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A Compact Ultra-Wide Band Antenna with a Notched Band for Wireless Communication Systems

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Abstract—An ultra-wide band (UWB) antenna with C-band and X-band notches for wireless communication is presented. The designed structure is printed on a material of "Rogers 4350B" with $\varepsilon_r = 3.66$, $\tan\delta = 0.0037$, and a thickness of 0.508 mm. This structure is designed to operate at a UWB range starting from 3.3 GHz up to 10.15 GHz with a stopband range from 6.75 GHz to 8.5 GHz. The rejected bands are the upper C-band (6.75 GHz–8 GHz) and the uplink X-band of the satellite (space to earth) from 7.25 GHz to 7.75 GHz. The overall antenna size is optimized, and its dimensions are $21 \times 30 \times 0.508\,\text{mm}^3$. The antenna gain varies from 2.1 to 4.2 dBi at the passband, and its total radiation efficiency is 96.4%. The suggested structure is designed and simulated using CSTMWS software. Moreover, a prototype of the proposed structure is fabricated and measured. The fabrication process was done using photolithography techniques, and the measurements were done using an R&S vector network analyzer. Good agreement is achieved between the simulated and measured results.

1. INTRODUCTION

UWB antennas with varied band-notch parameters are designed and built to eliminate UWB narrowband interference. Antennas for UWB are categorized into three types based on notch characteristics: fixed band notch frequencies, reconfigurable band notch frequencies, and continuously tuneable notch bands [1]. Spatial filters such as frequency selective surfaces (FSSs) above the antenna are used to reject unwanted bands and improve communication quality. However, the use of filters increases the cost and volume of the system, as well as insertion losses. Therefore, much research has been focused on the design of UWB antennas that have band rejection features to avoid potential interference from existing bands [2]. To obtain the single band notch characteristics, different types of techniques have been used by the researchers in recent years, such as slotted radiating patches, defected ground planes, slotted feed lines, installing stubs in the radiating patch, and structures based on parasitic elements. A single-notch microstrip antenna is made up of a square slot patch and a small vertical coupling strip. The antenna operates at a wide band from 3.05 GHz to 11.15 GHz, while rejecting the frequency band from 5.12 GHz to 6.08 GHz. At the passband, the antenna gain varies from 3.02 to 3.92 dBi, and also the radiation efficiency is larger than 82%. Lower performance for both gain and efficiency has been received over the stopband as presented in [3]. Slotted radiating patch approaches include circular, square, triangular, pi-shaped, U-shaped, inverted H-shaped, E-shaped, L-shaped, C-shaped, Split Ring Resonator (SRR), V-shaped, T-shaped, tulip-shaped, and numerous others are discussed in [4–9]. A novel UWB antenna has dual band notch characteristics at the Wireless Local Area Network (5.15 GHz–5.8 GHz) and WiMax (5.25 GHz–5.85 GHz) in order to avoid interference [10]. A triangular slot is created on the radiating element to get the notch function. Gain is about 2 dB at passband and lower at notch bands. Radiation efficiency is about 80% but at notch band about 35%. Another dual notch with traditional UWB

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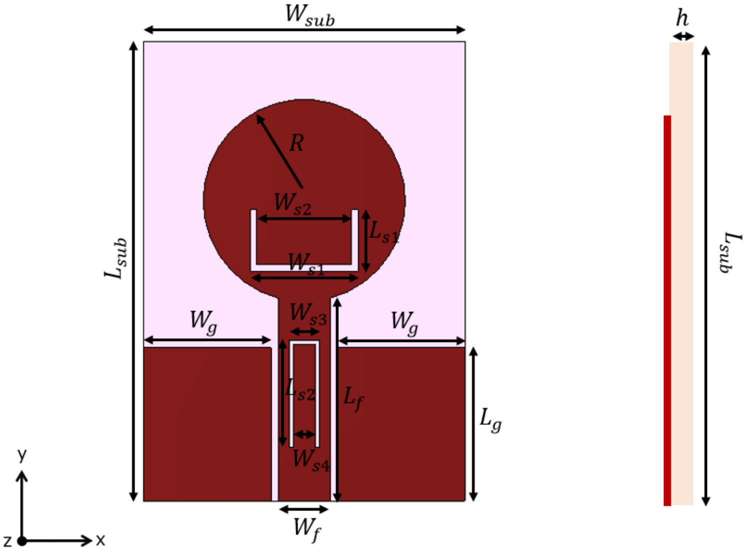
antenna is discussed [11]. The rejected bands are WLAN at 5 GHz (5.1 GHz–5.8 GHz) and the satellite X-band from space to earth (7.25 GHz–7.75 GHz). The patch with a step design with a modified π formed opening gets the ultra-wide band. The antenna with two-fold indent channels was intended. First, WLAN has notches setting a U-folded opening in the patch, and the second X-band has indents with a reversed T-shape in the ground plane.

In this paper, a compact coplanar UWB antenna with C-band and X-band notches for wireless communication is presented. The designed antenna has two reject bands: C-band and X-band, which are used for satellite communication systems. To obtain this design, a parametric analysis is performed using CSTMWS tools. This paper is prearranged as follows. Section 2 describes the complete antenna structure. The results of the discussion, optimization, and parametric study are presented in Section 3.

2. PROPOSED ANTENNA DESIGN

A compact coplanar UWB antenna is intended to operate at wide band range from 3.3 GHz to 10.15 GHz with a band reject frequency from 6.75 GHz to 8.5 GHz. The coplanar UWB antenna is printed on a substrate of Rogers 4350B with relative permittivity $\varepsilon_r = 3.66$, $\tan\delta = 0.0037$ and thickness $h = 0.508\,\text{mm}$. The overall antenna size is $(21 \times 30 \times 0.508\,\text{mm}^3)$. The complete geometry of the proposed antenna structure is shown in Fig. 1. The antenna consists of a simple circular patch antenna fed by a microstrip feedline and a partial ground. An optimization process for the width of the feedline and the gap between the feedline and ground is presented to select the 50-ohm matching point. Table 1 shows the dimensions of the structure in mm.



Top view
(a)

Side view
(b)

Figure 1. The complete geometry of the proposed antenna. (a) Top view, and (b) side view.

Table 1. The dimensions of the proposed structure.

Parameter	L_{sub}	L_{S1}	L_{S2}	R	h	L_f	L_g
Dimension (mm)	30	4	7	6.6	0.508	13.2	10
Parameter	W_{sub}	W_{S1}	W_{S2}	W_{S3}	W_{S4}	W_f	W_g
Dimension (mm)	21	7	6.2	2	1.42	3.35	8.325

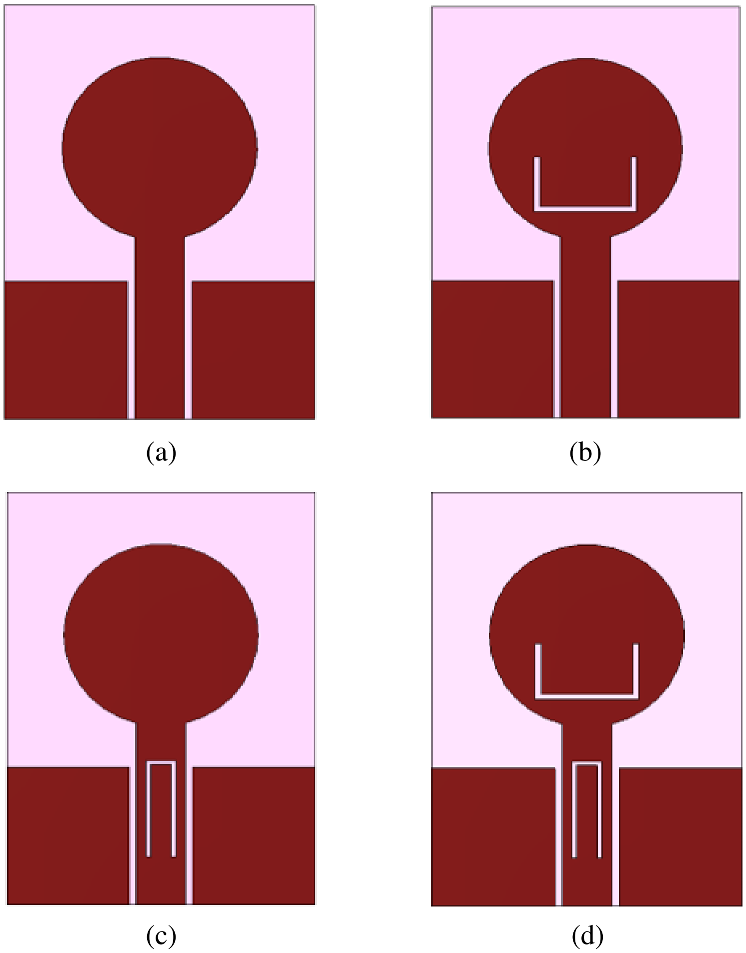


Figure 2. Improvement procedures of the designed structure, (a) 1st stage, (b) 2nd stage, (c) 3rd stage, and (d) 4th stage.

It went through four iterations to get the final designed antenna. Fig. 2 shows the four iterations that clarify the antenna design procedures. The first iteration is initiated with designing a coplanar circular patch antenna with a partial ground. In the next iteration, a U-shaped slot is cut on the patch antenna to create a notch band at a frequency of 8 GHz. This notch has a bandwidth of 0.75 GHz (from 7.25 GHz to 8.5 GHz). Then, another U-shaped slot is an inverted cut on the feedline to create another notch band at a frequency of 6.9 GHz. This notch has a bandwidth of 0.3 GHz (from 6.7 GHz to 7 GHz). In the last iteration, the two U-shaped elements were placed to generate a wideband reject notch with a bandwidth of 1.75 GHz (from 6.75 GHz to 8.5 GHz). Fig. 3 displays the S parameter (S_{11}) of the four iterations. As discussed, the notch of the return loss at the last iteration is the sum of the two notches that are produced from iterations 2 and 3.

To determine the suitable dimensions, a parametric analysis is conducted for each dimension separately while the other parameters are held constant. Fig. 4 presents the effect of changing the width of the notch, which tends to produce the notch around the frequency of 8 GHz. The dimension chosen is 6.2 mm. Fig. 5 discusses the surface current distribution of the UWB antenna at frequencies of 6.9 GHz and 8 GHz. The patch antenna is surrounded by the partial ground plane's maximum surface current, which improves performance at the middle working frequency, as seen in the figure. This demonstrates that the ground plane's central region and the radiating patch's outer borders are where electromagnetic waves from the antenna are emitted. The UWB antenna's current distribution is shown in Fig. 6, which also includes two slots for notching the X-band and C-band. Fig. 6(a) shows

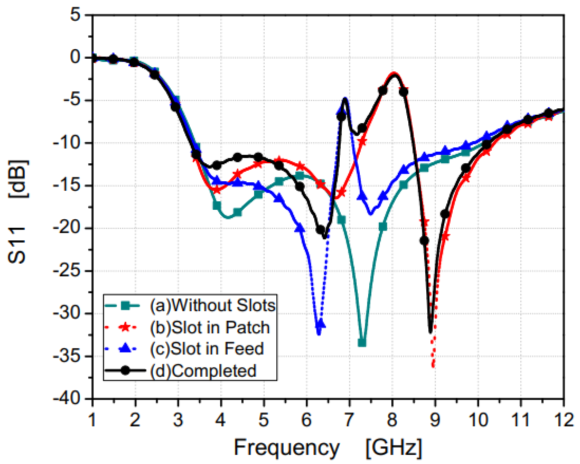


Figure 3. The S_{11} (S-parameter) of the designed structure, (a) 1st stage, (b) 2nd stage, (c) 3rd stage, and (d) 4th stage.

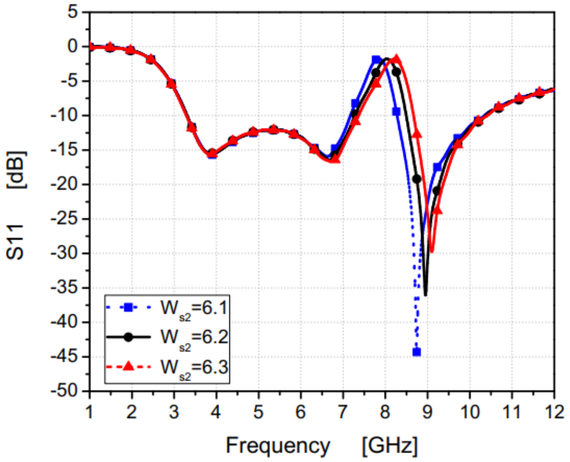


Figure 4. Discusses the parametric study of changing the values of the width W_{s2} and its effects.

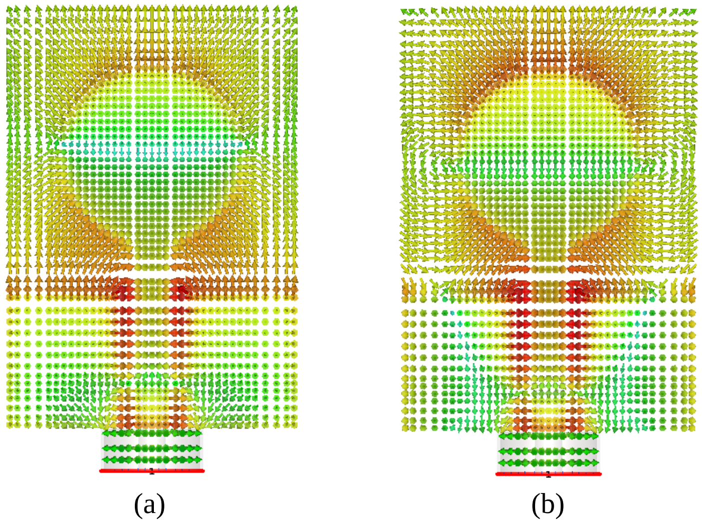

(a)
(b)

Figure 5. Surface current distribution of the fundamental UWB antenna at frequencies: (a) 6.9 GHz, and (b) 8 GHz.

that at 6.9 GHz, the maximum current distribution is concentrated around the inverted U-slot that is placed on the feedline. The radiating patch's current distribution is asymmetric and multidirectional. Furthermore, the feedline and the center of the partial ground plane of the antenna exhibit the highest surface current, showing that these components are also involved in the antenna's electromagnetic wave blockage. Fig. 6(b) illustrates the surface current distribution of the UWB antenna at 8 GHz. As a result of a large portion of electromagnetic energy being stored around the U-slot rather than being radiated into free space, the radiation efficiency at this band is seen to decrease. This is indicated by the apparent maximum current being concentrated around the U-slot that is placed on the radiated patch. The simulated radiation patterns for the designed structure are introduced both with and without notches at the yz-plane. The selective frequencies that were chosen to be present are 5 GHz, 8 GHz, and 10 GHz, as shown in Fig. 7. The overall gain of the suggested structure is introduced in Fig. 8. At the passband, the designed antenna gain varies between 2.1 dBi and 4.2 dBi, while adding the slots reduces its value at the stopband notch. The total radiation efficiency of the designed structure at the

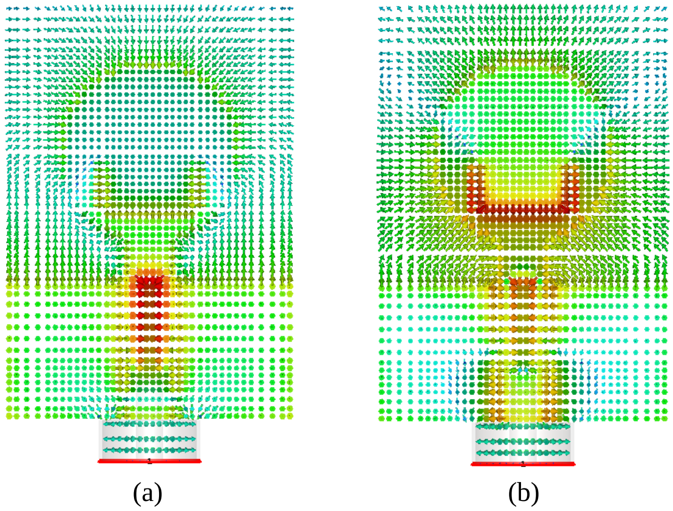


Figure 6. Simulated surface current distribution of the UWB antenna with two slots in the patch and feedline at frequencies: (a) 6.9 GHz, and (b) 8 GHz.

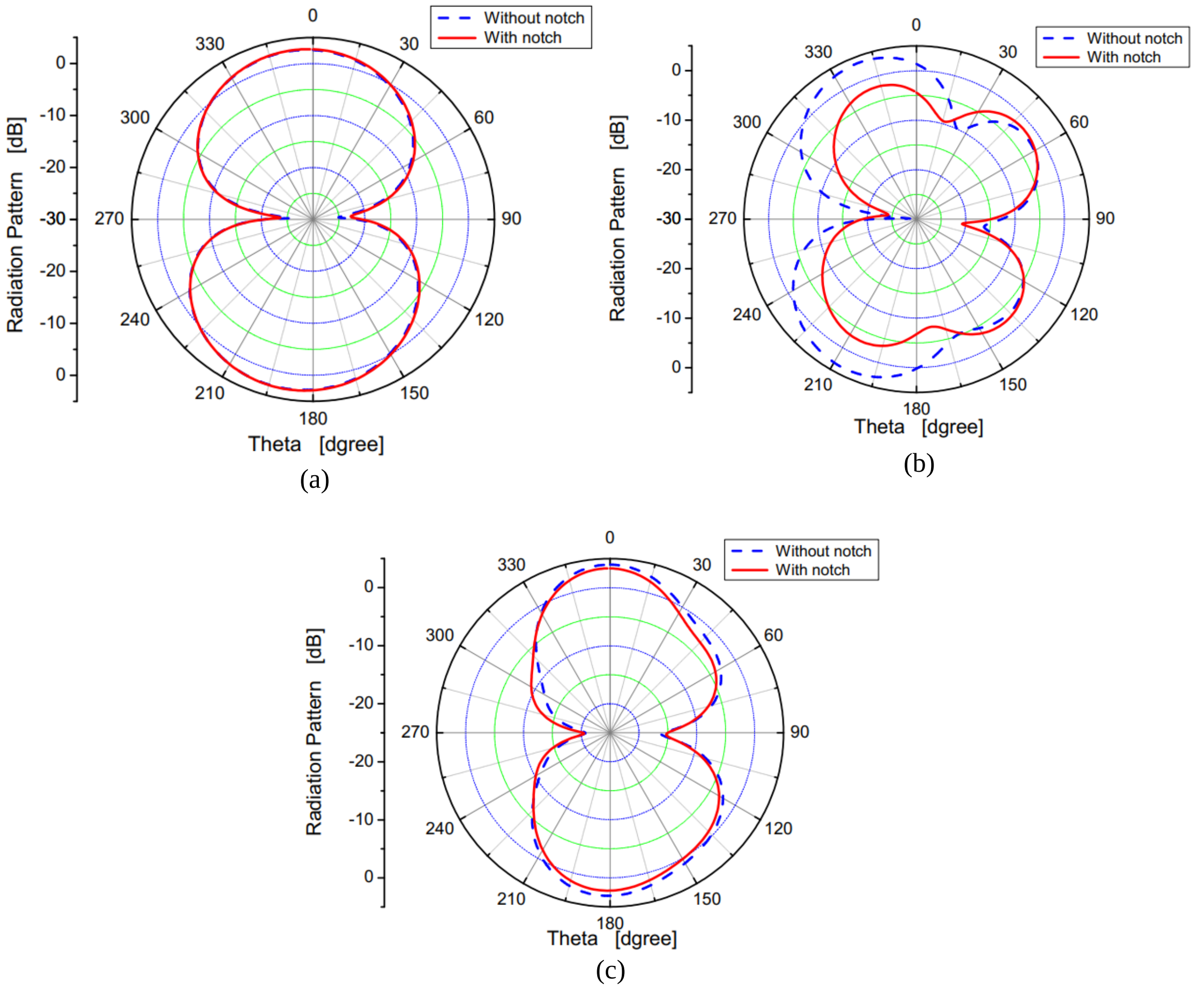


Figure 7. The simulated radiation patterns for the designed antenna at certain different frequencies of: (a) 5 GHz, (b) 8 GHz, and (c) 10 GHz.

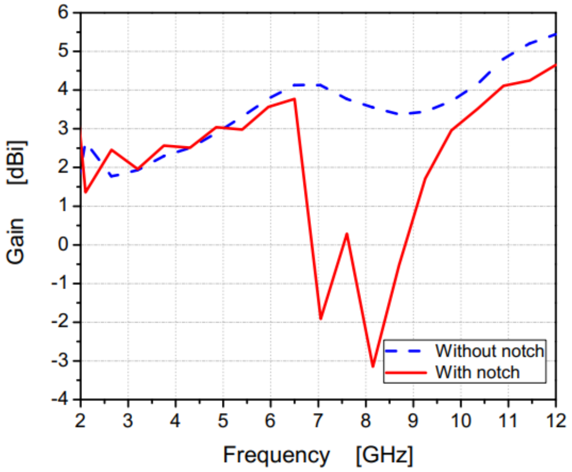


Figure 8. Presents the overall gain of the designed antenna with and without notches.

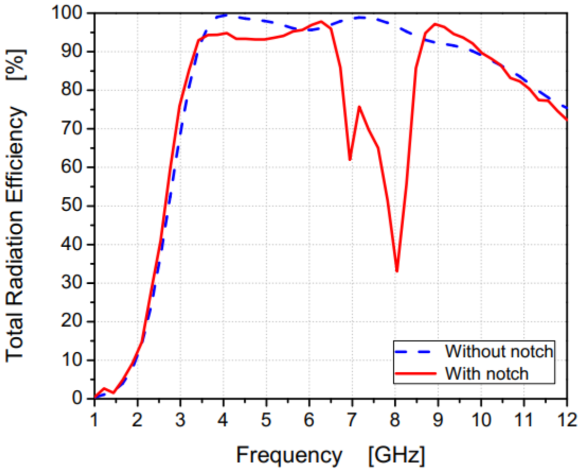


Figure 9. Shows total radiation efficiency of the suggested structure.

pass band is 96.4%, while it has also been decreased to 33% over the stopband after adding the slots as shown in Fig. 9.

3. RESULTS AND DISCUSSIONS

CST MWS software is used to design and simulate the suggested structure. The two prototypes of the proposed UWB antennas are fabricated using the photolithography method, one without slots and the other with slots. These antennas were also measured using a vector network analyzer (R&S ZVA 67). Fig. 10 shows the two fabricated antennas. In Fig. 11, the simulated and measured S-parameters (S_{11}) against frequency are illustrated for the fabricated antenna without slots. The two results displayed a good match, with some slight deviations between them due to the fabrication tolerance, SMA soldering

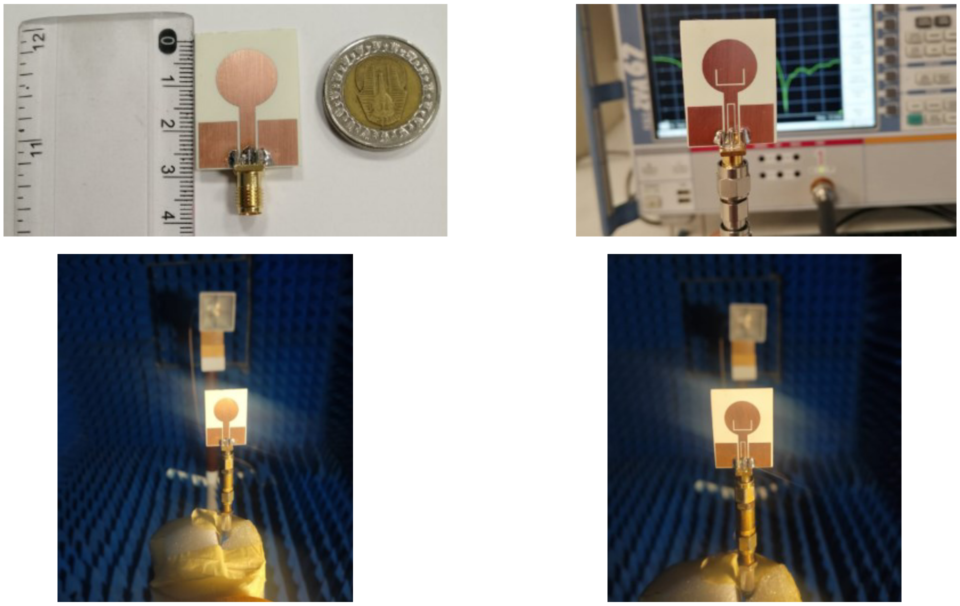


Figure 10. The two prototypes of the designed structure without slots and with slots.

process, measurement environment, and the used tools. The simulated and measured S-parameters (S_{11}) against frequency are also clarified for the fabricated antenna with slots in Fig. 12. As shown in Figs. 11 and 12, the measured bandwidth of the fabricated antenna without applying slots at -10 dB is started from 3.7 GHz to 11.18 GHz, while a wide rejected band is created from 6.63 GHz to 8.31 GHz for the fabricated antenna after adding slots. The results from the simulation and measurement are in good agreement. The radiation pattern of the proposed antenna is also measured for both with and without slots. The comparison between simulated and measured radiation patterns is introduced in Fig. 13. As shown in this figure, good agreement is achieved between the simulated and measured results for both designs. A comparison of the proposed antenna structure with the previous work of the UWB antennas with notches band is tabulated and illustrated in Table 2.

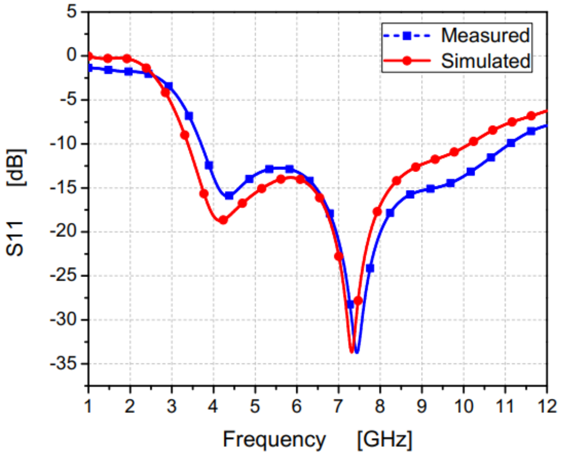


Figure 11. The comparison between the measured and simulated S_{11} of the suggested structure without slots.

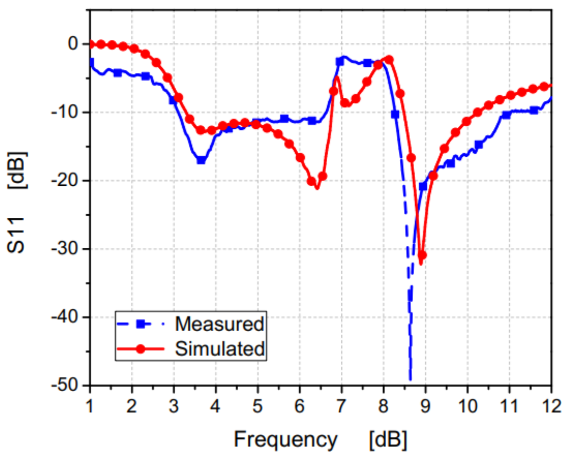
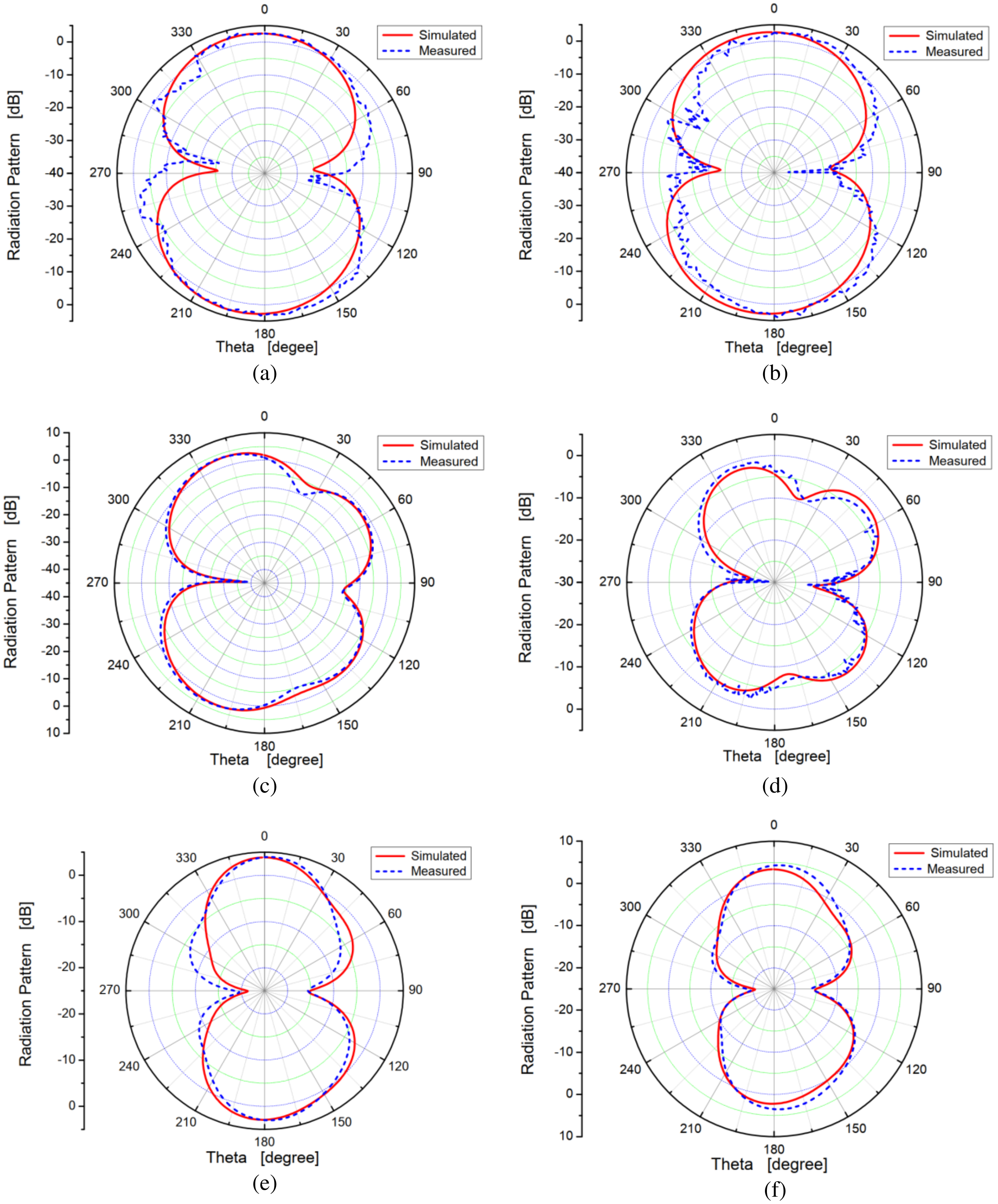


Figure 12. The comparison between the measured and simulated S_{11} of the suggested structure with slots.

Table 2. A comparison of the proposed antenna structure with the previous work of the UWB antennas with notches band.

	Substrate	Frequency of Notch Bands [GHz]	Notch Bandwidth [%]	Notch bands		Impedance Bandwidth [GHz]	Antenna Size
[2]	FR-4	5	7.24	Single	WLAN	3.2–10.6	30 mm × 35 mm
[6]	FR-4	5.15–5.85 7.25–7.75	10 7.2	Dual	WLAN X-Band	3.1–10.8	41 mm × 41 mm
[9]	FR-4	4.94–6.72	25	Single	WLAN	3.05–11.15	15 mm × 15 mm
[10]	FR-4	5.15–5.8 5.25–5.85	10	Dual	WLAN WiMAX	3.1–10.6	16 mm × 25 mm
[11]	FR-4	5.1–5.8 7.25–7.75	10 7.2	Dual	WLAN X-Band	3.1–10.6	30 mm × 35 mm
This Work	**Rogers 4350B**	**6.75–8.5** **7.25–7.75**	**26.12**	**Dual**	**C-Band** **X-Band**	**3.3–10.15**	**21** mm × **30** mm



(a) (b) (c) (d) (e) (f)

Figure 13. The comparison between the measured and simulated radiation pattern of the proposed antenna without and with slots at different frequencies: (a) without at 5 GHz, (b) with at 5 GHz, (c) without at 8 GHz, (d) with at 8 GHz, (e) without at 10 GHz, and (f) with at 10 GHz.

4. CONCLUSION

A compact coplanar UWB antenna with C-band and X-band notches for wireless communication is introduced. The antenna is designed to operate at an ultra-wide band range started from 3.3 GHz up to 10.15 GHz with a stopband range from 6.75 GHz to 8.5 GHz. The dismissal bands are the upper C-band (6.75 GHz–8 GHz) and the uplink X-band of the satellite (space to earth) from 7.25 GHz to 7.75 GHz. The antenna gain varies from 2.1 dBi to 4.2 dBi at the passband, and its total radiation efficiency is 96.4%, while a wide rejected band is created from 6.63 GHz to 8.31 GHz for the fabricated antenna after adding slots. The presented structure is designed, simulated, fabricated, and measured. The results from the simulation and measurement are in good agreement.

REFERENCES

1. Kaur, K., A. Kumar, and N. Sharma, "A review of ultra wideband antennas with band notched characteristics," *Proceedings of the International Conference on Innovative Computing & Communications (ICICC)*, March 2020.
2. Mullick, T. U., M. E. Ershad, M. A. Matin, and A. Rahman, "Design of UWB antenna with a band-notch at 5 GHz," *Loughborough Antennas & Propagation Conference (LAPC)*, 1–4, 2012.
3. Liu, H., C. Ku, T. Wang, and C. Yang, "Compact monopole antenna with band-notched characteristic for UWB applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 397–400, 2010.
4. Madany, Y. M., A. I. Almahallawy, and H. M. Elkamchouchi, "Methodology of band rejection/addition for microstrip antennas design using slot line theory and current distribution analysis," *2014 Loughborough Antennas and Propagation Conference (LAPC)*, 602–606, IEEE, 2014.
5. Goyal, P., "UWB antenna with dual notch functionality for reducing VSWR," *Journal of Adv Research in Dynamical & Control Systems*, Vol. 12, No. 3, 91–96, 2020.
6. Moradi, N., F. Nazari, H. Aliakbarian, and F. A. Namin, "Compact ultrawideband monopole antenna with continuously tunable notch band characteristics," *Progress In Electromagnetics Research C*, Vol. 118, 71–81, 2022.
7. Wang, X. and Y. Sun, "Ultra-wideband MIMO antenna with double notched band," *Cross Strait Radio Science & Wireless Technology Conference (CSRSWTC)*, 1–3, 2020.
8. Alotaibi, S. and A. Alotaibi, "Design of a planar tri-band notch UWB antenna for X-band, WLAN, and WiMAX engineering," *Technology & Applied Science Research*, Vol. 10, 6557–6562, 2020.
9. Rashid, M. A., S. M. Shah, H. Majid, A. Ponniran, and F. Hassan, "A highly miniaturized ultra-wideband antenna with a triple-band notch for wearable applications," *International Journal of Electrical and Electronic Engineering & Telecommunications*, 74–81, 2022.
10. Khan, M., "Design and analysis of a compact UWB band notch antenna for wireless communication," *Engineering Proceedings*, Vol. 3, 2020.
11. Karanam, P., A. Tejasri, K. Sandeep, U. Kumar, and G. Swarupa, "Design of UWB antenna with WLAN & X-band notch for wireless communication," *International Journal of Engineering and Technology (UAE)*, Vol. 7, 484–488, 2018.