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UWB TAPERED-SLOT PATCH ANTENNA WITH RECONFIGURABLE DUAL BAND–NOTCHES CHARACTERISTICS

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Abstract

An ultra-wideband patch antenna (UWB) that makes use of tapered slot technology is designed and analyzed in this article. Coplanar waveguide feeds the projected antenna. The presented antenna displayed superior UWB performances with -10 dB return-loss bandwidth, ranging from1.9 to 12 GHz. The projected slot antenna has another benefit of minimizing the interference effect of the narrow band communications conducted by two notch bands operating at 3.3–3.8 GHz (WiMAX) and 5.1-6 GHz (WLAN and HIPERLAN/2), respectively. The Dual-Bands rejection is generated by etching out a complementary split ring resonator (CSRR) from the patch and placing a trapezoidal split ring resonator (TSRR). Adaptable single or dual band rejection characteristic has been added to the behavior of the UWB antenna, by mounting electronic switching across SRR and CSRR. Furthermore, the presented UWB slot antenna is printed on FR4-epoxy substrate (ε_r = 4.4) and it has overall size of 55×48×1.5 mm^3.

Keywords : Bi-directional Antenna, UWB, Split Ring Resonator, Dual Band-Notch Antenna, Reconfigurable Antenna.

I. Introduction

The 7.5 GHz (3.1-10.6) GHz Ultra-wideband (UWB) band was made available by the Federal Communication Commission (FCC) in 2002. The UWB antennas have attractive properties in communication standard for industrial and commercial due to its low cost and high data rate for short distance, as well as low power spectral density[I, VII, VIII]. Ultra-wideband is simply interfered with narrow-band applications such as WiMAX (3.3–3.8) GHz and HIPERLAN/2 and IEEE 802.11a (5.15 GHz–5.825 GHz) [XVI]. Thus, to avoid these unwanted potential interferences for these narrow band signals, several methods were presented to produce band stop filter, but at expense the performance of system including filter or UWB antennas with notches[V, XVII, XIX, XX, XXVI, XIII, XXI, XXII, XXIII, XXIV].

There are several attractive techniques to design UWB antenna with multiband rejection characteristic, such as creating of resonators or slots of various shapes such as E-shaped, U–shape, annular, L–shape, H-shaped, C-shaped slots, by etching slots on either in radiating elements or in ground planes. Other methods utilized split ring resonators (SRR) and defected ground structures (DGS) to create band notches. The drawback of these techniques is that electromagnetic waves may leak, resulting in deterioration radiation patterns [XIX, XX, XXVI, XIII, XXV, XXVII].

To overcome these disadvantages, attractive method for designing UWB antenna based on reconfigurability technique is presented. A reconfigurable frequency rejection in planarUWB microstrip antennas is very attractive in many wireless communication technologies. Consequently, countless researchers have motivated on this topic. The concept of the traditional band-stop reconfiguration can be achieved with aid of removing or adding an electronic switching circuit for slot or resonating structure [XXV].

Switches are introduced by varactor [XVIII] or p-i-n diodes [XVIII, X, XII], MEMS [II], or photoconductive [XI] switches. Moreover, reconfigurable notches can be accomplished by controlling the slot of the defected ground plane [XIV], or adjusting the parasitic elements size of [XV]. However, most of these configurations have complex structures, which is difficult to fabricate and adjust.

In this work, UWB tapered slot microstrip antenna with dual switchable band-rejections is projected and investigated. The switchable two band rejections is presented to reduce the interference for WiMAX radiation in the range (3.3–3.8) GHz and IEEE 802.11a, application in the range (5.1-6.1) GHz. Stop band filter is represented by etching split single circular ring in the radiator patch for HIPERLAN/2 and IEEE 802.11a. Whereas printing a quasi-trapezoidal configuration parasitic single split ring resonator (SSRR) is used to reject (3.3–3.8) GHz band. Electronic switches mounted along the parasitic SRR and CSRRs to achieve reconfigurable band notches.

The work is structured as follows: Section 2 describes the projected UWB antenna geometry of dual band-notchedcharacteristics. The reconfigurable dual band- notch antenna characteristics are presented in Section 3; Finally, The conclusions are introduced in section 4.

II. UWB Antenna Design

Figure (1) displays the structure of projected reconfigurable tapered slot UWB with two band-stops. The UWB antenna is included of two symmetrical radiator tapered slot and fed from 50 Ω coplanar waveguide ground plane. The projected UWB microstrip radiator is fabricated on FR-4 epoxy substrate of (ε_r= 4.4), loss tangent 0.02 and thickness of 1.5mm is used in this design. The substrate dimensions are 55mm×48mm. The equations of outer and inner radiation flare edges are given by [XXVIII]:

$$y = k_1 e^{O_r} + k_2 \tag{1}$$

$$k_1 = \frac{y_2 - y_1}{e^{x_2 O_r} - e^{x_1 O_r}} \tag{2}$$

$$K_2 = \frac{y_1 e^{x_2 O_r} - y_2 e^{x_1 O_r}}{e^{x_2 O_r} - e^{x_1 O_r}} \tag{3}$$

Where: y_1 and y_2 represent the initial and end of the inner tapered slot, while O_r represent the opening rate. The resonant frequency of notching is [XII]:

$$f_o = \frac{c}{2L_{slot}\sqrt{\varepsilon_{eff}}} \tag{4}$$

By properly adjusting the parameters dimensions for the projected UWB antenna structure, an UWB impedance matching from 1.9 to 12 GHz can be accomplished. The simulation analysis of the projected structure is performed utilizing the High Frequency Structure Simulator Ansoft HFSS [III, VI]. The projected tapered slot radiator structure includes two band-rejection resonators. The first notch-band is obtained by using a quasi-trapezoidal shape parasitic single split ring resonator (SSRR), which resonate at 3.8 GHz (for WiMAX band). The second band notch has been achieved by adding a complimentary single split ring resonator (CSSRR), which resonate at 5.5 GHz for HIPERLAN/2 and IEEE 802.11a (5.15 GHz–5.825 GHz). The optimized design parameters of the projected antenna are presented in Table 1.

Table 1: Optimized design parameters of the projected antenna

Parameters	**L**	**W**	**W_L**	**L_S**	**W_f**
Value (mm)	48	55	24	40.92	2.4
Parameters	**a**	**b**	**c**	**d**	**h**
Value (mm)	7.1	3.6	2.59	2.31	1.5
Parameters	**s**	**t**	**e**	**f**	**g**
Value (mm)	0.29	0.018	2.4	4	0.4

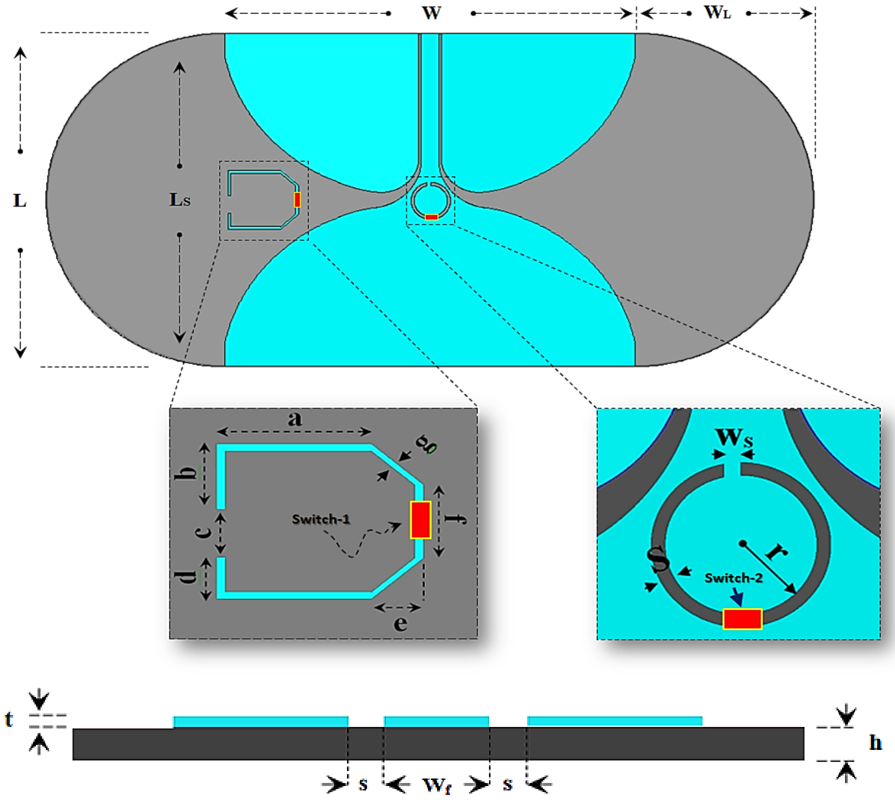


Fig. 1. 2D structure of the projected slot UWB antenna

III. Results and discussion

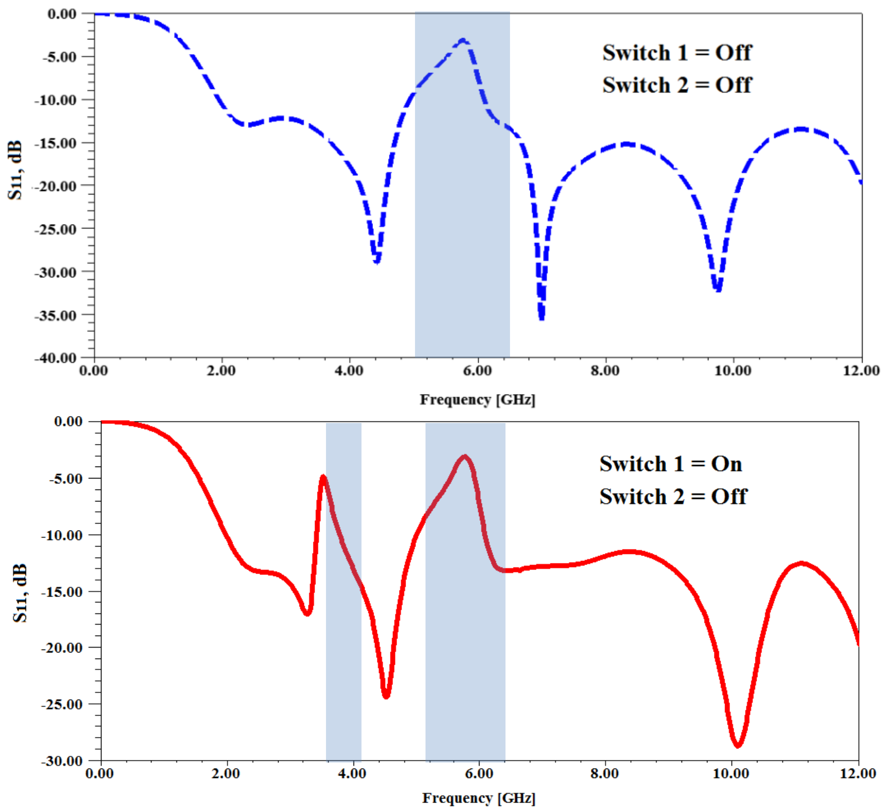
In order to study the performance of reconfigurable slot taper antenna and switching between the two bands rejection, two ideal electronic switches (PIN diodes) are mounted along the SRRs. The two PIN diodes are represented by a thin strip line with two states, ON state and OFF state. Switch–1is placed along parasitic split ring resonator (SRR) and switch-2 is placed along complementary split ring resonator (CSRR). There are possible four cases which explain the behavior of these two switches.

Table 2: Combination of different states of PIN diodes.

	PIN-D_1	PIN-D_2	Band-Notch
State-1	OFF	OFF	5.5 GHz
State-2	OFF	ON	None
State-3	ON	OFF	3.8 GHz, 5.5 GHz
State-4	ON	ON	3.8 GHz

Figure 2 displays the simulation of return loss (S_{11}). The designed antenna has an impedance bandwidth of 1.9–12 GHz for a return loss less than 10 dB, except the frequency notched bands WiMAX frequency (3.8 GHz) and at WiMAX band (5.5 GHz).

Now, in order to study the effect of two switches states on generating band-notches, several general modes are examined. When two switches are open circuit (off state), S_{11} is shown in Figure 2-a. It is noticed that band-notch is established at 5.5 GHz. When Switch-1 is in conductive state and switch-2 is off, the band reject is generated by quasi trapezoidal ring at the WiMAX frequency (3.8 GHz) and at WiMAX band (5.5 GHz) as displayed in Figure 2-b. On the other hand, when switch-2 is in conductive case and switch one is off state. In this case, there are no band-notch behaviors at two bands. The last case is related to conductive state for two ideal diodes. The band-notch is produced at the WiMAX frequency (3.8 GHz).



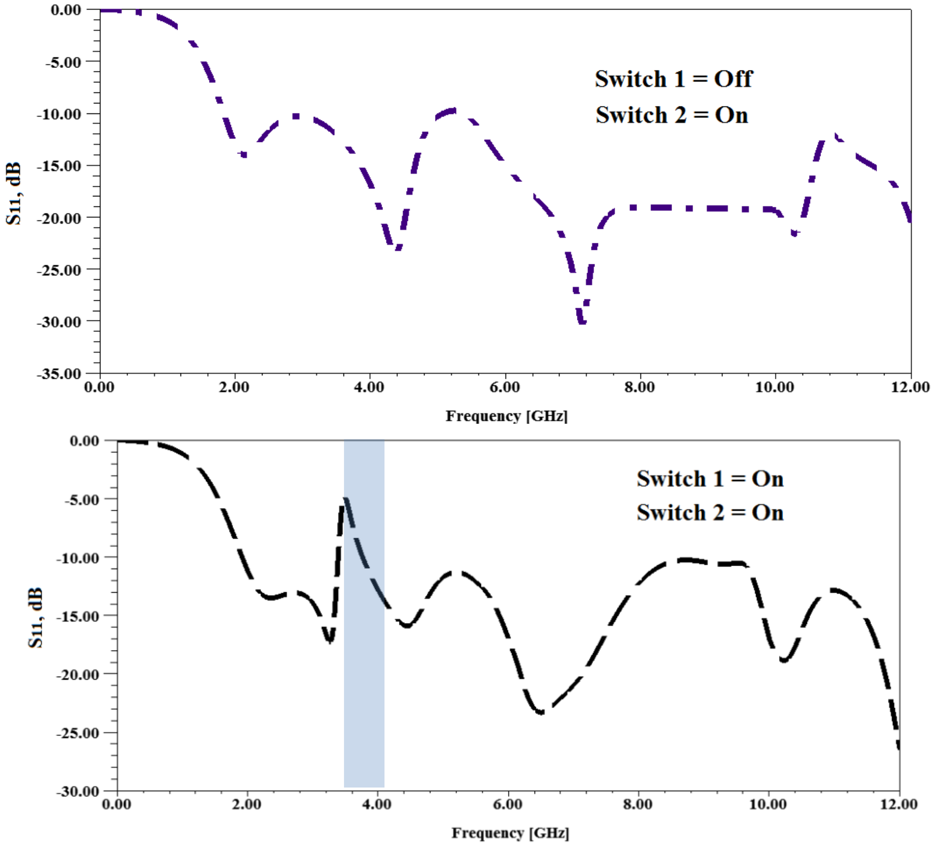


Fig. 2. Simulated and measured S_{11} of the UWB antennas for all switching cases.

Figure 3 demonstrates the simulated peak gains of the projected antenna with and without dielectric lens in addition to the two resonators notches. It is seen that the peak gain is quasi stable across the operating frequency range with a sharp gain reduction at the rejected frequency bands.

Figure 4 presents the principle radiation patterns (E– and H–planes) at different frequencies. It is noticed that the radiation pattern is end-fire. Figure 4 displays antenna current distribution at the resonant bands of 3.6 GHz for case 4 and at 5.5 GHz for case 3, at these two frequencies the resonators will yield band-notch and it can observe that from the current distribution.

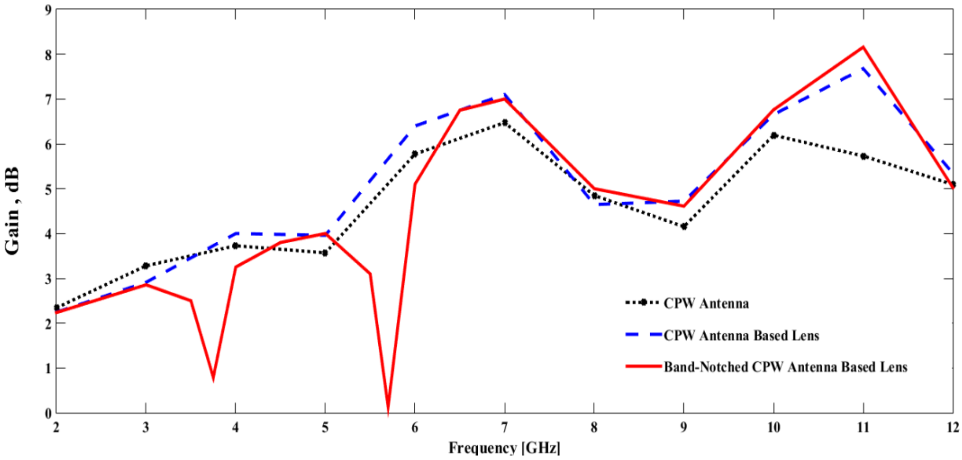
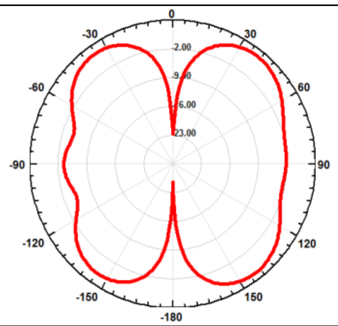
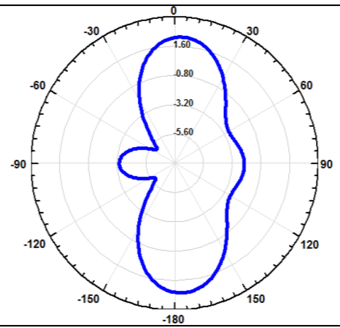
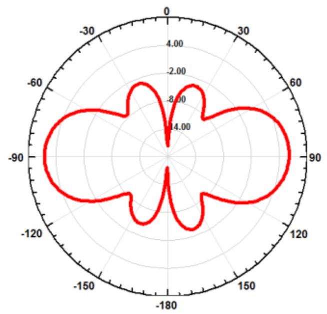
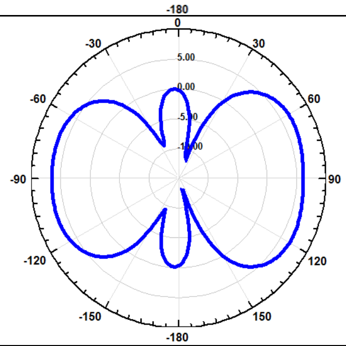


Fig. 3.peak gains spectra of the projected band-notched antenna with and without the dielectric lens

Figure 5 shows the simulated surface current distribution on the parasitic rectangular ring patch at 3.6 GHz. The current varies in the circumferential direction and indicating that the resonator was excited at that frequency resulting a notch band at 3.6 GHz. In order to understand the working mechanism of 5.5 GHz notch, the simulated current distribution is shown in Figure 5 As illustrated in Figure 5 for the second notched-band current density is concentrated more at the circular slot resonator.

E-Plane		H-Plane
	4.5 GHz	
	6.8 GHz	

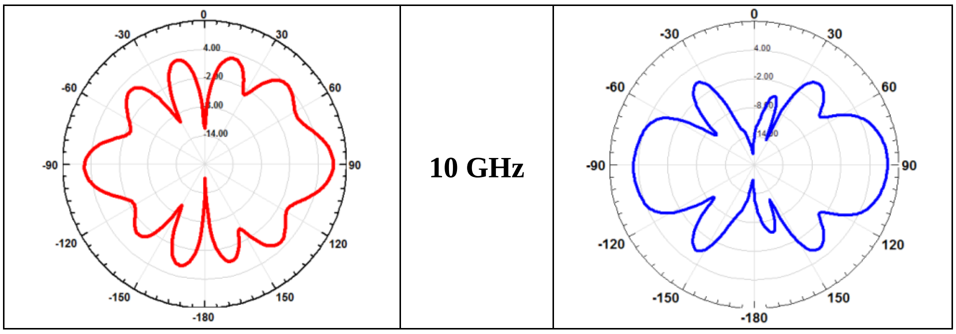
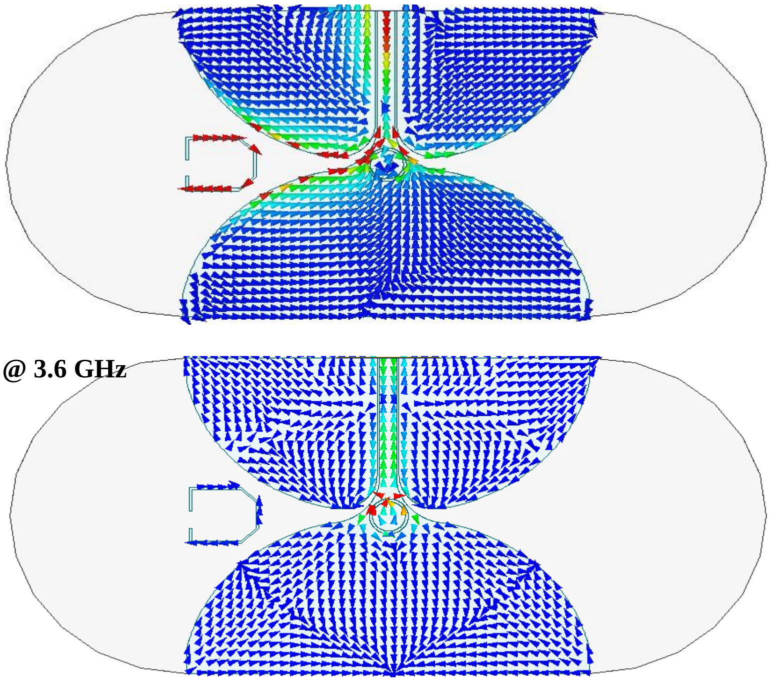


Fig. 4. E and H–planes radiation patterns at various operating frequencies



@ 3.6 GHz

@ 5.5 GHz

Fig. 5. Current distribution of the projected antenna at band-notch frequencies.

Table 3: Comparison of the projected antenna with previous works.

Work	Size [mm]	Max. Gain	Bandwidth [GHz]	notch -band
[20]	50×50	<4	2.5-11	Dual-band notch
[21]	47×47	5.3	2.4–12	Dual-band notch
[11]	55×52	4.8	4-7.3	Dual-band notch
[8]	29×23	N.A	2.91 – 15.3	Dual-band notch
[22]	24×32	4.8	2.5-11	Dual-band notch
Projected work	55×48	8.2	1.9 - 12	Dual-band notch

IV. Conclusion

In this article, a new shape of reconfigurable UWB slot antenna has been designed and analyzed. The projected UWB antenna behavior has been verified experimentally. A quasi-trapezoidal shape parasitic SSRR is printed next to slot UWB antenna and CSSRR is etched on the radiators which are used to perform the dual band-notched. The UWB microstrip antenna is printed on Epoxy FR-4 substrate with overall size 55×48×1.5 mm^3. The projected UWB antenna covers band from (1.9 to 12) GHz. It has variable dual-band rejections in order to reject the interference in narrow band such as WiMAX (3.8 GHz), WLAN and HIPERLAN/2 (5.5 GHz). The intended antenna design incorporates switched electronically based on p-i-n diode to reduce the unwanted interfering signals. The projected UWB antenna gives four frequency responses by depending on strategy of switches changing states (On/OFF). Measured and simulated results are compared and observed to be in reasonable agreement. Therefore the designed antenna can be used in variety applications that are overcome interferences problems between UWB and two bands at WLAN and WiMAX. Moreover, the projected UWB antenna has bi-directional radiation pattern.

Conflict of Interest:

There was no relevant conflict of interest regarding this article.

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