International Research Journal in Global Engineering and Sciences. (IRJGES)
ISSN : 2456-172X | Vol. 5, No. 4, December - February, 2021
Pages 16-24 | Cosmos Impact Factor (Germany): 5.195
Received: 02.12.2020 Published: 28.02.2021

COMPACTED UWB ANTENNA WITH TWO PORTS AND TRI-NOTCHED BAND PROPERTIES

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Abstract

This research presents a compact two-port MIMO antenna with tri-notched band characteristics specifically designed for UWB applications. This study employs notching methods to notch the co-existing wireless communication bands such as Worldwide Interoperability for Microwave Access (WiMAX), ARN band, and Wireless Local Area Network (WLAN). The UWB works within the frequency range of 3.1 to 10.6 gigahertz (GHz). The antenna has dimensions of 26 × 40 × 0.8 mm3 and is constructed on a low-cost FR4 substrate. The antenna comprises two rectangular monopole antennas, PM1 and PM2, that are powered by a 50-ohm coplanar waveguide. In order to minimise the mutual connection between them, the two patches are positioned perpendicular to each other. In order to reduce the mutual coupling and enhance the impedance bandwidth, a rectangular ground strip is inserted between two planar monopole antennas. This study describes the etching of T-shaped slots and inverted L-shaped slots on two patches to form notches at the WiMAX band (2.94-3.73 GHz) and the ARN band (4.35-5.05 GHz) correspondingly. In addition, U-shaped slots are strategically positioned on the feed lines of the two patches in order to effectively attenuate the WLAN frequency range (5.7-6.2 GHz). The simulation results demonstrate that the suggested antenna achieves a favourable impedance bandwidth ranging from 2 to 11 GHz, with a return loss (S11) of less than or equal to -10 dB and a mutual coupling (S21) of less than -20 dB. The findings indicate that the antenna exhibits a radiation efficiency over 90% and has very favourable radiation characteristics, with the exception of the notched bands. The antenna design is simulated using Ansoft HFSS Software.

Keywords: Band notch, frequency interference, HFSS software, isolation, multipath fading, multiple input multiple output (MIMO), mutual coupling, Ultra-wideband (UWB).

Introduction

Current and future technologies rely on wireless communication systems like 4G and 5G, which need increased data speeds, quality, and coexistence with narrow-band systems. The FCC allowed commercial ultra-wideband (UWB) uses in the unlicensed frequency range from 3.1 to 10.6 GHz in 2002 [1]. Due to its increased data speeds, low power, cheap cost, and excellent quality, UWB technology is increasing quickly in wireless personal area networks, radar systems, and imaging systems. However, frequency interference with other communication systems and multipath fading are the biggest UWB issues .

Short-range, high-speed data and wireless communication in ultra-wideband demands little power at high frequencies. Narrow band systems like WiMAX (2.94-3.73 GHz) and WLAN (5.15-5.825 GHz) may conflict with systems. The only way to remove frequency interference is using a UWB antenna with frequency notching at the offending frequency band. UWB has several wireless communication uses. Digital communication now largely uses MIMO technology to satisfy needs. MIMO uses multiple transmitter and receiver antennas. It boosts communication range and data rate without bandwidth [2,3]. Thus, the UWB system with MIMO technology is optimal for reducing multipath fading and improving

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service quality and capacity.

Mutual coupling is the electromagnetic interaction between MIMO antenna components. Portable devices' closely spaced antennas create high mutual interaction. Due to strong antenna signal correlation, this mutual coupling generates impedance mismatch, which reduces radiation efficiency and UWB antenna radiation pattern deviations, reducing MIMO system channel capacity. Thus, reducing antenna mutual coupling and isolating ports are crucial. Antenna designers struggle to fit several antennas in portable wireless devices [4]. Thus, a small UWB-MIMO antenna with band-notch features and low mutual coupling is necessary.

Recently, WLAN and WiMAX antenna designs [5,6] and UWBMIMO antenna designs [7-10] have been developed to reduce mutual coupling and increase antenna isolation. U-slots in antenna element feed lines [5,6], radiating elements perpendicular to each other and stubs to ground [7], etching a tree-like structure on the bottom ground [8], a T-shaped slot and a line slot on the ground [9], and a Y-shaped slot on the T-shaped protruded ground plane [10]. The UWB-MIMO antennas in [7-10] lack band notch features. Methods for creating notching functions include inserting $\lambda/4$ and $\lambda/2$ slot resonators on the ground plane [11], etching two rectangular stubs [12], and U-shaped slots in the antenna feed line [13, 14]. Isolation and notching characterise [11-14] antenna designs.

Few designs are small enough while others are intricate. Thus, a simple compact band-notched UWB-MIMO antenna with minimal mutual coupling is required. A Compact MIMO Antenna with WLAN Band-Notch Characteristics for Portable UWB Systems was proposed to increase antenna element isolation and impedance bandwidth [15].

A Compact Two-Port MIMO Antenna with Tri-Notched Band is presented for portable wireless devices in this study. The proposed antenna is 26 × 40 × 0.8mm3, which is smaller than previous designs [7-10, 13,14]. A 50-ohm coplanar waveguide excites two planar monopole antennas (PM1 and PM2) perpendicular to each other to decrease mutual coupling. The suggested antenna has a decent impedance bandwidth ($S11 \leq 10$ dB) and minimal mutual coupling ($S21 < -20$ dB T-shaped slots and inverted L-shaped slots are etched on two patches to generate notches at WiMAX (2.94-3.73 GHz) and ARN (4.35-5.05 GHz), and U-shaped slots are etched on PM1 and PM2 feed lines to create WLAN notches. VSWR < 2, high radiation efficiency, and favourable radiation characteristics are achieved by the proposed antenna.

Antenna Design:

Antenna Geometry

Fig.1(a) shows the triple-notch UWB-MIMO antenna configuration. The suggested antenna is 26 × 40 × 0.8mm3. The substrate has 0.8 mm thickness, 4.4 dielectric constant, and 0.02 loss tangent. On FR4 epoxy dielectric material, the antenna is engraved. The proposed antenna has two rectangular planar monopole radiating components (PM1 and PM2) with sizes LR × WR (see Fig.1(a)). Two rectangular planar monopole antennas are supplied by a 50-ohm waveguide measuring FL1 × WF. Joining LG × WG with LG × L creates common ground. The planar monopoles PM1 and PM2 are perpendicular to each other to decrease mutual interaction and increase antenna port isolation. To increase antenna impedance bandwidth and isolation, a rectangular SL × SW strip is extended from the ground plane between the monopoles. T-slot resonators are placed on the two patches to create the band notch at 2.93-3.73 GHz (WiMAX band), L-slot resonators are placed on the two patches below the T-slot resonator to create the band notch function at 4.35-5.05 GHz (ARN band), and a U-slot is placed on the two feed lines to create the band notch at 5.7-6.2 GHz. Table 1 shows the antenna dimensions designed using Ansoft's HFSS 13 version.

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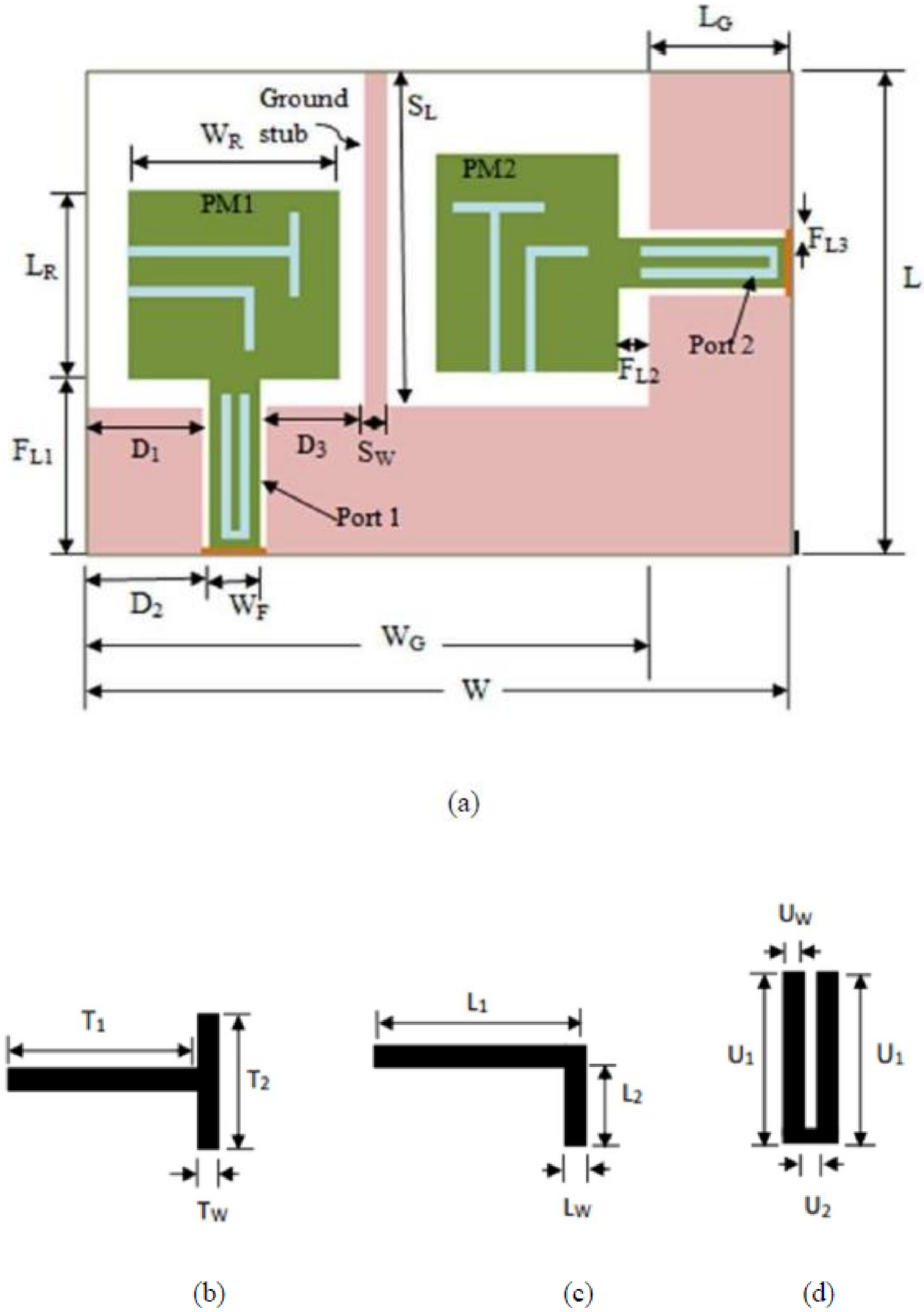

Fig.1 (a) Geometry of Proposed antenna, (b) T-slot resonator, (c) Inverted L-slot resonator, (d) U-slot resonator.

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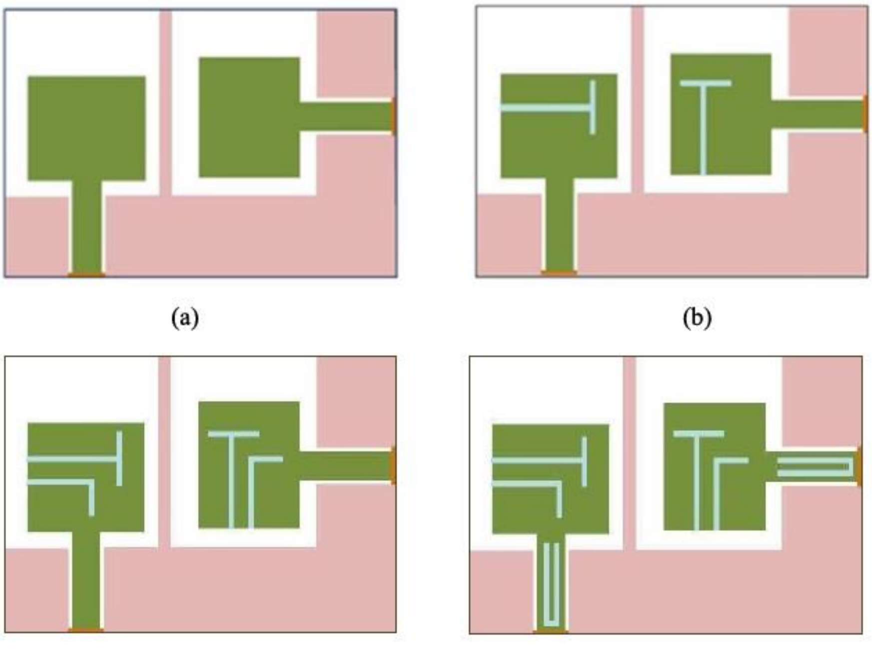
Table 1. Proposed UWB-MIMO antenna dimensions

Parameter	Value (mm)	Parameter	Value (mm)
L	26	WF	1.8
W	40	WG	3.2
D_1	5.1	WR	11
D_2	6.1	T1	8.7
D_3	11.2	T2	5.2
FL1	9.5	TW	0.3
FL2	1.5	L1	6.3
FL3	0.3	L2	3
L_G	8	LW	0.3
L_R	10	U1	7.6
SL	18	U2	0.4
SW	1	U_W	0.3

Antenna Evaluation and Working

Fig.2(a) shows the basic UWB-MIMO antenna, Antenna-1. Fig.2 and Fig.3 illustrate the triple band notched MIMO antenna's return loss and mutual coupling at each level. The antenna-1 in Fig.2(a) works from 2-11 GHz, as indicated in Fig.3. The single notch with T-shaped slot on the two radiating patches in Fig.2(b) of Antenna-2 notches the WiMAX band range from 2.8-3.73 GHz. Fig.2(c) shows a dual band notched antenna, Antenna-3, made by etching two inverted L-shaped slots on the two radiating patches of Antenna-2. At 2.8-3.73 and 4.26-5.06 GHz, Antenna-3 generates twin notches. Finally, Antenna-3's two feed lines are etched with WLAN band stop resonators to create the triple notch antenna. As illustrated in Fig.2(d), the suggested antenna provides the third notch from 5.73-6.29 GHz and 2.8-3.73 and 4.26-5.06 GHz bands.



(a) (b) (c) (d)

Fig.2 (a) Antenna-1 (b) Antenna-2 (c) Antenna-3 (d) Proposed antenna

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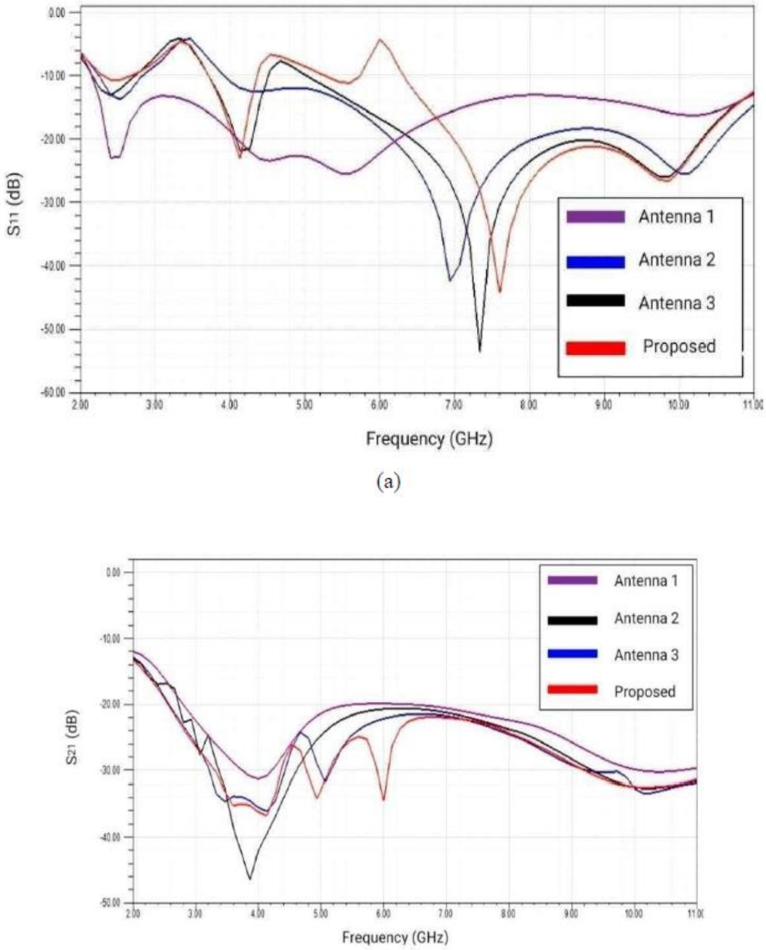

(a)

(b)

Fig.3 (a) Return loss parameters of Proposed antenna at four stages (b) Mutual coupling parameters of Proposed antenna at four stages

Effects of T-slot, L-slot, and U-slot:

This section presents the impact of T-slots, inverted L-shaped slots, and U-shaped slots of varying lengths on the return loss of UWB MIMO antenna at notch bands. The band-stop characteristics of this design are achieved by creating T-shaped and inverted L-shaped slots on the two radiating patches, as well as U-shaped slots on the feedlines of the two patches. The lengths of the notches at centre frequencies are λ/4, λ/4, and λ/2, where λ represents the guided wavelength determined by equation (1).

$$\lambda = c f N \sqrt{\varepsilon r + 1/2} \quad (1)$$

In addition, the lengths of the band notch resonators may be calculated using equations (2) and (3) as follows:

LN1 = LN2 (2)

LN3 (3)

The symbol c represents the velocity of light, fN represents the notch centre frequency, LN1, LN2, LN3

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represent the total lengths of the resonators, and εr indicates the dielectric constant. The correct notching locations may be obtained by selecting appropriate resonator lengths, as shown by equation (2) and equation (3). The computed total lengths for frequencies of 3.32 GHz, 4.7 GHz, and 5.95 GHz are 13.7mm, 9mm, and 15.3mm respectively, with an εr value of 4.4. On the other hand, the planned total lengths for frequencies of 3.26 GHz, 4.66 GHz, and 6.01 GHz are 13.9mm, 9.3mm, and 15.6mm respectively. The impact of the resonator lengths on the placements of the notch bands and their centre frequency is evident from equation (2) and equation (3). The resonator's notch frequency is inversely proportional to its length.

Results and Discussion

Fig.4 (a) to (d) show the surface current distributions for T-slot, L-slot, and U-slot at frequencies of 3.32 GHz, 4.7 GHz, 5.95 GHz, and the resonant frequency of 9.8 GHz, respectively. The numbers below indicate that the antenna does not emit energy at the notching slots. Consequently, the suggested antenna efficiently mitigates the frequency interference caused by the current narrow band systems. As a result, the antenna emits a greater amount of energy while maintaining a good return loss, which is below -10dB.

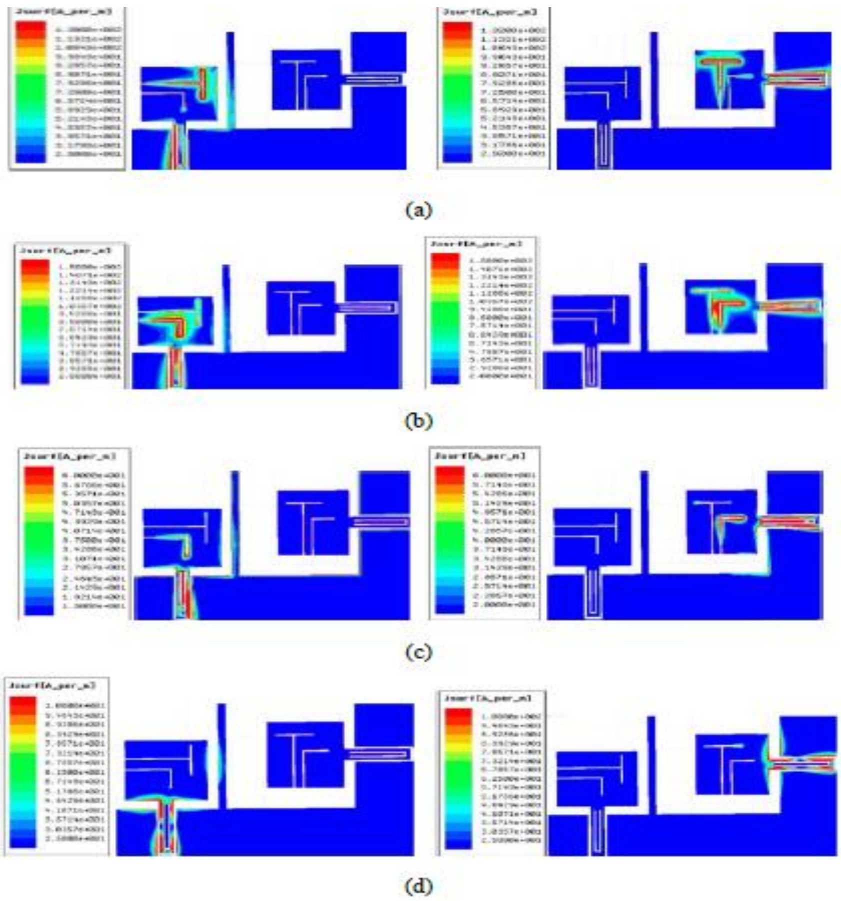

Fig.4 (a) Current distribution at 3.32 GHz when port-1 and port-2 are excited.
(b) Current Distribution at 4.7 GHz when port-1 and port-2 are excited.
(c) Current Distribution at 5.95 GHz when port-1 and port-2 are excited.
(d) Current Distribution at 9.8 GHz when port-1 and port-2 are excited.

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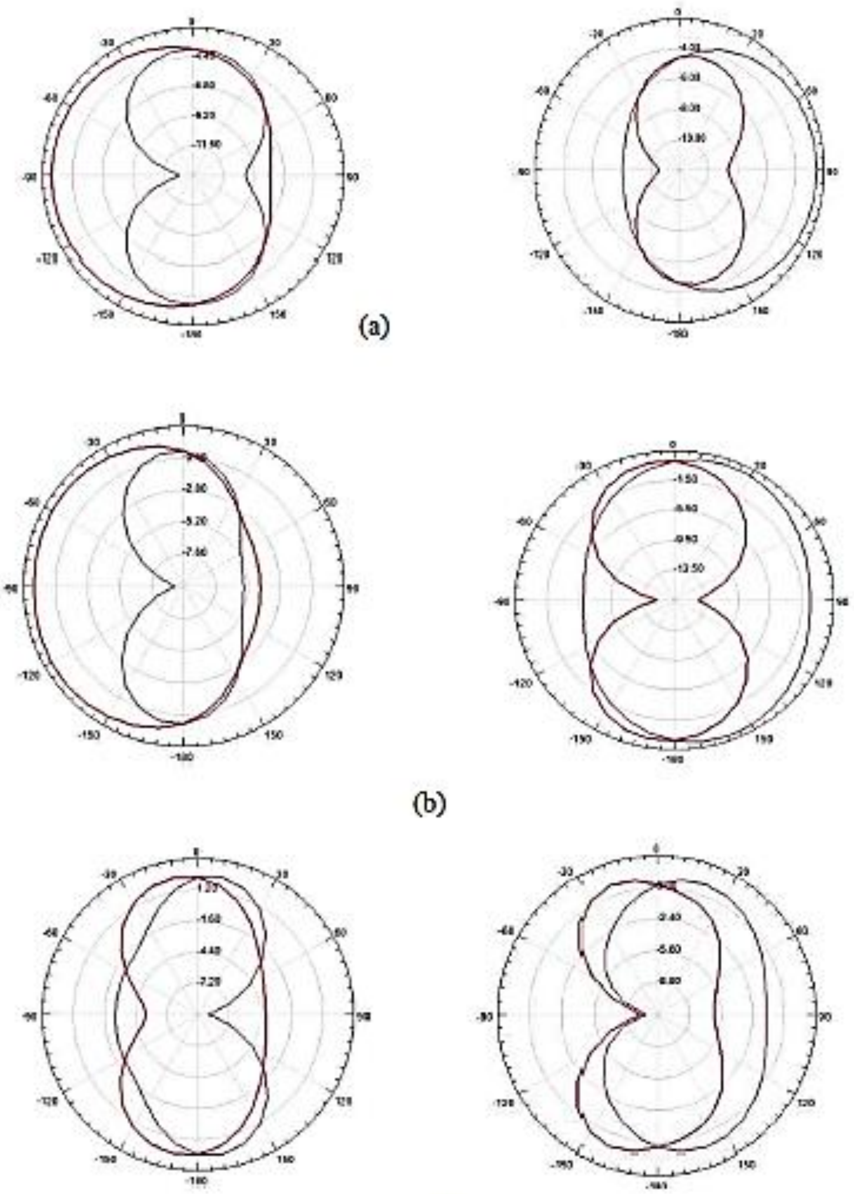
The Fig.5 (a) to (c) show the simulated 2-D radiation patterns of the Proposed antenna on the E-Plane and H-Plane for frequencies of 4.1 GHz, 7.6 GHz, and 9.8 GHz. The antenna exhibits a bi-directional pattern in the E-Plane and an omnidirectional pattern in the H-Plane.



(c)

Fig.5 (a) Radiation patterns at 4.13 GHz when port-1 and port-2 are excited.
(b) Radiation patterns at 7.6 GHz when port-1 and port-2 are excited.
(c) Radiation patterns at 9.8 GHz when port-1 and port-2 are excited.

Figure 6 displays the VSWR, whereas Figure 7 illustrates the radiation efficiency of the antenna under consideration. The VSWR is less than 2 and the Radiation efficiency is over 90% throughout the frequency range of 2 to 11 GHz, except at the band notches. The findings demonstrate that the suggested antenna successfully mitigates the interference caused by narrow band systems.

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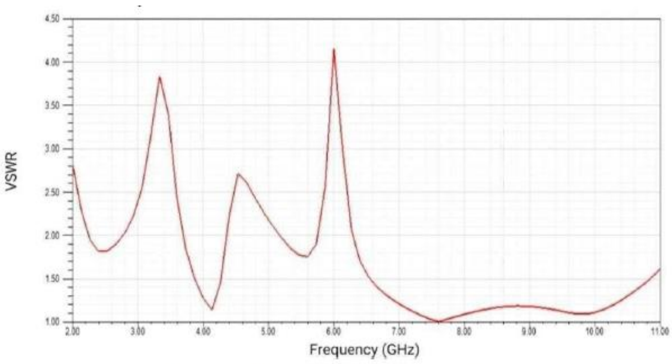

Fig.6 Simulated VSWR characteristics

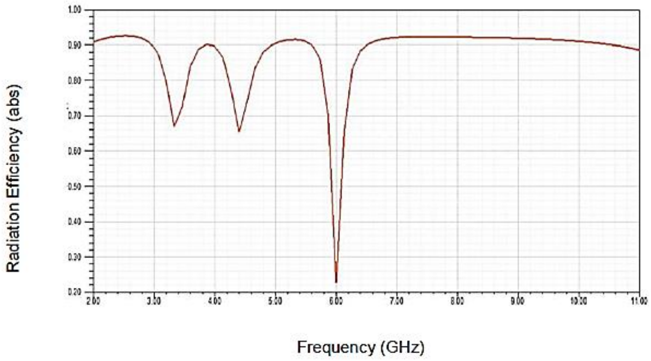

Fig.7 Simulated Radiation efficiency

Conclusion

This study proposes a Compact Two-Port MIMO antenna with Tri-Notched band characteristics at WiMAX, ARN, and WLAN bands for portable wireless Ultra-wideband systems. The MIMO antenna design consists of two rectangular monopoles that are connected to a 50-ohm coplanar waveguide for feeding. The two patches are positioned at right angles to each other in order to minimise the interference between them. In order to increase the level of isolation and optimise the impedance matching, a rectangular strip is added to the ground plane. The two patches are etched with T-shaped slots and inverted L-shaped slots to form notches at the WiMAX band (2.94-3.73 GHz) and ARN band (4.35-5.05 GHz) accordingly. In addition, U-shaped slots are strategically positioned on the feed lines of the two patches in order to effectively attenuate the WLAN frequency range (5.7-6.2 GHz). The simulation results demonstrate that the Proposed antenna achieves a favourable impedance bandwidth ranging from 2 to 11 GHz, with a return loss (S11) of less than or equal to -10 dB and a mutual coupling (S21) of less than -20 dB. The findings indicate that the antenna exhibits a radiation efficiency over 90% and has very favourable radiation characteristics, with the exception of the notched bands.

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