International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 14, Number 1 (2021), pp. 1-14

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Compact Two-Port MIMO Antenna with Tri-Notched Band Characteristics for UWB Applications

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Abstract

A Compact Two-Port MIMO Antenna with Tri-Notched Band Characteristics for UWB Applications is presented in this paper. The co-existing wireless communication bands like Worldwide Interoperability for Microwave Access (WiMAX), ARN band and Wireless Local Area Network (WLAN) are notched in this paper by using notching techniques. The UWB operates at the frequency range of 3.1-10.6 GHz. The overall size of the antenna is 26 × 40 × 0.8 mm^3 and it is fabricated on a low-cost FR4 substrate. The antenna consists of two rectangular monopole antennas PM1 and PM2, which are fed by 50-ohm coplanar waveguide. The two patches are placed perpendicularly in order to reduce the mutual coupling between them. To further minimize the mutual coupling and also to increase the impedance bandwidth a rectangular ground strip is protruded between two planar monopole antennas. In this paper, T-shaped slots and inverted L-shaped Slots are etched on the two patches to create notches at WiMAX band (2.94-3.73 GHz) and ARN band (4.35-5.05 GHz) respectively. Also U-shaped slots are placed on the feed lines of the two patches to suppress the WLAN band (5.7-6.2 GHz). The simulated results shows that the proposed antenna achieves the good impedance bandwidth which is obtained from 2-11 GHz with return loss ($S_{11} \leq$ -10 dB) and the mutual coupling ($S_{21} <$ -20 dB). The results show that the antenna has the radiation efficiency above 90% and considerably good radiation properties except at the notched bands. The antenna design is simulated by using Ansoft HFSS Software.

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

1. INTRODUCTION:

The present and future technologies mostly depend on wireless communication systems like 4G and 5G demand for higher data rates, enhanced quality and coexistence with the existing narrow-band communication systems. In 2002, The Federal Communications Commission (FCC) authorised the unlicensed frequency spectrum from 3.1 to 10.6 GHz as ultra-wideband (UWB) for commercial applications [1]. The UWB technology has been growing rapidly due to its advantages like higher data rates, low power, low cost, and good quality and its applications like wireless personal area networks, radar systems and imaging systems. However, in UWB the frequency interference with other communication systems and multipath fading are the major problems that are needed to be solved.

Ultra-wideband is a short range, high-speed data and wireless communication which requires low power to operate in high frequencies. The existing narrow band systems like WiMAX (2.94-3.73 GHz), WLAN (5.15-5.825 GHz) may cause frequency interference to systems. Therefore, UWB antenna with frequency notching function at the interfering frequency band is the only solution which eliminates the frequency interference. UWB has many applications in the wireless communication technologies.

In recent times, Digital communication is mostly using multiple input multiple output (MIMO) technology to meet the requirements. The MIMO system consists of multiple antennas at the transmitter and the receiver. It improves the communication range and data rate without the need of additional bandwidth [2,3]. Hence, the UWB system with MIMO technology is the best solution to reduce multipath fading and to improve the quality of service and the system capacity.

The electromagnetic interaction between the antenna elements in MIMO system is known as mutual coupling. The closely spaced antennas in portable devices cause strong mutual coupling between antennas. This mutual coupling causes impedance mismatch which degrades radiation efficiency and UWB deviations in antenna radiation pattern due to its high correlation between antenna signals and therefore decreases the channel capacity of MIMO system. So, the reduction of mutual coupling between antennas and isolation between ports are essential. However, placing multiple antennas in a limited space of portable wireless device is a big challenge for antenna designers [4]. Therefore, the design of a compact UWB- MIMO antenna with band-notch functions and less mutual coupling is essential.

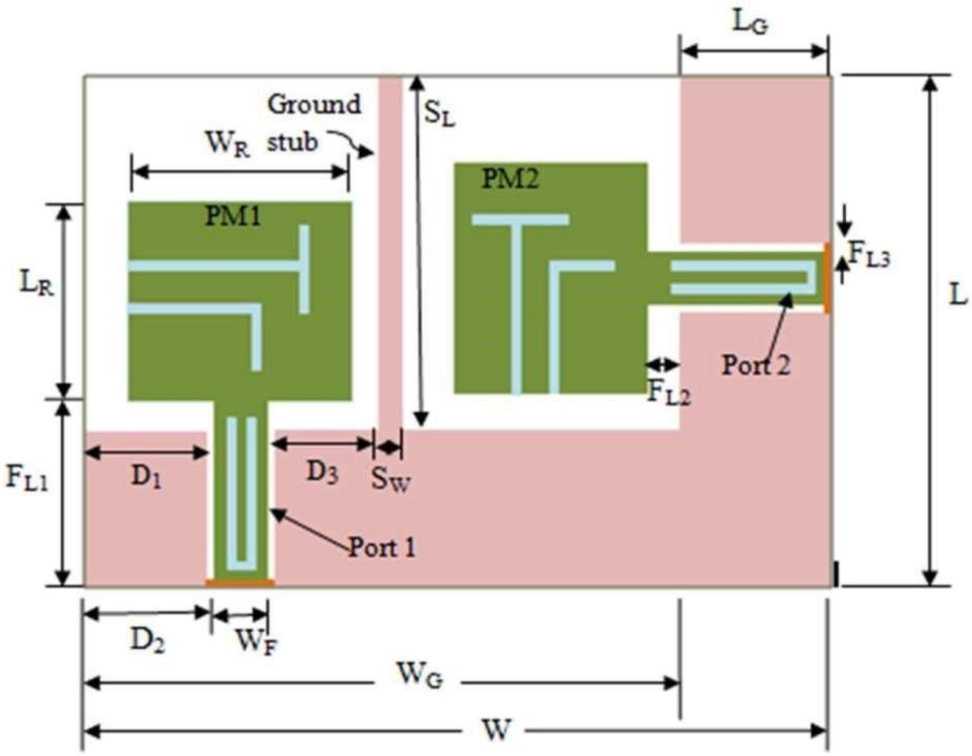
Various antenna designs have been proposed in the past years for WLAN and WiMAX in [5,6], and for UWBMIMO systems in [7-10] to minimize mutual coupling and to improve the isolation between the antenna elements. The designs include placing U-slot in the feed line of the antenna elements [5,6], adding radiating elements perpendicular to each other and inserting 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 adding a Y-shaped slot on the T-shaped protruded ground plane [10]. However, the UWB-MIMO antennas in [7-10] do not provide any band notch characteristics. To create notching functions, Methods include inserting $\lambda/4$ and $\lambda/2$ slot resonators on the ground plane [11], etching two rectangular stubs on the ground plane [12], U-shaped slots in the feed line of the antenna [13, 14]. The antenna designs in [11-14] exhibit isolation and notching characteristics. But some designs are not compact enough and a few are complex in nature. Hence, the design of a simple compact band-notched UWB-MIMO antenna with low mutual coupling is needed. To further improve the isolation between the antenna elements and the impedance bandwidth, a Compact MIMO Antenna with WLAN Band-Notch Characteristics for Portable UWB Systems was designed [15].

In this paper, a Compact Two-Port MIMO Antenna with Tri-Notched Band characteristics for portable wireless devices is proposed. The dimensions of the Proposed antenna are $26 \times 40 \times 0.8mm^3$ which is small when compared to the other designs presented earlier in [7-10, 13,14]. The proposed design consists of two planar monopole antennas (PM1 and PM2) which are placed perpendicular to each other to reduce mutual coupling and are excited by a 50-ohm coplanar waveguide. The proposed antenna achieves good impedance bandwidth ($S_{11} \leq 10$ dB) and low mutual coupling ($S_{21} < -20$ dB). To create notches at WiMAX band (2.94-3.73 GHz) and ARN band (4.35-5.05 GHz), T-shaped slots and inverted L-shaped slots are etched on two patches respectively and Ushaped slots are etched on the feed lines of PM1 and PM2 to create notch at WLAN band (5.7-6.2 GHz). Good VSWR < 2, high radiation efficiency and good radiation characteristics are obtained by the Proposed antenna.

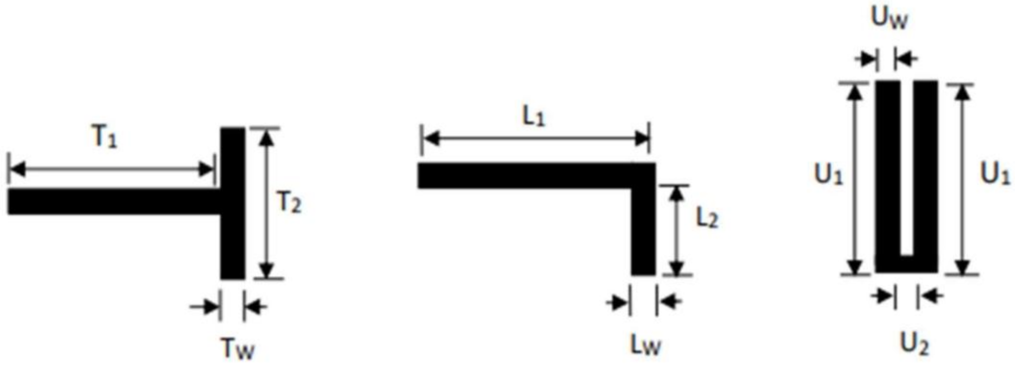
2. ANTENNA DESIGN:

2.1 Antenna Geometry

The geometry of the Proposed UWB-MIMO antenna with triple notch is depicted in Fig.1(a). The size of the proposed antenna is $26 \times 40 \times 0.8mm^3$. The Substrate is having thickness of 0.8 mm, dielectric constant of 4.4 and loss tangent of 0.02. The antenna is etched on FR4 epoxy dielectric material. The proposed antenna comprises of two rectangular planar monopole radiating elements namely PM1 and PM2 having sizes $L_R \times W_R$ as shown in Fig.1(a). The two rectangular planar monopole antennas are fed by the 50-ohm waveguide having the dimensions of $F_{L1} \times W_F$. By joining $L_G \times W_G$ and $L_G \times L$ common ground is formed. To improve the isolation between antenna ports and to reduce the mutual coupling, the planar monopoles PM1 and PM2 are positioned perpendicularly to each other. To improve the impedance bandwidth of an antenna and further enhance isolation, a rectangular long strip of $S_L \times S_W$ is extended from the common ground plane between the monopoles. T-slot resonator shown in Fig.1(b) is placed on the two patches to create the band notch at 2.93-3.73 GHz (WiMAX band), L-slot resonator in Fig.1(c) is 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 which is shown in Fig.1(d) is placed on the two feed lines to create the band notch at 5.7-6.2 GHz (WLAN band). Ansoft's HFSS 13 version is used to design the proposed antenna and the dimensions are shown in the Table 1.



(a)



(b) (c) (d)

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

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

2.2 Antenna Evaluation and Working

Antenna-1 is the basic UWB-MIMO antenna which is shown in Fig.2(a). Fig.2 and Fig.3 shows the evaluation of the triple band notched MIMO antenna and the corresponding return loss and mutual coupling at each stage. The Antenna-1 which is shown in Fig.2(a) is working from 2-11 GHz as observed from Fig.3. The Antenna-2 shown in Fig.2(b) constitutes single notch with T-shaped slot on the two radiating patches which notches the WiMAX band range from 2.8-3.73 GHz. By etching a couple of inverted L-shaped slots are incorporated on the two radiating patches of Antenna-2, dual band notched antenna namely Antenna-3 which is shown in Fig.2(c) can be formed. Antenna-3 is generating dual notches from 2.8-3.73 GHz and 4.26-5.06 GHz. Finally, the proposed triple notch antenna is designed by etching WLAN band stop resonator on the two feed lines of Antenna-3. The proposed antenna is providing the third notch from 5.73-6.29 GHz in addition to 2.8-3.73 and 4.26-5.06 GHz bands as shown in Fig.2(d).

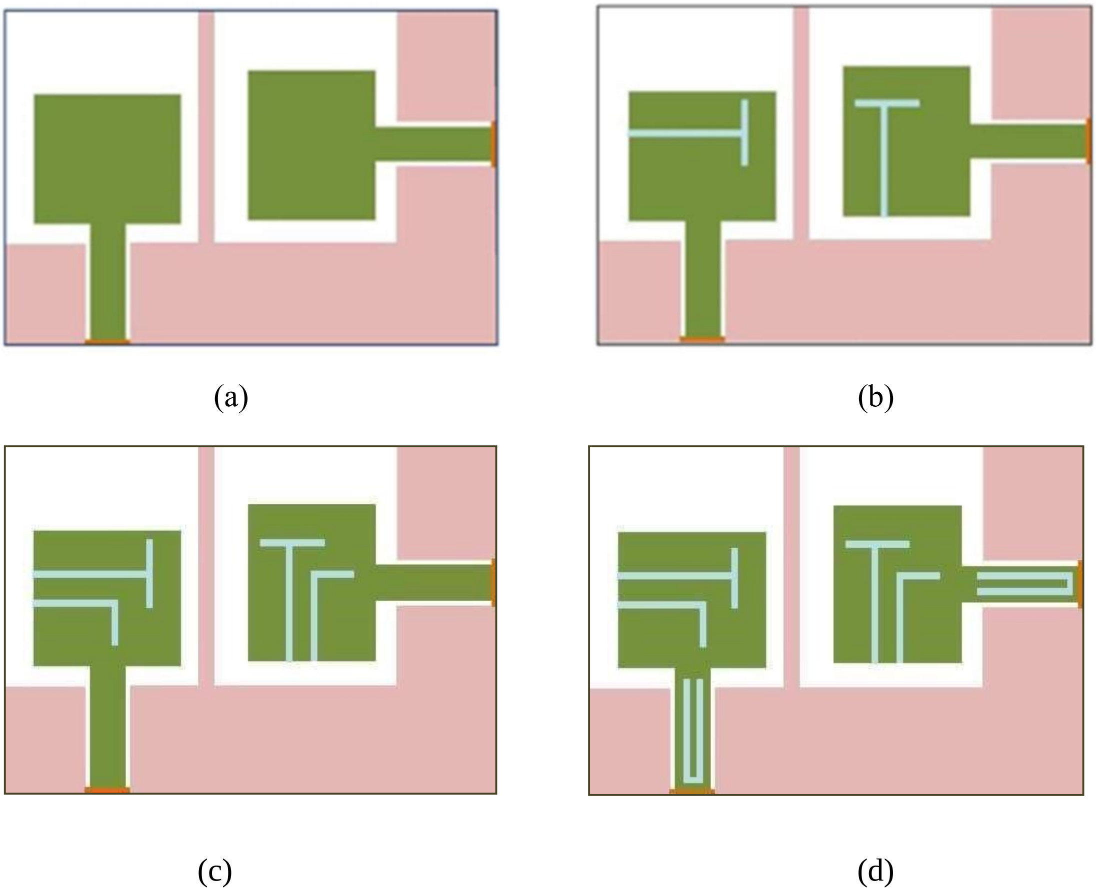
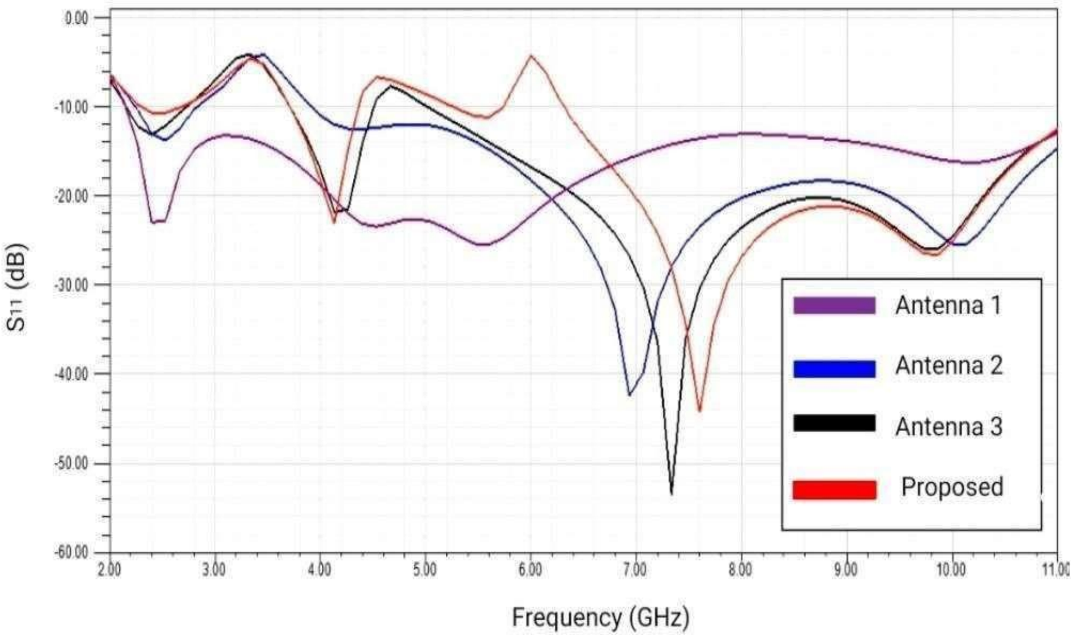
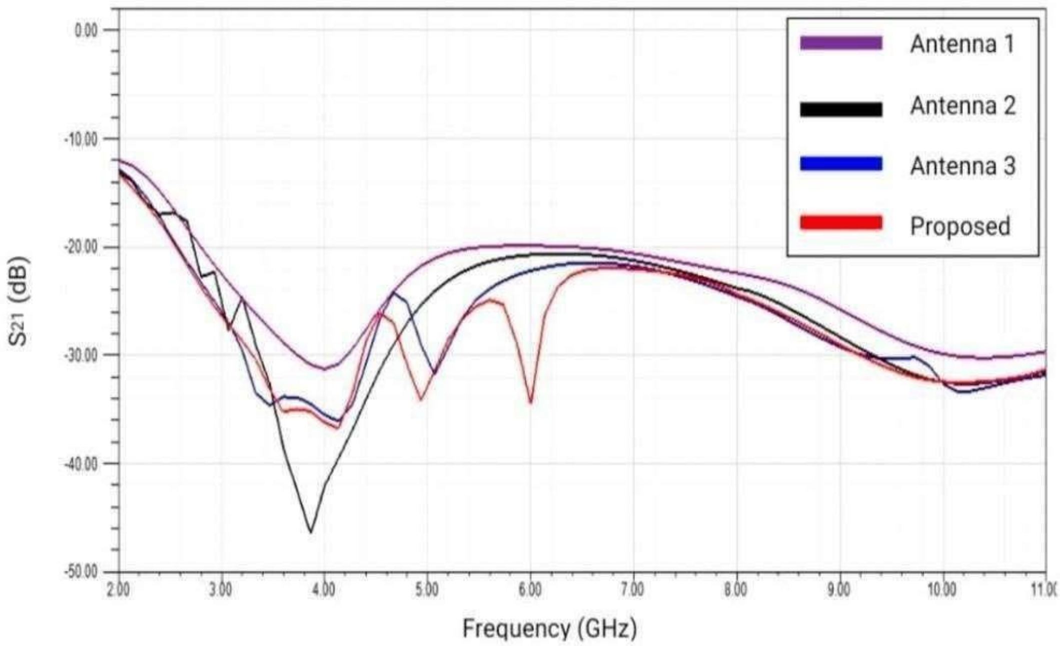


Fig.2 (a) Antenna-1 (b) Antenna-2 (c) Antenna-3 (d) Proposed antenna



(a)



(b)

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

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

The effects of T-slots, inverted L-shaped slots and U-shaped slots with different lengths on the return loss of UWB MIMO antenna at notch bands are presented in this section. In this design, the band-stop features are attained by etching T-shaped slots and inverted L-shaped slots on the the two radiating patches and U-shaped slots on the feedlines of the two patches. The lengths of the notches at center frequencies are having lengths λ/4, λ/4 and λ/2 where λ is the guided wavelength, which is specified by the equation (1).

$$\lambda = \frac{c}{f_N\sqrt{\varepsilon_r + 1/2}} \tag{1}$$

Moreover, the overall lengths of the band notch resonators can be determined using the equation (2) and equation (3) which are given by

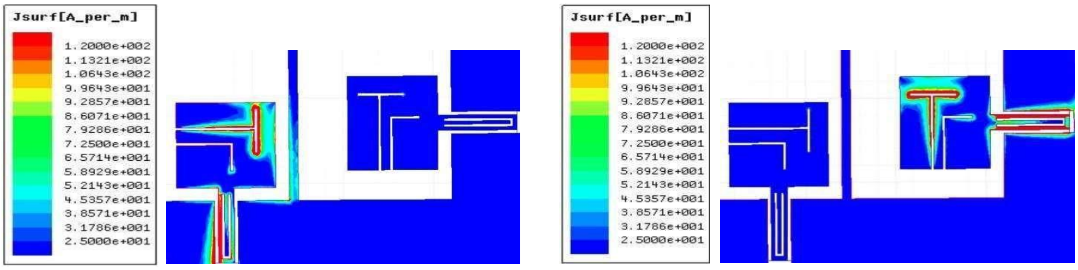
$$L_{N1} = L_{N2} = \frac{c}{4f_N\sqrt{(\varepsilon_r + 1)/2}} \tag{2}$$

$$L_{N3} = \frac{c}{2f_N\sqrt{(\varepsilon_r + 1)/2}} \tag{3}$$

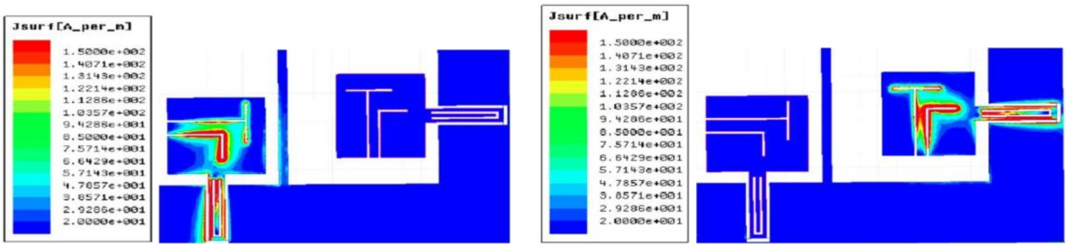
Where c is the velocity of light, f_N denotes the notch center frequency, L_{N1}, L_{N2}, L_{N3} represents the total lengths of the resonators and ε_r indicates the dielectric constant. From equation (2) and equation (3), the desired notching positions are determined by the selection of suitable resonator lengths. With ε_r of 4.4, the calculated total lengths are 13.7mm at 3.32 GHz, 9mm at 4.7 GHz and 15.3mm at 5.95 GHz whereas the designed total lengths are 13.9mm at 3.26 GHz, 9.3mm at 4.66 GHz and 15.6mm at 6.01 GHz. It is clearly observed from equation (2) and equation (3) that the resonators lengths have a significant effect on the notch band positions and its center frequency. The length of the resonator is inversely proportional to its notch frequency.

3. RESULTS AND DISCUSSION

Fig.4 (a) to (d) shows the surface current distributions for T-slot, L-slot and U-slot at 3.32 GHz, 4.7 GHz, 5.95 GHz and at the resonant frequency of 9.8 GHz respectively. The below figures shows that the antenna doesn't radiate the energy at the notching slots. Therefore, the proposed antenna effectively suppresses the frequency interference from the existing narrow bands systems and hence, the antenna radiates more energy with a good return loss which is less than -10dB.



(a)



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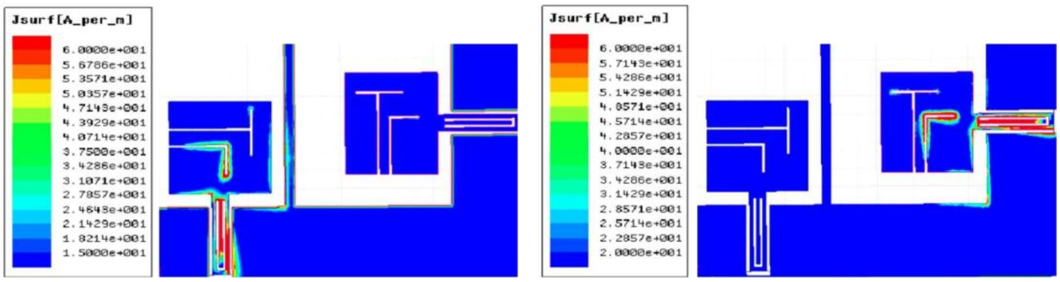
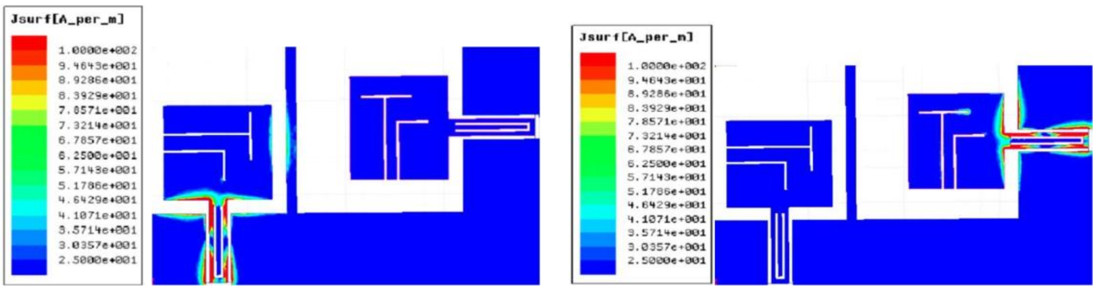


(c)



(d)

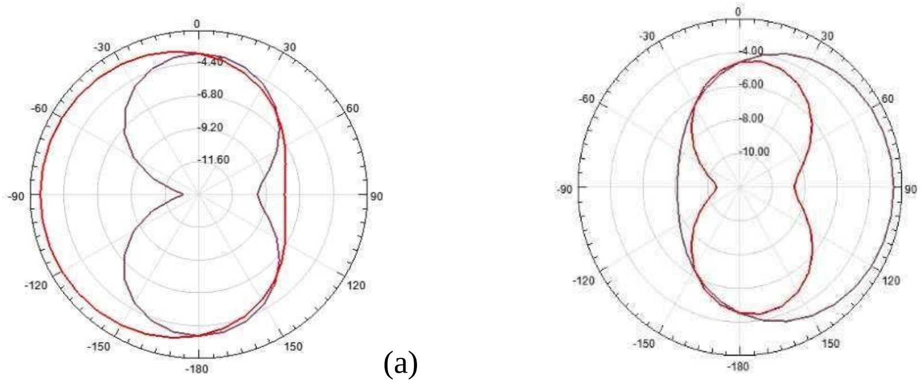
Fig.4 (a) Current distribution at 3.32 GHz when port-1 and port-2 are excited.

(b) Current Distribution at 4.7 GHz when port-1 and port-2 are excited.

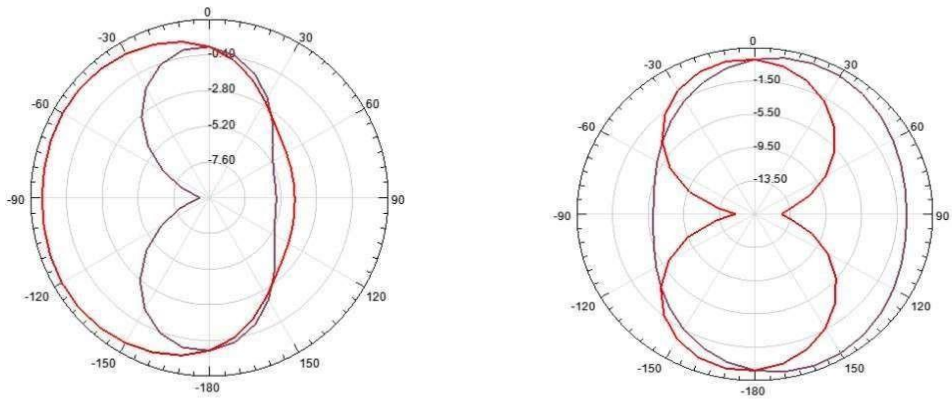
(c) Current Distribution at 5.95 GHz when port-1 and port-2 are excited.

(d) Current Distribution at 9.8 GHz when port-1 and port-2 are excited.

The simulated 2-D radiation patterns of the Proposed antenna on the E-Plane, H-Plane at 4.1 GHz, 7.6 GHz and 9.8 GHz shown in Fig.5 (a) to (c). The antenna achieves the bi-directional pattern on the E-Plane and Omni directional pattern on the H-Plane.



(a)



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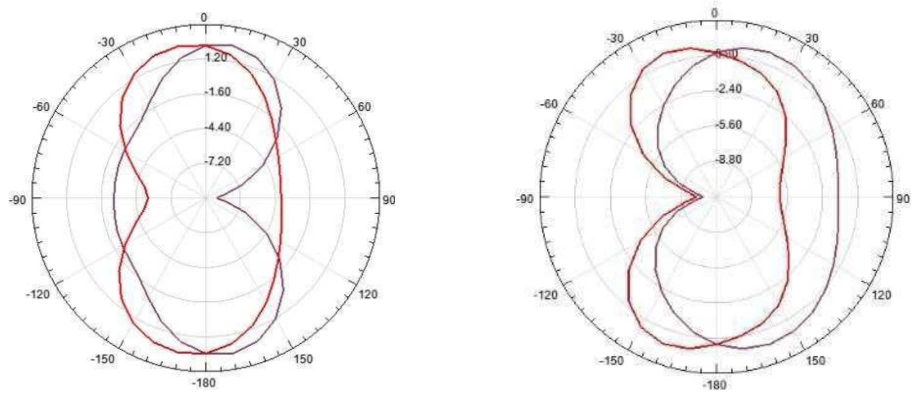

(c)

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.

The VSWR and the radiation efficiency of the proposed antenna are shown in Fig.6 and Fig.7 respectively. The VSWR < 2 and the Radiation efficiency of above 90% throughout the working band 2 to 11 GHz are achieved excluding at the band notches. These results shows that the proposed antenna effectively suppresses the interference from narrow band systems.

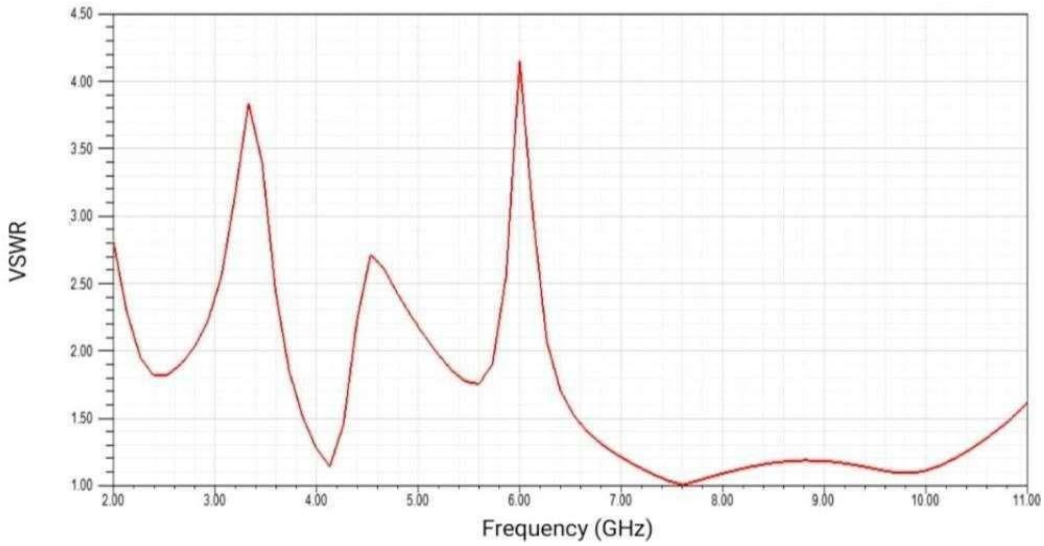

Fig.6 Simulated VSWR characteristics

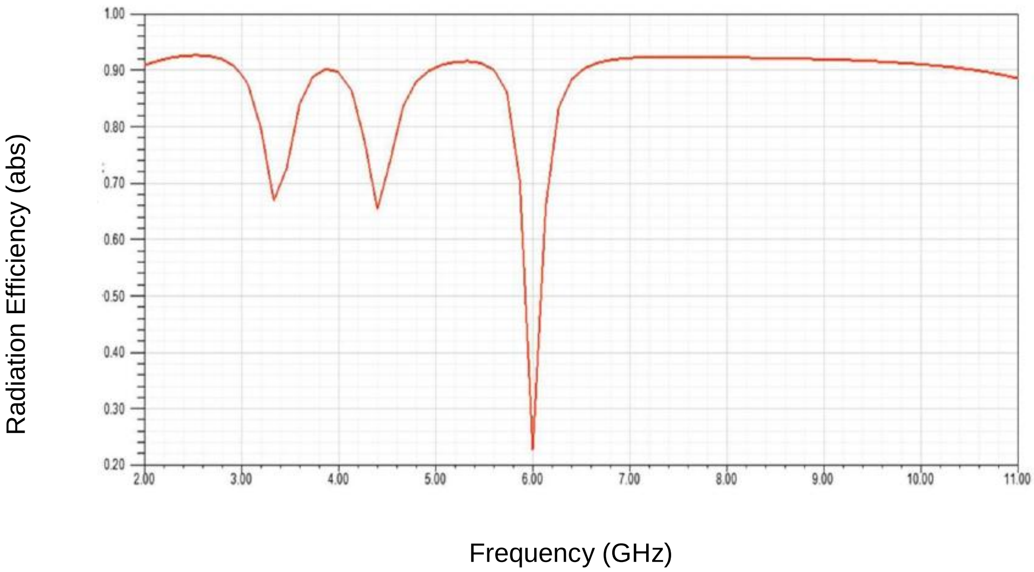

Fig.7 Simulated Radiation efficiency

4. CONCLUSION

In this paper, a Compact Two-Port MIMO antenna with Tri-Notched band characteristics at WiMAX, ARN and WLAN bands are proposed for portable wireless Ultra-wideband systems. The Proposed MIMO antenna comprises of two rectangular monopoles which are fed by 50-ohm coplanar wave guide. The two patches are placed perpendicularly in order to reduce the mutual coupling. To enhance the isolation and to improve the impedance matching, a rectangular strip is extended from the ground plane. T-shaped slots and inverted L-shaped slots are etched on the two patches to create notches at WiMAX band (2.94-3.73 GHz) and ARN band (4.35-5.05 GHz) respectively. Also U-shaped slots are placed on the feed lines of the two patches to suppress the WLAN band (5.7-6.2 GHz). The simulated results shows that the Proposed antenna achieves the good impedance bandwidth which is obtained from 2-11 GHz with return loss ($S_{11} \leq$ -10 dB) and the mutual coupling ($S_{21} <$ -20 dB). The results show that the antenna has the radiation efficiency above 90% and considerably good radiation properties except at the notched bands.

REFERENCES:

[1] Federal Communications Commission (FCC), "Revision of part 15 of the commission's rules regarding ultrawideband transmission systems first rep. and order," ET Docket 98-153, FCC 02-48, Adopted: Feb. 2002; Released: Apr. 2002.

[2] Kaiser, T., Z. Feng, and E. Dimitrov, "An overview of ultra-wide-band systems with MIMO," Proceedings of the IEEE, Vol. 97, 285–312, Feb. 2009.

[3] Ben, I.M., L. Talbi, M. Nedil, and K. Hettak, "MIMO-UWB channel characterization within an underground mine gallery," IEEE Trans. Antennas Propagation, Vol. 60, No. 10, 4866–4874, 2012.

[4] Zheng, L. and N.C. Tse, "Diversity and multiplexing: A fundamental trade-off in multiple-antenna channels," IEEE Trans. Inf. Theory, Vol. 49, No. 5, 1073–1096, 2003.

[5] Yahya, L.S., K.H. Sayidmarie, F. Elmegri, and R.A. Abd-Alhameed, "Arc-shaped monopole antennas with reduced coupling for WLAN and WIMAX applications," Proc. of IEEE 7th International Conference Internet Technologies and Applications (ITA), 218–223, Wrexham, Wales, UK, 2017.

[6] Sayidmarie, K.H. and L.S. Yahya, "Double-monopole crescent-shaped antennas with high isolation for WLAN and WIMAX applications," Frequency (GHz) Antenna Fundamentals for Legacy. Mobile Applications and Beyond, I. Elfergani, et al., eds., Chap. 3, Springer, 2018.

[7] Liu, L., S.W. Cheung, and T.I. Yuk, "Compact MIMO antenna for portable devices in UWB applications," IEEE Trans. Antennas Propagation, Vol. 61, 4257–4264, 2013.

[8] Zhang, S., Z.N. Ying, J. Xiong, and S.L. He, "Ultrawideband MIMO/diversity antennas with a tree-like structure to enhance wideband isolation," IEEE Antennas Wireless Propag. Lett., Vol. 8, 1279– 1282, 2009.

[9] Luo, C.M., J.S. Hong, and L.L. Zhong, "Isolation enhancement of very compact UWBMIMO slot antenna with two defected ground structures," IEEE Antennas Wireless Propag. Lett., Vol. 14, 1766–1769, 2015.

[10] Tao, J. and Q. Feng, "Compact ultrawideband MIMO antenna with half-slot structure," IEEE Antennas Wireless Propag. Lett., Vol. 16, 792–795, 2017.

[11] Zheng, Z.A., Q.X. Chu, and Z.H. Tu, "Compact band-rejected ultrawideband slot antennas inserting with λ/2 and λ/4 resonators," IEEE Trans. Antennas Propagation, Vol. 59, No. 2, 390– 397, 2011.

[12] Liu, L., S.W. Cheung, and T.I. Yuk, "Compact MIMO antenna for portable UWB applications with bandnotched characteristic," IEEE Trans. Antennas Propagation, Vol. 63, No. 5, 1917–1924, 2015.

[13] Sayidmarie, K.H. and T.A. Nagem, "Performance evaluation of band-notch techniques for printed dual band monopole antennas," International Journal of Electromagnetics and Applications, Vol. 3, No. 4, 70–80, 2013.

[14] Majeed, A.H., A.S. Abdullah, K.H. Sayidmarie, R. A. Abd-Alhameed, F. Elmegri, and J.M. Noras, "Compact dielectric resonator antenna with band-notched characteristics for ultrawideband applications," Progress in Electromagnetics Research C, Vol. 57, 137–148, 2015.

[15] Chandrasekhar R. Jetti, Venkateswara R. Nandanavanam, "Compact MIMO Antenna with WLAN BandNotch Characteristics for portable UWB systems," Progress in Electromagnetics Research C, Vol. 88, 1-12, 2018.

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