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Dual Trident UWB Planar Antenna with Band Notch for WLAN

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Abstract—In this paper a compact microstrip fed ultra-wideband antenna with a band notch characteristic is presented. The proposed antenna consists of two tridents and two split ring resonators. The overall size of the antenna is 26 mm × 24 mm × 1.53 mm. By adding the uneven split ring resonators to the dual trident ultra-wideband antenna, a band notch of 5.05 GHz to 5.9 GHz is achieved. The band notch is adjusted by the size and the split locations of the resonators. CST microwave studios software was used to simulate the design. The measured $|S_{11}|$ (dB) pass band and notch band agree with the simulation within the frequency band from 3.65 GHz to 12.85 GHz.

1. INTRODUCTION

In recent era, ultra-wideband (UWB) communication system and its application to high speed data transfer and video streaming are becoming popular. The UWB band is from 3.1 GHz to 10.6 GHz and was assigned by the FCC in 2002. There are many challenges to design a UWB antenna including impedance matching over the full bandwidth, maximizing gain, and minimizing the size. Additionally, it is necessary to avoid interference with the IEEE 802.11a standard which is from 5.15 GHz to 5.9 GHz and within the UWB bandwidth. Table 1 shows a quick comparison of the size, notch band, and gain of several UWB antennas.

The first UWB antenna with notched characteristics in Table 1 used the extended strip and loaded strip methods to achieve a size of $28.5 \times 28.5 \times 0.635\,\mathrm{mm}^3$ and 5–6 GHz notch band [1]. In [2], by using a fork-shaped radiating element an overall size of $36 \times 24 \times 1.524\,\mathrm{mm}^3$ and a notch band from 4.96 GHz to 5.96 GHz was achieved. An octagonal shaped planar antenna is presented in [3] and has a size of $30 \times 30 \times 1.6\,\mathrm{mm}^3$. This antenna utilizes PIN diodes to achieve the band notch. A planar antenna for 5–6 GHz notch band was proposed in [4] which has a size of $32 \times 30 \times 1.6\,\mathrm{mm}^3$. A novel fork shaped planar monopole antenna was designed in [5] with the size $35 \times 30 \times 0.769\,\mathrm{mm}^3$. The band notch was achieved using the open loop resonator connected to a radiating element. A compact antenna with sharp band notch characteristics was reported in [6] and it has size $30 \times 36 \times 0.8\,\mathrm{mm}^3$. The band notch is achieved by using the slits in the radiating element and the resonators along the microstrip feed line. A monopole antenna was proposed in [7] with physical size $40 \times 30 \times 0.8\,\mathrm{mm}^3$. Two symmetrical microstrip resonators are used to achieve the band-notch. A compact microstrip fed single and triple band-notch antennas are presented in [8] with dimensions of $35 \times 35 \times 1.6\,\mathrm{mm}^3$. The elliptical split ring resonators are used to achieve the band-notches. A padding patch antenna was designed in [9] with the size $44 \times 38 \times 1.57\,\mathrm{mm}^3$. This antenna utilizes the padded patch to achieve the band-notch. The padding patch is placed over the radiating element of UWB antenna, which makes it unstable. The padding patch will add another 1.57 mm height to the antenna. A miniaturized monopole-slot antenna with substrate integrated waveguide was presented in [10] with an actual size $47 \times 40 \times 1.01\,\mathrm{mm}^3$. Multiple band rejections are observed in this antenna design. Other UWB antenna designs with notch bands are proposed over the course of years indicated in [11–17]. The antenna proposed in the paper achieves notch band for IEEE 802.11a and has the minimum area than the antennas listed.

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Table 1. Comparison with published UWB antennas with notch-band.

Published Antennas	Size (mm^3)	Notch band (GHz)	Maximum Gain (dBi)	Area (mm^2)
[1]	28.5 × 28.5 × 0.635	5–6	4.5	812.5
[2]	36 × 24 × 1.524	4.96–5.96	5.5	864
[3]	30 × 30 × 1.6	4.95–6.1	9	900
[4]	32 × 30 × 1.6	5–6	6.5	960
[5]	35 × 30 × 0.769	5.24–5.52	5	1050
[6]	30×36×0.8	5.15–5.35	4.8	1080
[7]	40 × 30 × 0.8	5.2–5.8	5.5	1200
[8]	35 × 35 × 1.6	5.15–5.85	6.5	1225
[9]	44 × 38 × 1.57	5.35–5.8	-	1672
[10]	47 × 40 × 1.01	5–5.67 5.7–6.1	4.5	1880
[11]	50 × 40 × 1.6	5.15–5.87	5.5	2000
[12]	50 × 40 × 26	5–6	4.5	2000
[13]	45 × 50 × 1.27	4.9–5.85	7	2250
[14]	48 × 48 × 0.8	5.1–6	6	2304
[15]	50 × 50	5.16–5.82	5.2	2500
[16]	50 × 50 × 0.8	4.6–6.2	5.5	2500
[17]	90 × 90	5.1–6	9.5	8100
Proposed Antenna	26 × 24 × 1.53	5.05–5.9	6.85	624

Table 2. Final dimensions of antenna.

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
R_1	8.75	R_7	0.5	G_6	0.45
R_2	5	R_8	0.5	G_7	4.7
R_3	2	R_9	0.25	F_1	0.5
R_4	1	R_{10}	0.5	F_2	1
R_5	4.5	G_4	10	L_f	6.5
R_6	0.6	G_5	2	W_f	4.6
L_2	3	T	1	L_g	5
G_1=G_2	2	L_1	12	L_{sub}	24
G_3	4	W_1	18	W_{sub}	26

2. ANTENNA DESIGN

The dual trident planar UWB antenna design is presented in [18]. Two uneven split ring resonators are placed symmetrically along to the microstrip feed line and are used to achieve the single band notch. The microstrip feed line has a characteristic impedance of 50 ohms. The substrate is made of Rogers's material RT duroid 5880LZ with dielectric constant of 1.96 and loss tangent 0.0019. It has a thickness of 1.53 mm including copper. The antenna structure is symmetrical along the feed line. The two tridents are connected by 1 mm arms which T-off from the feed line. The initial simulated antenna design uses

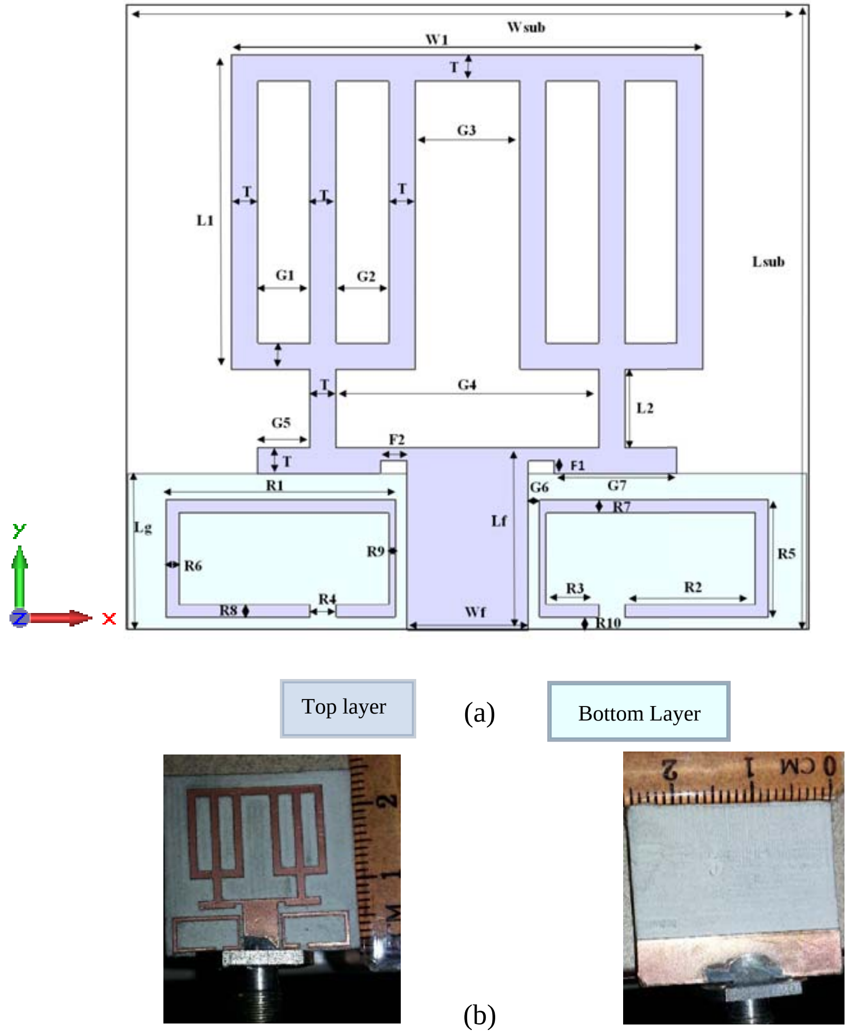

Figure 1. Proposed antenna design. (a) Antenna geometry. (b) Fabricated antenna.

split ring resonator arms with width of 1 mm. CST microwave studio® was used to optimize the design. The final antenna design and fabricated antenna is shown in Figure 1. The proposed antenna has a size of W_{sub} which is equal to 26 mm and L_{sub} which is equal to 24 mm. The optimized antenna dimensional details are presented in Table 2. The LPKF S-62 milling machine was used to fabricate the antenna.

3. PARAMETRIC ANALYSIS OF ANTENNA

The effect of the various parameters on impedance bandwidth and band notch performance is presented in this section. The initial split ring resonator is designed with a width of 1 mm and gives a notch band from 5.49 GHz to 6.35 GHz The width of the split ring resonator arm (R_9) has been optimized to 0.25 mm. The optimized design with dimensions given in Table 2 achieves a notch band from 5.08 GHz to 5.9 GHz. The results are compared in Figure 2. The effect of length of the split ring resonator (R_5) on $|S_{11}|$ and band notch is shown in Figure 3.

The initial width of ring resonator is calculated as $\lambda_g/4$ at 5.5 GHz, which is R_1 and is equal to 9.74 mm. The width of the split ring resonator (R_1) effects on the band notch is shown in Figure 4. The optimal R_1 value is 8.75 mm The length of dual trident element (L_1) is optimized to 12 mm. The effect of L_1 on impedance bandwidth and notch for WLAN band is shown in Figure 5.

The simulated and measured results of impedance bandwidth of the proposed antenna are in good

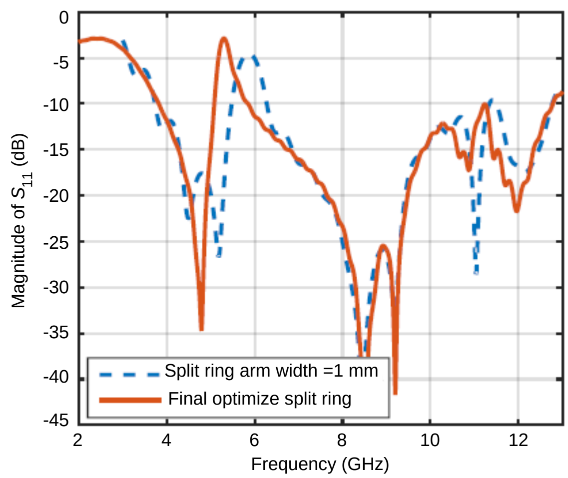

Figure 2. Simulated $|S_{11}|$ vs. frequency of initial and final split ring.

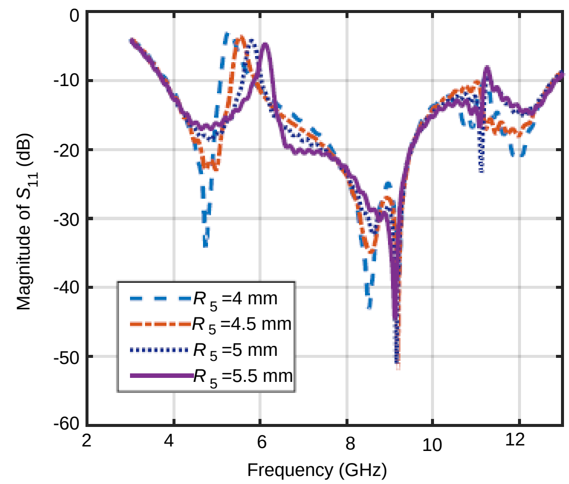

Figure 3. Simulated $|S_{11}|$ vs. frequency of R_5.

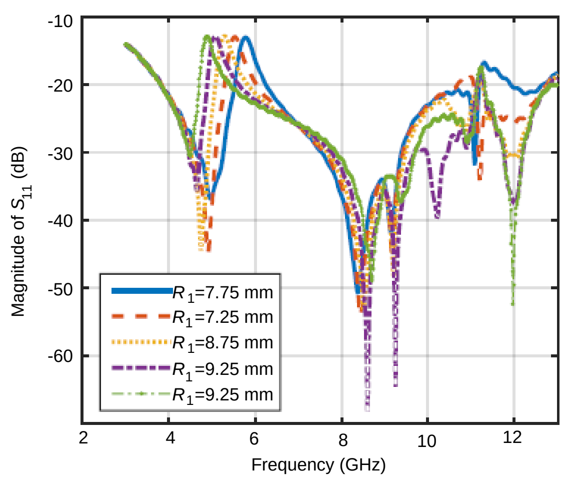

Figure 4. Effect of R_1 on notch band.

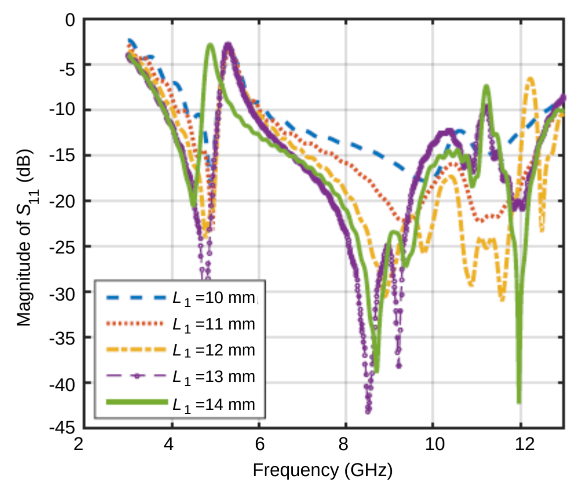

Figure 5. Length of trident arm (L_1) effect on notch band.

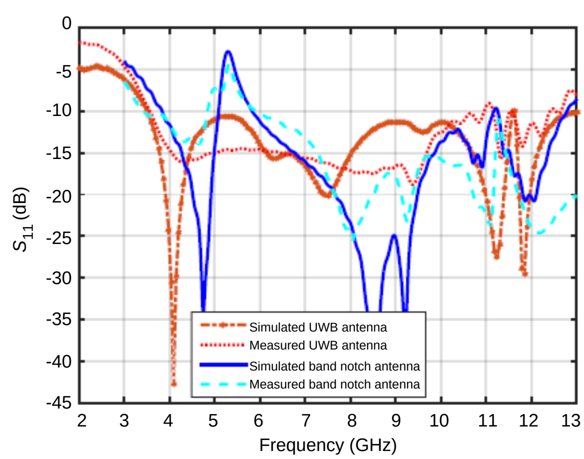

Figure 6. Comparison of simulated and measured impedance bandwidth with and without split ring resonators.

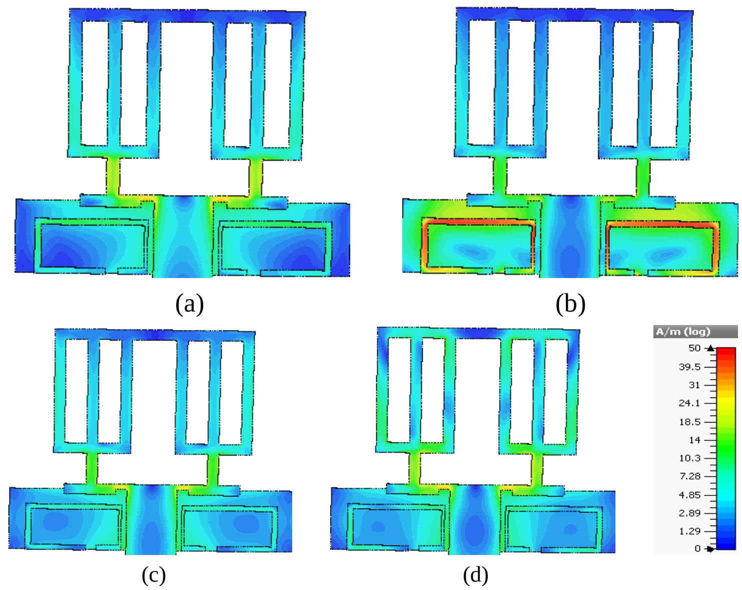

Figure 7. Current distributions, (a) 4.4 GHz, (b) 5.5 GHz, (c) 7.5 GHz, and (d) 9.5 GHz.

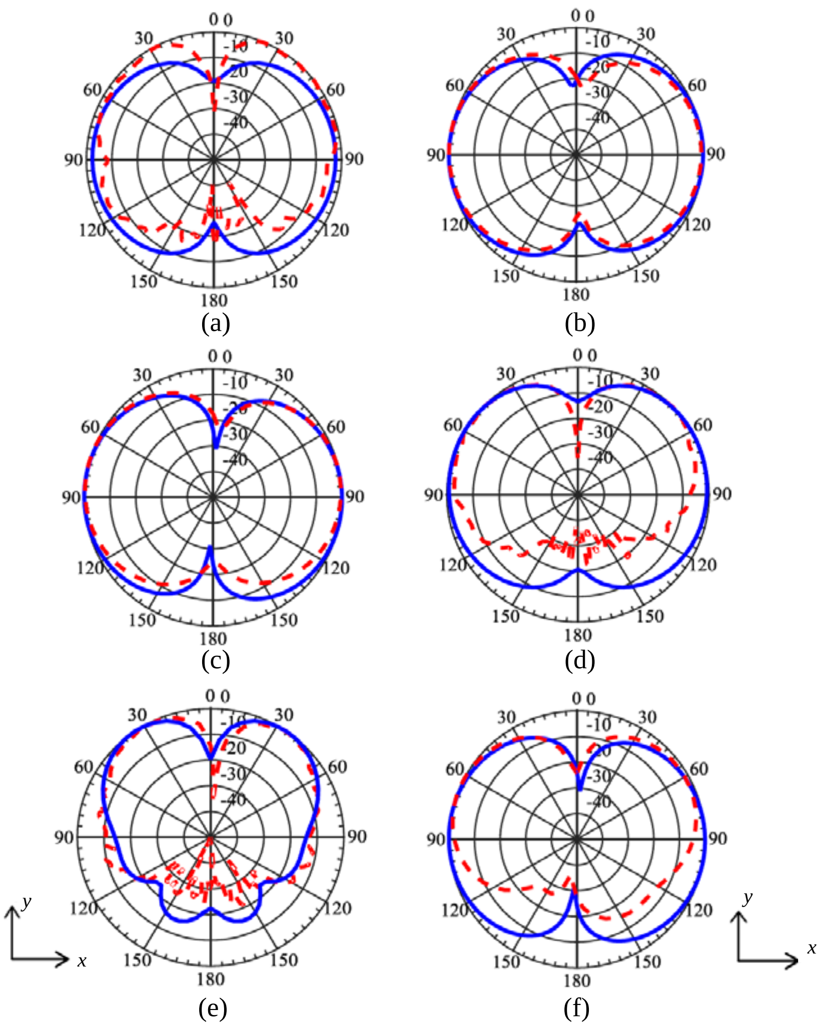

Figure 8. Simulated (Solid line — blue) and measured (Dashed line — red) radiation patterns (a), (c), (e) XY and (b), (d), (f) YZ planes, (a), (b) 5 GHz, (c), (d) 7 GHz, (e), (f) 10 GHz.

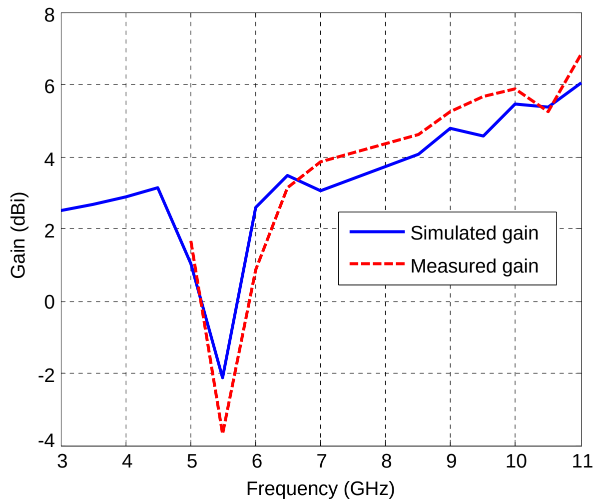

Figure 9. Simulated gain (solid blue line) and measured gain (dashed red line).

agreement with each other. The antenna is operating over a wide frequency range from 3.65 GHz to 12.85 GHz with notch band from 5.05 GHz to 5.95 GHz. The simulated and measured impedance bandwidths are shown in the Figure 6.

Figure 7 shows the simulated current distribution at different frequencies. It is observed from Figure 7(b) that at 5.5 GHz most of the current is distributed in the split ring. This affects the impedance matching at frequency from 5.05 GHz to 5.95 GHz. As shown in Figures 7(a), (c) and (d), due to less current distribution on the split ring resonator at other frequencies, there are no effects on the impedance matching at other frequencies.

The simulated and measured radiation patterns of the antenna at 5 GHz, 7 GHz, and 10 GHz are shown in Figure 8. It can be seen from the XY and YZ plane radiation patterns that the antenna is exhibiting a radiation pattern similar to that of a monopole antenna. The measured gain and simulated gain throughout the frequency of operation are presented in Figure 9. From the simulated results it is observed that the antenna gain varies from 1.05 dBi to 6.03 dBi. The measured gain of antenna varies from 1.87 dBi to 6.85 dBi. In the notch band, simulated gain at 5.5 GHz is -2.11 dBi and measured gain is -3.77 dBi. The antenna gain is measured from 5 GHz onwards due to the hardware limitation in the antenna lab. The NSI near field spherical anechoic chamber is used to measure the antenna gain and radiation patterns.

4. CONCLUSIONS

A novel dual trident UWB antenna with WLAN band notch has been presented in this paper. It is designed with two tridents to operate in UWB frequency band, with two uneven split ring resonators to achieve the notch band and with a partial ground plane on the back side of substrate. Most of the UWB antennas failed to achieve the notch band from 5.15 GHz to 5.9 GHz, but the proposed antenna achieved the band notch from 5.05 GHz to 5.9 GHz with uneven split ring resonators. The antenna has minimum size of 26 mm $\times$ 24 mm $\times$ 1.53 mm. It has an impedance bandwidth from 3.65 GHz to 12.85 GHz and notch band for WLAN. The antenna design exhibits a radiation pattern similar to that of a monopole antenna and has a maximum gain of 6.85 dBi at 11 GHz. It is shown that the simulated and measured results are in good agreement.

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