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Design UWB antenna with notch band for WiMAX application

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ABSTRACT

During the last two decades, radar, remote sensing, and imaging applications have all made use of ultra-wide band (UWB) technology. UWB systems are susceptible to interference from narrowband signals, hence this work provides a single-notch antenna for the UWB system. There are two stages to the design process. After creating the baseband antenna, it is necessary to create a notched band UWB antenna by carving a slot into patch antenna. In the UWB range (3.1-10.6) GHz, the UWB antenna has the dimensions of 20x30 mm with substrate thickness 1.6 mm made from FR4 lossy. The design relative permittivity was 4.3, a rectangular patch with a portion of the ground is used in the design. A typical slot-shaped resonator is connected to the patch to reject a frequency band (3.273-3.81) GHz which is a world interoperability for microwave access (WiMAX) to solve the problem of the interference with other bands in UWB system For WiMAX applications. The suggested UWB filter will achieve notch band response centered at the resonance frequency of 3,4 GHz. Analysis CSTS v2020 software was used to carry out the simulation. Priority should be given to what has been learned rather than what has been accomplished.

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1. INTRODUCTION

Wireless technology has allowed ultra-wide band (UWB) to coexist with nearby communication systems in its radio environment. The simplicity, compact size, low cost, lightweight, low complexity and high data rate of UWB technology make it a popular choice [1], [2]. UWB signals often have a large absolute or relative bandwidth (bandwidth divided by carrier frequency). Use of wide transmission bandwidths, such as better barrier penetration and covert operation as well as interference rejection and coexistence with narrow bandwidth (NB) systems may provide several benefits. In fact, there are significant challenges in UWB signal production, transmission, propagation, processing, and system architecture that need more research. High data rates (up to 500 mbps) and short-range transmission (G 10 m) are only two of the numerous uses of UWB technology [3]-[5], low-rate communications with accurate geolocation and vacillation and systems of radar, which offer extraordinarily high spatial resolution and the ability to overcome barriers, such as wireless "USB" such as infrastructures between computer components or wireless links among components of operating systems [6]-[8].

The Federal government has approved the commercial usage of ultrawideband technology in the frequent range of 3.1 GHz to 10.6 GHz [2] in the United States. Otherwise, neighboring WiMAX communication systems (which run at frequencies ranging from 3.2 to 3.8 GHz) create interference with the UWB system since they operate at frequencies higher than the UWB system's designed bandwidth [9], [10]. Because of this, notched features on the UWB antenna are required in order to reduce interference from other neighboring communication systems. In order to establish frequency notched band characteristics on a UWB antenna, an appropriate structure may be etched into the antenna [11]-[13].

The antenna in question rejects just one band of the UWB spectrum, and it is a limited band at that. WiMAX technology has just been shown to be used by the network. Slot antennas for ultra-wideband communications may only be capable of functioning in a single notch band [14]-[16]. A rectangular UWB monopole antenna with a π-shaped slots resonator is installed within it for WiMAX band rejection [16], and the resonator is tuned to the frequency of the WiMAX band.

UWB range of 3.1 GHz to 10.6 GHz as shown by the simulation's, the antenna is capable of avoiding the interference caused by the WiMAX. The H-plane of the antenna provides an omnidirectional patterrn over the whole bandwidth of the antenna [17]-[21]. Some of research which suggest the same problem is listed as:

a. An individual patch of a radiating patch has dimensions of 11.86 mm (L) x 8.96 mm (W), or 5.43 mm x 7.43 (L2) for the combination of a pair of monopoles lengthwise and widthwise, according to [22]. The substrate is 16 mm (L) x 20 mm (W) x 1.6 mm thick. This antenna arrangement has been used to mimic the 10 GHz resonance frequency. Dielectric constant ε_r=2.2 e was achieved using Duroid as the substrate material. Two monopoles with a partial ground plane and steps at the bottom of the patch were employed for the required broad bandwidth. At the same time, to avoid interference with other frequency bands included inside the passband, the center bottom of the radiating patch was fitted with a strip bar.
b. The proposed antenna for Dhakar's antenna design in 2015 [23] is printed on an FRP substrate 1.6 mm thick and has a 4.4 V permittivity and a 0.25 V loss tangent. The primary structural components of this proposed antenna are as follows: a square radiating patch with W- and O-shaped slots carved into it, a 50 Ω microstrip feed line printed on the substrate, a partial ground plane with a pair of U-shaped slots printed on the opposite side of the substrate. For achieving a characteristic impedance of 50 Ω over the whole frequency range of 3.05-14.1 GHz, the square patch has dimensions of 8 mm by 8 mm and the width Wf of the microstrip feed line has been fixed at 2 mm.
c. While Kumar and Kamatham [24] suggested a coplanar beveled feed in 2019, they advocated dual band-rejection. Antenna for ultra-wideband FR-4 substrate (permittivity 4.4, tanδ=0.02) with overall dimensions of 20x14x1.6 mm^3 is used to print the antenna's twin fork radiating element loaded with a pair of inverted L-shaped stub resonators. A rectangular ground plane symmetrically surrounds the 50 Ω CPW feed. It has a ground plane of 5.5x4.5 mm^2 and 2 mm in the width feed line. It is possible to acquire dual notched bands to cover the WiMAX and WLAN operating bands with enhanced impedance matching (3.4-3.8 GHz and 4.5-5.5 GHz) (2.6 GHz -11.6 GHz).
d. In 2019, Zhong *et al.* [25] operated in the 2.7 to 10.7 GHz frequency range; its radiating patch is in the form of a gradient curve, and its ground plane is asymmetrical. In order to construct unwanted bands at C-band (3.60-4.32) GHz, "WLAN" bands (5.17-5.32) GHz and (5.80-5.93) GHz, and ITU band (7.8-8.2) GHz, respectively, four different slots, consisting a two meandering slots, cap-shaped slot, and a split-ring, are working.

In this paper we would propose the antenna design in two sections first is the design of an UWB antenna and its simulation results, and in the second part we explain the design of antenna with inserting the pi shaped resonator and its simulated results.

2. DESIGN ULTRA-WIDE BAND ANTENNA

As illustrated in Figures 1(a) and (b), the projected UWB antenna has the dimensions of 20×30 mm. The design relative permittivity was 4.3, and the thickness was 1.6 mm; loss is equivalent to 0.02, and the pattern is printed on FR4. Radiating ground and structure, bottom and top patches are printed on the substrate's surface. Wf (3.137 mm), the microstrip feedline width, serves as a 50 ohm resistor between the end of the feeding strip and the ground plane. Using the staircase patch construction in Figure 1, we may increase the antenna's bandwidth to encompass the UWB spectrum, design's dimensions is shown in Table 1.

2.1. Design of band notched ultra-wide band antenna

This section explains the band-notch characteristics of a UWB antenna. A single notched band may be executed by etching a π -configuration notch in the radiating patch of another UWB antenna. Details of the antenna's design may be found in Table 1. It is possible to compute the notched frequency's dimensions using (1) [10]:

$$F_{Notch} = \frac{C}{2L\sqrt{\varepsilon_{eff}}} \quad (1)$$

Where C is the speed of light, L is the length of the resonator, and ε_{eff} is the effective dielectric constant.

Figure 2 represented $S_{11}$of the UWB antenna while Figure 3 represented VSWR of the UWB antenna. Table 1 lists the ideal parameters for simulating the suggested antenna, which is represented in Figures 4(a)-(c) where (a) is the designed antenna, (b) and (c) are the dimensions of the antenna.

Figure 1. Antenna design dimensions (a) in front view and (b) in back view

Table 1. Dimensions of the planned antenna (mm)

L	W	L_p	W_p	W_g	L_g	W_f
30	20	26	12	3	12	3.137
a	b	c	d	e	f	f_1
1	2	0.5	0.5	0.2	8.5	0.8
f_2	s	g	s_1	Lg1		
9.9	1.5	0.5	1.5	6		

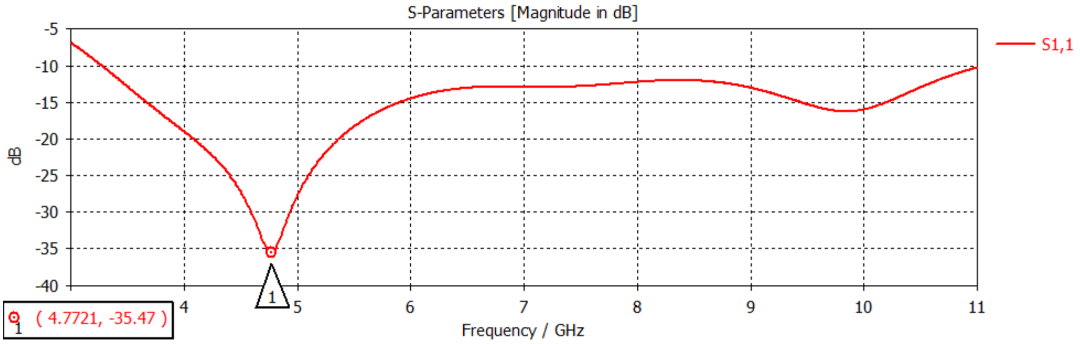


Figure 2. UWB antennas simulated (s_11)

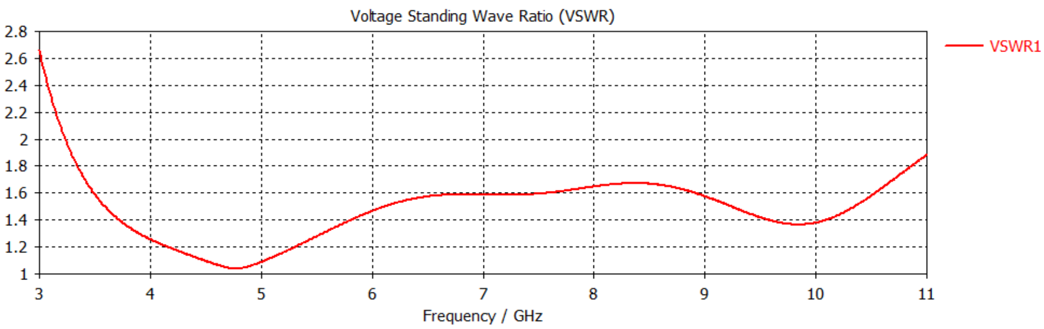
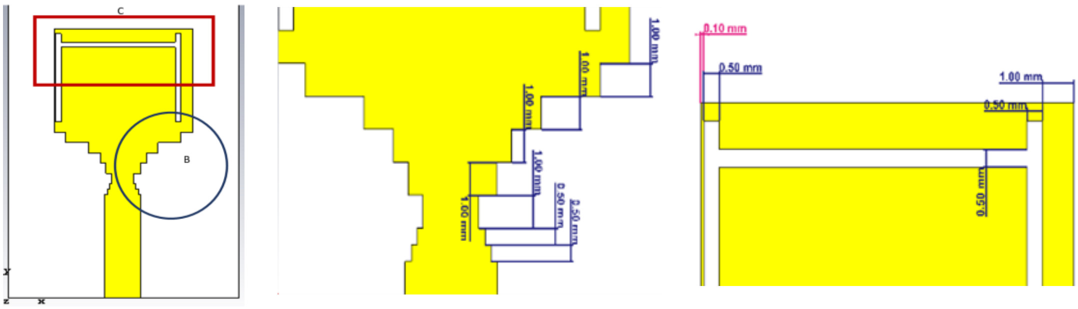


Figure 3. Antennas simulated VSWR



(a) (b) (c)

Figure 4. Suggested antenna with π- shaped resonator (a) front view, (b) dimensions in section B, and (c) dimensions in section C

3. RESULTS AND DISCUSSION

For the purpose of covering the whole UWB band, this antenna has been developed to have wideband performance ranging from 3.10 to 10.60 GHz with an S11 of less than 10 dB. An antenna's abii to focus radiated power in a given direction, or the antenna's ability to absorb incoming radiation, is referred to as its gain. "The ratio of highest voltage or current to lowest voltage or current at each site it investigates as a measure of mismatch between the line and the load" is how VSWR is described in electrical engineering. Figure 5 displays the simulated reflection coefficients, while Figures 6 and 7 illustrate the voltage standing wave ratio and the antenna's actual gain. It's clear that things are looking up.

For VSWR<2, the antenna covers the whole UWB range, with single-notch bands of 3.3–3.8 GHz having VSWR>2. If one looks at Figure 8, one can see that the surface current distributions are more concentrated in one direction and cancel each other out at the notch frequency. For frequency rejection, the π-shaped filter structure of the UWB antenna has a considerable impact. In order to generate a frequency notch band, the antenna does not emit at this particular frequency. Because of this, we may infer from the present distributions that the frequency-notch functions result from the π-shaped filter structure [11]-[13].

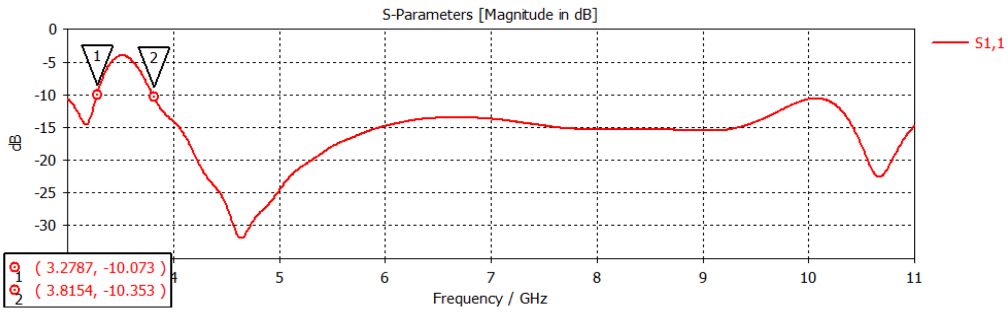


Figure 5. S_{11} simulation results of the antenna

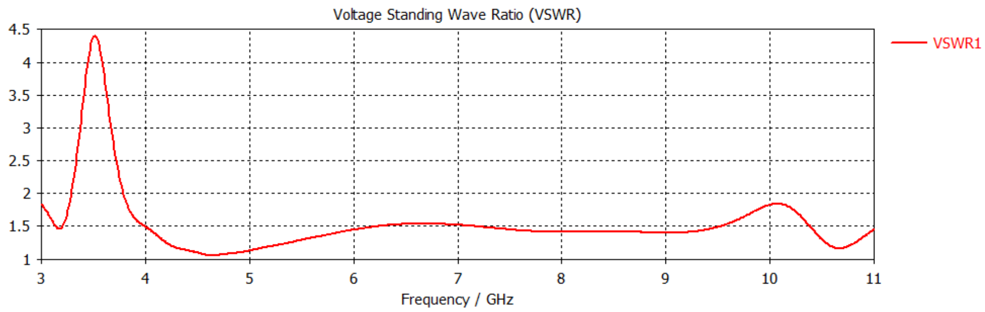


Figure 6. VSWR simulation results of the antenna

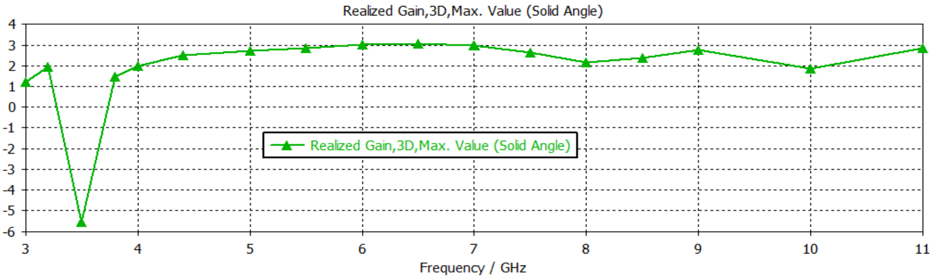


Figure 7. Realized gain simulation results

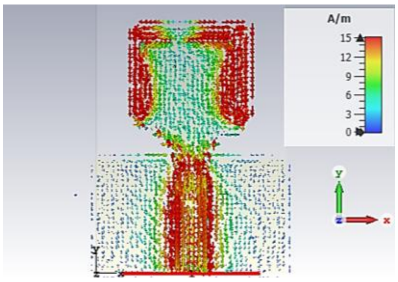


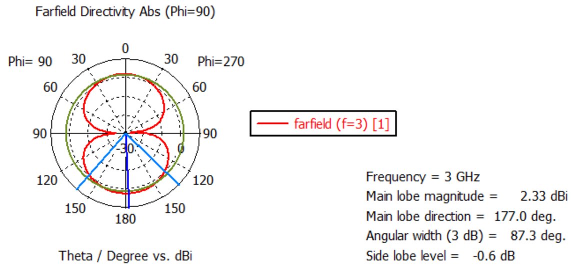
Figure 8. Frequency (3.5 Ghz) surface current distribution in notch band resonant

3.1. Surface current distribution

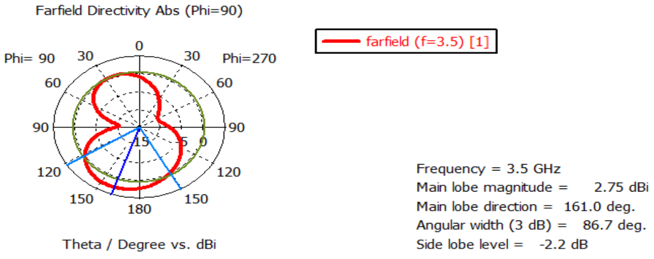
The surface current pattern at 3.5 GHz frequencies is shown in Figure 8. The colors on the scale are arranged in decreasing order by the scale's current value. Regions in red have better current distribution than those marked in yellow, green, and so on.

3.2. Radiation pattern

Figures 9(a) and (b) depicts the 3, and 3.5 GHz observed radiation patterns for the UWB antenna. Single-band UWB antenna's measured radiation pattern at (a) 3 GHz and (b) 3.7 GHz. The E-plane and H-plane are both represented by antennas that are printed in the x–y plane. It may be considered that the E-radiation plane's pattern is monopole-related, and the H-radiation plane's pattern is practically Omnidirectional except in the notched frequency range. The comparison with previous literature is shown in Table 2.



(a)



(b)

Figure 9. Shows radiation patterns at (a) 3 GHz and (b) 3.5 GHz

Table 2. Comparison with published work

Ref.	Antenna size (mm^3)	Notching structure	Notch band (GHz)
[14]	20 × 20 × 0.8	radiating patch with two slots cutting & two (PIN) diode embedding	3.15–3.85
[15]	40 × 35 × 1.5	CSRR resonators	3.3–3.7
[16]	37.8 × 27.1 × 1.6	inverted pi-slot & double split-ring resonators (DSRRs)	3.67- 6.5
This work	20 × 30 × 1.6	Pi shaped slot resonator	3.27-3.8

4. CONCLUSION

This paper detailed planar UWB antennas that are fed by microstrips, which are intended to avoid interference between the WiMAX and other UWB bands from occurring. An UWB monopole antenna's radiating patch is embossed with a π-shaped resonator in order to produce the desired notch band. The suggested antenna has a VSWR of 2 from 3.1 GHz to 10.6 GHz, which covers the whole UWB range, with the exception of a notch band from 3.3 GHz to 3.7 GHz (WiMAX).

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REFERENCES

[1] M. Z. Win, D. Dardari, A. F. Molisch, W. Wiesbeck and J. Zhang, "History and Applications of UWB [Scanning the Issue]," in *Proceedings of the IEEE*, vol. 97, no. 2, pp. 198-204, Feb. 2009, doi: 10.1109/JPROC.2008.2008762.

[2] D. Deslandes and K. Wu, "Single-substrate integration technique of planar circuits and waveguide filters," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 51, no. 2, pp. 593-596, Feb. 2003, doi: 10.1109/TMTT.2002.807820.

[3] J. P. Liu, Z. Q. Lv, and X. An, "Compact substrate integrated waveguide filter using dual-plane resonant cells," *Microwave Optical Technology Letters*, vol. 58, no. 1, pp. 111-114, 2016, doi: 10.1002/mop.29501.

[4] F-T. Liang and X. An, "Wideband bandpass filters using corrugated substrate integrated waveguide and periodic structures," *Microwave Optical Technology Letters*, vol. 57, no. 11, pp. 2665-2668, August 2015, doi: 10.1002/mop.29415.

[5] N. Tasouji, J. Nourinia, C. Ghobadi and F. Tofigh, "A Novel Printed UWB Slot Antenna With Reconfigurable Band-Notch Characteristics," in *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 922-925, 2013, doi: 10.1109/LAWP.2013.2273452.

[6] J.-S. G. Hong and M. J. Lancaster, "Microstrip filters for RF/microwave applications," *John Wiley & Sons*, 2001, doi: 10.1002/0471221619.

[7] M. Abdollahvand, G. Dadashzadeh and D. Mostafa, "Compact Dual Band-Notched Printed Monopole Antenna for UWB Application," in *IEEE Antennas and Wireless Propagation Letters*, vol. 9, pp. 1148-1151, 2010, doi: 10.1109/LAWP.2010.2091250.

[8] K. S. Ryu and A. A. Kishk, "UWB Antenna With Single or Dual Band-Notches for Lower WLAN Band and Upper WLAN Band," in *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 12, pp. 3942-3950, Dec. 2009, doi: 10.1109/TAP.2009.2027727.

[9] S. Barbarino and F. Consoli, "UWB circular slot antenna provided with an inverted-L notch filter for the 5 GHz WLAN band," *Progress In Electromagnetics Research,* vol. 104, pp. 1-13, 2010, doi: 10.2528/PIER10040507.

[10] D.-O. Kim, N.-I. Jo, H.-A. Jang, and C.-Y. r. Kim, "Design of the ultrawideband antenna with a quadruple-band rejection characteristics using a combination of the complementary split ring resonators," *Progress in electromagnetics research,* vol. 112, pp. 93-107, 2011, doi: 10.2528/PIER10111607.

[11] Y. Lin and K. Hung, "Compact Ultrawideband Rectangular Aperture Antenna and Band-Notched Designs," in *IEEE Transactions on Antennas and Propagation*, vol. 54, no. 11, pp. 3075-3081, Nov. 2006, doi: 10.1109/TAP.2006.883982.

[12] Y. Weng, S. Cheung, and T. Yuk, "Compact ultra-wideband antennas with single band-notched characteristic using simple ground stubs," *Microwave Optical Technology Letters,* vol. 53, no. 3, pp. 523-529, 2011, doi: 10.1002/mop.25817.

[13] Y. L. Zhao, Y. C. Jiao, G. Zhao, L. Zhang, Y. Song, and Z. B. Wong, "Compact planar monopole UWB antenna with band-notched characteristic," *Microwave Optical Technology Letters,* vol. 50, no. 10, pp. 2656-2658, 2008, doi: 10.1002/mop.23717.

[14] B. Badamchi, J. Nourinia, C. Ghobadi, and A. V. Shahmirzadi, "Design of compact reconfigurable ultra-wideband slot antenna with switchable single/dual band notch functions," *IET Microwaves, Antennas Propagation,* vol. 8, no. 8, pp. 541-548, 2014, doi: 10.1049/iet-map.2013.0311.

[15] D. Zhao, L. Lan, Y. Han, F. Liang, Q. Zhang and B. Wang, "Optically Controlled Reconfigurable Band-Notched UWB Antenna for Cognitive Radio Applications," in *IEEE Photonics Technology Letters*, vol. 26, no. 21, pp. 2173-2176, 1 Nov.1, 2014, doi: 10.1109/LPT.2014.2349961.

[16] P. Mayuri, N. D. Rani, N. B. Subrahmanyam, and B. T. Madhav, "Design and analysis of a compact reconfigurable dual band notched UWB antenna," *Progress In Electromagnetics Research C,* vol. 98, pp. 141-153, 2020, doi: 10.2528/PIERC19082903.

[17] L. C. Paul, M. H. Ali, R. Azim and T. K. Roy, "A Triple T-topped Planar Antenna for 5G/WiMAX Applications," *2021 3rd International Conference on Sustainable Technologies for Industry 4.0 (STI)*, 2021, pp. 1-5, doi: 10.1109/STI53101.2021.9732412.

[18] N. Waheed *et al*., "Ultra-Wideband antenna with WLAN and WiMAX band-notch characteristic," *2017 International Conference on Communication, Computing and Digital Systems (C-CODE)*, 2017, pp. 101-106, doi: 10.1109/C-CODE.2017.7918910.

[19] S. Gupta, S. Rawat, and S. Kumar, "A Compact Design of UWB Monopole Antenna with Dual Notched Bands for WiMAX Applications," *Journal of Nano- Electronic Physics,* vol. 14, no. 1, 2022, doi: 10.21272/jnep.14(1).01006.

[20] N. Taher, H. Elftouh, A. Zakriti, and N. A. Touhami, "CPW-fed planar ultra-wideband notched antenna at WiMAX frequency," vol. 32, pp. 723-728, 2019, doi: 10.1016/j.promfg.2019.02.276.

[21] M. Nejatijahromi, M. Rahman, and M. Naghshvarianjahromi, "Continuously tunable WiMAX band-notched UWB antenna with fixed WLAN notched band," *Progress In Electromagnetics Research Letters*, vol. 75, pp. 97-103, 2018, doi: 10.2528/PIERL18010819.

[22] A. S. Gour and D. Mathur, "A novel design UWB antenna having band notch characteristics," in *Proceedings of the SPIE*, 2013, vol. 8760, pp. 69-75, doi: 10.1117/12.2010240.

[23] P. K. Dhakar, R. K. Raj, D. Kumar, I. B. Sharma and R. Sharma, "A small square UWB antenna with dual rejection bands for WiMAX and WLAN applications," *2015 Communication, Control and Intelligent Systems (CCIS)*, 2015, pp. 25-30, doi: 10.1109/CCIntelS.2015.7437870.

[24] R. Kumar and Y. Kamatham, "Fork shaped with inverted L-stub resonator UWB antenna for WiMAX/WLAN rejection band," *AEU-International Journal of Electronics Communications*, vol. 110, p. 152881, 2019, doi: 10.1016/j.aeue.2019.152881.

[25] Z. P. Zhong *et al.*, "A compact CPW-fed UWB antenna with quadruple rejected bands," *Microwave and Optical Technology Letters*, vol. 61, no. 12, pp. 2795-2800, 2019, doi: 10.1002/mop.31976.

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