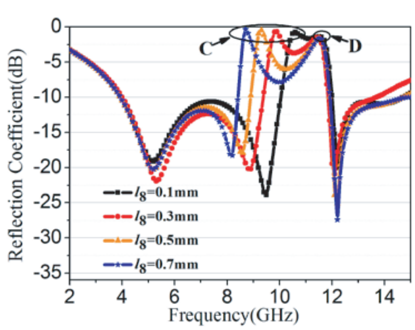


Figure 4. The reflection coefficient variations according to the value of l_8.

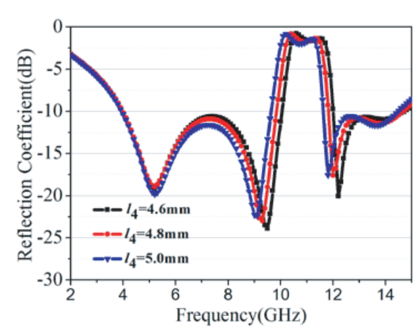
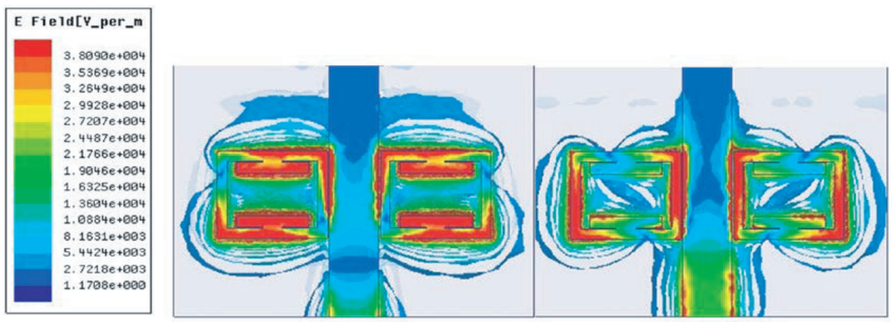


Figure 5. The reflection coefficient variations according to the value of l_4.

E-field distributions on the proposed antenna are depicted in Figure 6. It can be concluded that E field mainly distributes around the novel dual-T square resonator at 10.4 and 11.5 GHz. In detail, Figure 6(a) shows that the strong E-field distribution is observed around the dual-T stubs for the 10.4 GHz notch frequency band. Hence, it prevents the radiation at this particular frequency, and the stop band is created. Thus, we can infer that changing dimensions of dual-T stubs only affects the location of one point (C) in rejection bandwidth while the other remains fixed. So, adding the proposed novel dual-T square resonator near transmission line can affect antenna's radiation effectively, and the dimensions of the novel square resonator play a key role in controlling rejection bandwidth.

Figure 7 exhibits simulated E-plane and H-plane radiation patterns of designed antenna at 5, 9, 12 GHz. From the results, we can conclude that the proposed antenna has relatively omnidirectional radiation patterns. So, adding a novel dual-T square resonator beside the microstrip feedline has a little



(a) (b)

Figure 6. E field distributions on antenna at two frequencies: (a) 10.4 GHz and (b) 11.5 GHz.

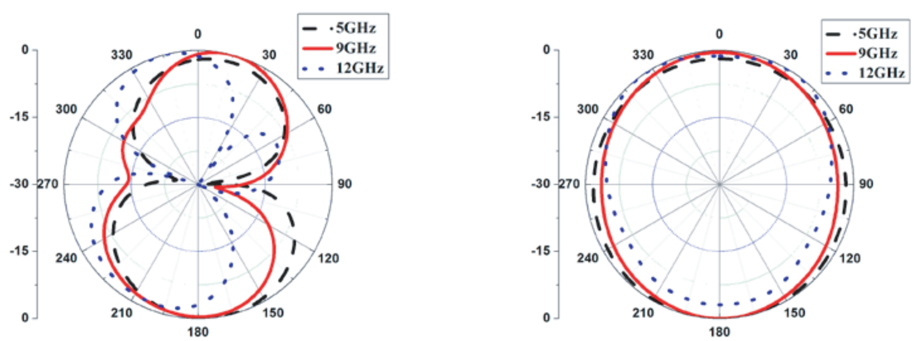


Figure 7. Simulated E-plane and H-plane radiation patterns at 5, 9, 12 GHz.

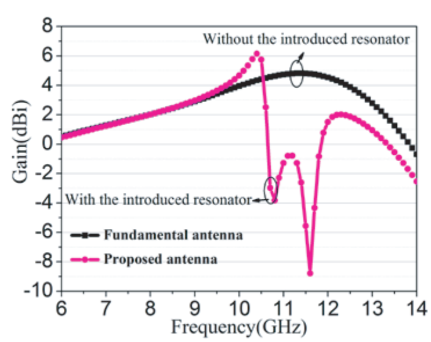


Figure 8. Simulated gain profile of fundamental and proposed antennas.

influence on radiation patterns of the antenna.

Simulated gain curves of fundamental and proposed UWB antennas are shown in Figure 8. Through the comparison, it is obvious that the gain of the proposed antenna is constant throughout the UWB except at the rejection bandwidth.

4. MEASUREMENT VERIFICATION

Figure 9 shows a photograph of the fabricated prototype. As shown in Figure 10, the measured and simulated impedance bandwidths are in agreement. The radiation patterns of the proposed antenna are measured in an anechoic chamber, and the measured E-plane and H-plane radiation patterns at 5, 9 and 12 GHz are shown in Figure 11. In H-plane, the antenna has omnidirectional radiation patterns, which indicates that it can work in all directions.

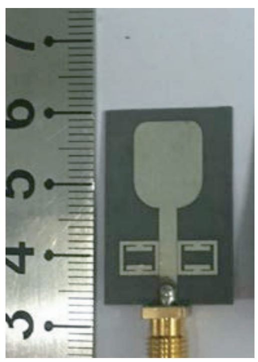


Figure 9. Photograph of proposed antenna.

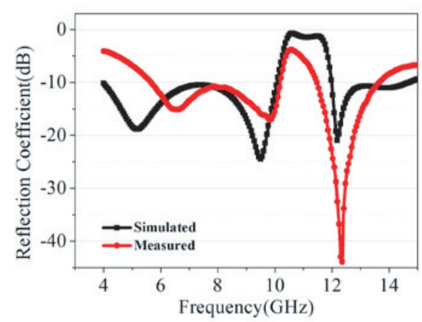


Figure 10. Measured and simulated results.

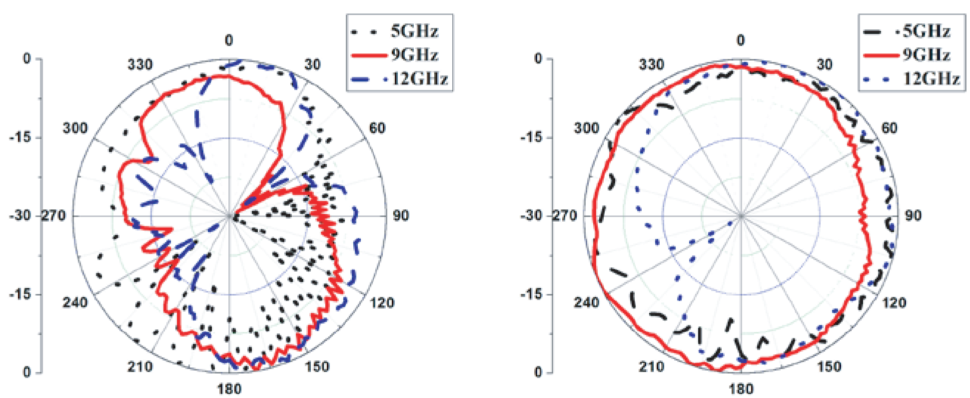


Figure 11. Measured E-plane and H-plane radiation patterns at 5, 9, 12 GHz.

5. CONCLUSION

In this paper, a novel UWB antenna with adjustable rejection bandwidth is proposed and fabricated. A wide rejection bandwidth can be achieved, and the rejection bandwidth an be adjusted by transforming the dimensions of novel dual-T stubs. At the aspect of size, dimensions of the antenna are 27 mm × 19 mm. Compared with recently published antennas, the proposed antenna is simpler. In [2], the size of antenna is 40 mm × 30 mm, In [3], dimensions of the structure are 40 mm × 20 mm, In [4], the antenna system is on a 27 mm × 34 mm sheet of substrate. Obviously, the proposed antenna is smaller and simpler. Simulated and measured results show that the proposed antenna has omnidirectional radiation characteristics.

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