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Design of Compact UWB Antenna with Single, Dual and Triple Band-Notched Characteristics Utilizing Split Ring Resonator

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ABSTRACT

A novel compact antenna for Ultra-Wideband (UWB) applications; design is being presented in this paper. The proposed design is fed using 50 ohm coplanar waveguide (CPW). A spacious impedance bandwidth is enacted covering the band from 3.1 GHz to more than 20 GHz with reflection coefficient superior to -10dB. Triple frequency notches are realized in order to assure coexistence with the narrow band applications allocating some of these frequency bands of WiMAX, WLAN and X-band satellite communication. Split ring resonator (SRR) is engraved in coplanar ground for both frequency bands rejection of IEEE 802.16 WiMAX (3.3-3.8 GHz) and IEEE 802.11 WLAN (5.15-5.825 GHz). Folded slot is etched in feed line for frequency band rejection of (7.25–8.395) GHz for X-band satellite communication. The suggested antenna has a total size of 24 × 18.5 × 1.5 mm^3. Omnidirectional radiation pattern with stable radiation characteristics is realized. Advantageous reconciliation is enacted between simulated and measurement consequence. To scrutinize the depiction of the prospective antenna in terms of attaining wideband operations, the commercially available simulation software CST STUDIO SUITE ver.2014 is adopted for numerical analysis.

Keywords:
UWB antenna, resonator, numerical analysis

1. Introduction

The declaration of unlicensed frequency band of 3.1 GHz to 10.6 GHz by Federal Communication Commission (FCC) had catered the vast claim for high speed and high data rate wireless communication over the short range mainly with low power [1]. Recently, a various shapes of monopole microstrip antennas have been announced [2-3]. The vital confront within these inquiries is the prominent tradeoff either valuable performance or size scaling. Compact antenna with broadband impedance matching, adequate gain and stable radiation pattern performs vital aspect to augment the miniaturization of overall size of communication devices. Among sundry miniaturization approaches are Quasi self-complementary, fractal shapes [4]. Some of UWB applications require the rejection of non-desired frequency bands by virtue of discrete band-stop filters as to overcome the dispute of electromagnetic interference (EMI). Recently many dual and a

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few multi band notched antennas having slot on feed line [5], radiating patch [6] are reported. Antennas with quarter wave length [7] and half wavelength [5] resonating structures are proposed in which the length of slot increases as frequency decreases [8]. Moreover, frequency band rejection can be achieved by etching SRR in ground [9].

In this paper a novel UWB compact antenna is proposed in which triple frequency bands rejection are realized. Double frequency bands rejection of WiMAX, WLAN is achieved by etching SRR in the coplanar ground, a third frequency band rejection of X-band satellite communication is achieved by engraving folded slot in the feed line. SRR can be thought out as a minuscule resonator with very high quality factor, it can be used to erect a filter with a band notch at certain frequency. SRR could be also used as slot type edifice to repudiate undesired frequency [10-12].

The proposed antenna covers the UWB from 3.1 GHz to more than 20 GHz. Furthermore, approximately Omni-directional radiation pattern through the overall band and observable good gain are achieved. Finally, both the measurement and simulation results are demonstrated. Good agreement is achieved between simulated and measurement results as a proof of concept.

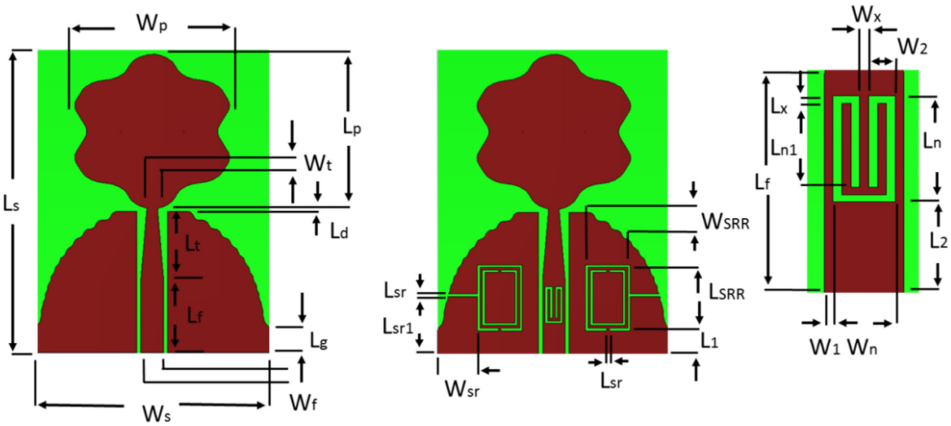
2. Design Geometry

Figure 1 demonstrates the architecture of the proposed monopole antenna. The antenna is printed on FR4 substrate with thickness h=1.5mm of relative permittivity of 4.5. The antenna is fed by 50 ohm CPW with center line of width W_f which is lineally tapered to width W_t in order to improve the matching impedance overall the operating bandwidth. The antenna shape is constructed by circularly merging seven hexagons with side length of L_h of which the exterior perimeter edges are blended with the value of B_{r1}. The ground plane is stair stepped with L_{st} and W_{st} which its exterior edges are consequently blended with B_{r2}.Blending the exterior perimeter edges with optimized values led to enhancing the impedance BW. Design of the triple band notches is achieved by two alternative geometrics. The first and second notches at fn1= 3.5 GHz and fn2= 5.5 GHz are realized by inserting open SRR in to the ground plane [11]. The two frequency notches are controlled by adjusting the value of geometrical parameters. The second notch at fn3= 8.1 GHz is realized by etching folded U-shaped slot in the feed line. The notched frequency is controlled by adjusting the value of geometrical parameters. To adjust the center frequencies of the notches and their bandwidths to achieve an efficient dual band-notched UWB antenna was the challenge at this point. The total lengths of the etched slots control the position of the rejected bands. The relationship between the notch frequency and U-shaped dimensions is accomplished by Equation (1)

$$\boldsymbol{F_{n3}} = \frac{c}{2\sqrt{\varepsilon_{eff}}(2Ln+2Ln1+2W2+Wn)} \quad (1)$$

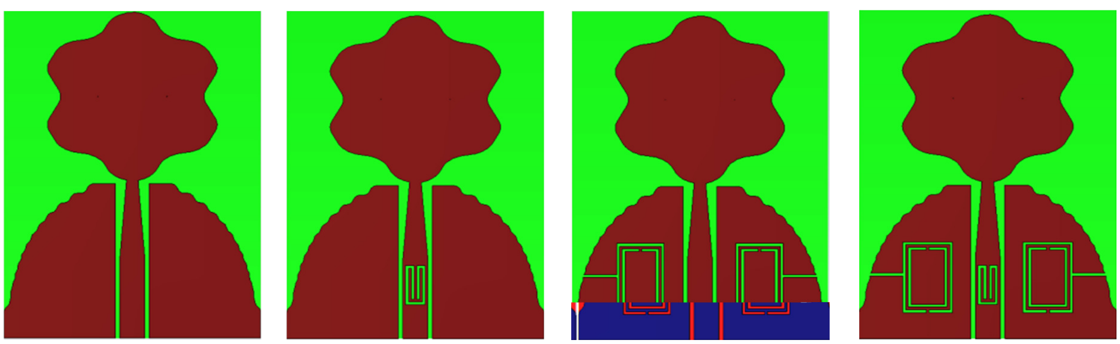
$$\boldsymbol{\varepsilon_{eff}} = \frac{\varepsilon r+1}{2} \quad (2)$$

The proposed monopole antenna features both physically and electrically small dimensions; 24×18.5×1.5mm^3; which provides a fairly small size when compared with widely used UWB monopole antennas. The optimized dimension values of the proposed design are listed given in Table 1.



a) Preliminary shape b) Final triple notched c) Folded U Slot

Fig. 1. Geometrical description of the proposed antenna



a) Without notches. b) Single notch c) Double notches d) Triple notches

Fig. 2. Geometrical description of design procedures

Table 1
Geometrical Parameters of the Proposed Antenna (mm)

Ls	Ws	Wf	Wt	Br1	Br2	Wp	Lp	Ld	Lg	Wsr	Lsr	Lsr1	L1	Lh	Lst
24.2	18.5	1.8	0.8	1.4	0.5	12.287	12.346	0.2	1.88	3.428	0.2	6.18	1.924	4	0.5
Wst	Lf	Lt	WSRR	LSRR	Wn	Ln	W1	Ln1	Wx	W2	Lx	L2	Wst		
5.2	5.9	5.9	3.6	5.2	1.4	2.9	0.2	2.7	0.2	0.6	0.2	2.5	5.2		

3. Results and Discussions

Figure 2 shows steps followed to reach the final proposed design; without notches, with single notch, with double notch, and with triple notch. The simulated VSWRs for four different cases are shown in Fig. 3. As shown in the surface current distribution plot in Fig. 4, the maximum concentration of the current is observed around the SRR and the folded U-shaped ensuring effective band stop at frequency rejected bands. For further clarification to the notches effect on the antenna performance Simulated design Gains are shown in Fig. 5. Note that high drop appeared at the notch frequency .The proposed antenna, using the optimized parameters is fabricated using photolithographic technique as shown in Fig.6. Both simulated and measured VSWRs are displayed in Fig.7. It should be noted that there are inconsistencies between the simulated and measured VSWRs. This may be accredited due to diverse influences, the most important of which is the fabrication tolerance, as the antenna is very small and may need higher precession fabrication facilities than those currently available.

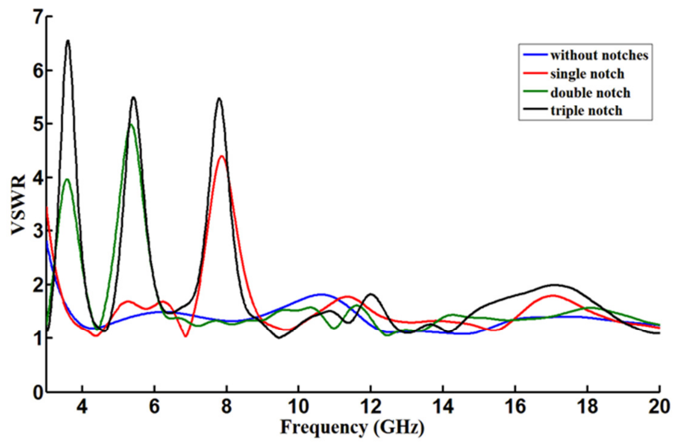


Fig. 3. Simulated VSWRs versus frequency for single, double, triple notched characteristics

Fig. 4. Current distributions of the proposed antenna with triple band-notched characteristics

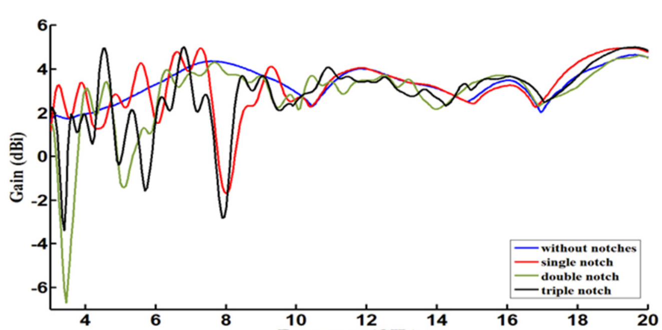


Fig. 5. Simulated Gains VSWRs versus frequency for single, double, triple notch

a) Preliminary shape. b) Final triple notched.

Fig. 6. Fabricated proposed triple notched antenna

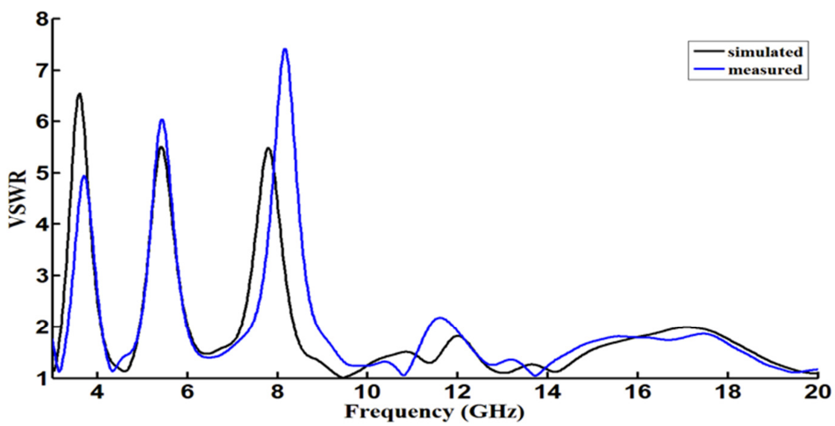


Fig. 7. Simulated and measured VSWRs versus frequency

Another vital factor is the soldering effect of the SMA connector which has not been accounted for during the simulation process. Radiation patterns of the proposed antenna which are nearly omnidirectional are shown in Fig.8, for three different frequencies, 4.5 GHz, 6.5 GHz, and 9.5 GHz, respectively.

4. Conclusion

A novel miniaturized coplanar waveguide-fed (CPW) printed monopole UWB antenna with triple band-notched characteristics based on split ring resonator (SRR) and folded U-shaped slot was presented. The design accomplishes BW from 3.1 to more than 20 GHz. The structure achieves nearly omnidirectional radiation pattern all over the operating bandwidth. Moreover, the proposed antenna has a simple elementary shape .The proposed design is substantiated by experimental measurements.

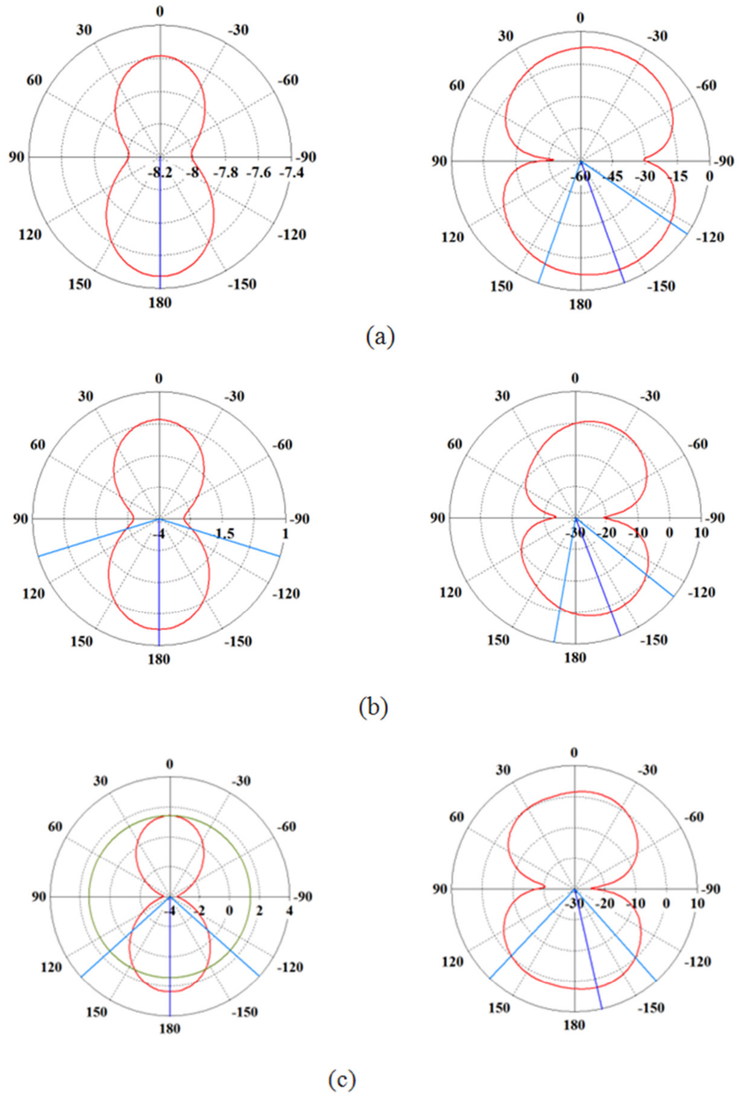


Fig. 8. Simulated and measured Radiation patterns at three different frequencies, (a) 4.5 (b) 6.5 and (c) 9.5 GHz, for the triple notched proposed antenna

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