International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

A Compact Semi Square Split Ring Resonator Slotted Flag Shaped MIMO Antenna for Band Notched UWB Applications

B.Priyadharshini, B.T.P Madhav, M.Hema Sasank, M Venkateswara Rao, P Vamsi Krishna, J.J.S.N.S.K kavya, K.Abhinav Narayana

Abstract*: In this articlea band notched multiple-input-multiple-output (MIMO) antenna with improved isolation is presented. The proposed antenna consists of a semi square split ring resonator (SRR) which is slotted on the two flag shaped patches. Two inverted semi square SRR are placed in the patch to get notch at WIMAX band (3.3GHz-3.8GHz) throughout the band the isolation is above 11db is observed and it is achieved with the placement of T-shaped stub on the ground plane. Proposed antenna is fabricated on FR4 epoxy substrate and simulated and measured results have been verified. The proposed antenna works at WLAN band (at 5.64GHz) and satellite communication (at 7.42GHz). In respect to this the envelope correlation coefficient (ECC), diversity gain (DG) and radiation patterns are discussed.

Index Terms*: Semi square split ring resonator (SRR), multiple-input-multiple-output (MIMO), ultra-wideband (UWB), envelope correlation coefficient (ECC), and diversity gain (DG).

I. INTRODUCTION

As the back bone of 4G and 5G wireless communications, multiple-input-multiple-output(MIMO) technology has immensely drawn attention in recent years due to its salient features such as high data rate and ability to mitigate multipath fading without sacrificing transmitted power. Semi square split ring resonator structure has been used in this paper to achieve notch band as well as high isolation after the notch band.Ultra-wideband technology is the technique predominantly used in wireless communication because of its high data rate, immunity to multipath interference and low power consumption.

Revised Manuscript Received on 30 May 2019.

***** Correspondence Author

B.Priyadharshini*, Assistant professor at K L University.

B.T.P Madhav, Professor and Communication Systems research Head in the Electronics and Communication Engineering .

M.Hema Sasank, pursuing his Bachelor of Technology in the department of Electronics and communication Engineering at K L University.

M Venkateswara Rao, pursuing his Ph.D. in Metamaterial Antennas from Antennas and Liquid Crystals Research Centre of ECE department, K L Deemed to be University.

P Vamsi Krishna, pursuing bachelor of technology in the department of electronics and communication engineering at K L University.

J.J.S.N.S.K kavya, pursuing bachelor of technology in the department of electronics and communication engineering at KL University.

K.Abhinav Narayana, pursuing bachelor of technology in the department of electronics and communication engineering at KL University.

It is best suited for short range communication and its bandwidth requirement is equitable i.e. in terms of GHz [1-2]. Introducing one or more notch bands enhance the isolation of MIMO[3].The Coplanar Waveguide (CPW) fed radiating elements are separated by a metal strip which acts as a reflector of EM waves and decreases mutual coupling. The dual band notched antenna has a square split ring resonator(S-SRR) which increases isolation between the resonating frequencies. The SRR reduces the radiation effect of one element on the other [4].

High isolation S_{12}>20dB is achieved in [5] by placing different sized split ring resonators (SRR) between two monopole antennas ,one operating in UWB region and other operating with broadband applications. It has very low envelope correlation coefficient (ECC) and radiation effect of one element of other is reduced.SRR in 4 elements and 8 element orthogonal structures for resonating at WIFI/WIMAX/4G/LTE and 5G applications to provide isolation between the lower bands and enhance inter-radiator coupling efficiency [6].Due to the advancements regarding antenna size, the demand for miniaturized structures increased. As an effect of it, MIMO antenna needs to handle several problems such as mutual coupling. When the MIMO elements are not well spatially diversified then it leads to increase in envelope correlation coefficient (ECC), reduced gain, increased mutual coupling and increases loss in channel capacity. Disparate methods are investigated to isolate and decouple the radiating elements. Two bent slits are kept in the ground plane structure to enhance impedance bandwidth at higher frequencies and to mitigate mutual coupling at lower frequencies [7]. The perpendicular geometry of the radiating elements of the MIMO and presence of narrow slot causes high isolation and reduced of mutual coupling [8]. A rotationally symmetrical MIMO antenna with artificial magnetic conductor (AMC) ground plane is proposed [9] to isolate with higher bandwidth. Metamaterial, neutralization line and modified ground structure are some novel methods to reduce mutual coupling in MIMO. Introduction of parasitic slots in the MIMO antenna shown a further reduction of mutual coupling [10]. The distance between radiating elements of MIMO must be placed at minimum distance of $\lambda/2$ and must be diversified spatially. Metamaterial can enhance isolation or reduce mutual coupling between radiators even though the MIMO radiating elements are placed within small distance [11].

In [12], the proposed antenna has substrate with one side having microstrip feeding and other side associated by means of a short ground strip and two modified U-shape stubs to provide isolation and impedance bandwidth. Wireless body area network (WBAN) include several applications related to medical and military fields which uses the service of on-body antennas [13].In such antennas a parameter called specific absorption rate (SAR) decides the efficiency of the antenna, which is found to be 0.92 W/kg for 1mW input power and ECC is found to be below 0.1. A compact printed UWB MIMO antenna with high isolation is proposed in [14], which has combination of added monopole antenna element and slot element that suits portable UWB applications.

Electromagnetic interference is a serious problem faced in UWB communication band i.e. 3.1GHz to 10.6GHz set by federal communications commission (FCC) in 2002.Very advanced techniques are found to meet our requirement of reducing electromagnetic interference. In [15], the four element MIMO antenna has resonant stub with U-shaped microstrip feedline which are divided by a dash lines placed diagonally and orthogonal to each other. It spontaneously suppresses CM waves and mitigates electromagnetic interference. Highly isolated and decoupled MIMO antenna elements are proposed in [16] and [17] where the slots used in the same are placed orthogonally to reduce mutual coupling. Dual notch bands are achieved in [18] where the proposed antenna has a defected ground structure with step shaped slot etched to it. The structure also uses orthogonal geometry to attain high isolation and polarization diversity. Thanks to the Y-shaped defected ground structure with step slots, without which mutual coupling reduction is not be possible.

A quad band circularly polarized antenna with metamaterial and complimentary split ring resonator (C-SRR) is proposed in [19] to achieve enhanced bandwidth. Due to the introduction C-SRR the properties of the metamaterial is improved. A Conformal antenna is loaded with SRR on one side of the substrate and the other side is loaded with C-SRR with defected ground structure to enhance notch band characteristics in ultra-wideband (UWB)[20].A novel filtenna is achieved by placing SRR in ground plane and observed to show metamaterial properties. It showed band reject filter characteristics. Thanks to SRR,without which improvement of return loss and enhancement of bandwidth might not be possible[21].To improve gain and bandwidth of the antenna an SRR slot is introduced in half mode substrate integrated waveguide(SIW) on its top. It achieved a high gain of 22dB when compared to micro strip patch antenna[22-38].

In this paper, a compact flag shaped MIMO antenna with semi square split ring resonator (SRR) slots is designed to operate at ultra-wideband (UWB) frequencies with a notch band present in between. The semi square SRR is designed with two L-shaped slits and two inverted L-shaped slits to provide high isolation between bands by providing notch band between them. Due to the semi square structure only one notch band is achieved. The flag shaped elements are fed by rectangular feedlines.The ground structure has semi circular slots etched on it and a T-shaped stub to provide enhancement in reduction of mutual coupling. The antenna is fabricated on 26 × 28 FR4 epoxy substrate with 0.8mm thickness and achieved UWB from 1.96GHz to 8.83GHz with a notch band of 2.84GHz to 4.41GHz.

II. ANTENNA DESIGN

The design of proposed antenna is shown in Figure 1. The 2×2 MIMO antenna is fabricated on a FR4 epoxy substrate of dimensions 26×28×0.8 mm3, with dielectric loss tangent of 0.02 and relative permittivity 4.4 as shown in Figure 2. The antenna has two flag shaped patches which are etched with semi square split ring resonators (SRR) slots on it. The semi square SRR slot on the radiating elements is a combination of two L-shaped slots and two inverted L-shaped slots placed adjacent to each other. The two patches are fed by two microstrip rectangular feedlines which are used to provide good impedance matching. These two feedlines are connected to two ports using two trapezoidal structures. The ground structure has semi circular cuts at even intervals and a rectangular T-stub is placed in between the semi circular slots. The optimized values of the antenna parameters are shown in Table 1.The optimized values are derived from parametric analysis of the antenna parameters of the proposed antenna designed in ANSYS HFSS 19.0.

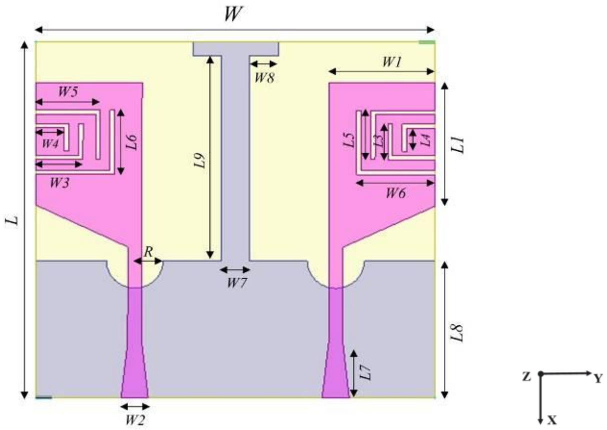
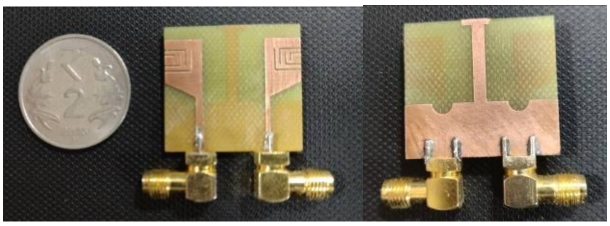


Figure 1: Geometry of proposed antennna.



(a) (b)

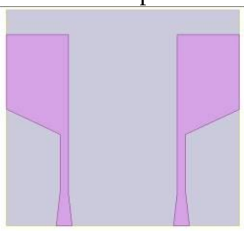
Figure 2: Geometry of fabricated antennna (a) Front view (b) Top view.

The evolution of the proposed antenna is shown in Figure 3.First, the flag shaped patches are fed by rectangular microstrip feedlines (Antenna-1) with normal ground structure (Figure 3 (a)) and a narrow bandwidth [8.72GHz to 9.36GHz] has been attained, with operating frequency 9GHz.Later, semi circular slots are introduced in the ground structure (Antenna-2) to expand the impedance bandwidth. A rectangular T-shaped stub is introduced to the previous iteration to attain high isolation at low frequencies and to enhance the impedance bandwidth (Figure 3 (b)).A ultra-wideband is achieved [2.02GHz to 9.59GHz] covering entire S-band and C-band.

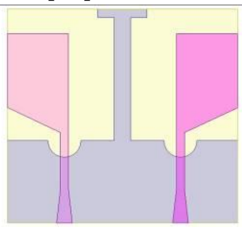
Finally, the proposed antenna is evolved from Antenna-1 and Antenna- 2, in which semi square SRR slot is introduced to get a ultra-wideband (UWB) from 1.98GHz to 8.83GHz with a notch band of 2.84GHz to 4.41GHz.The simulated S-parameters are shown in Figure 4.

Parameter	Value	Parameter	Value
W	28	L5	3.6
L	26	W6	5.5
W1	7.45	L6	4.7
L1	9	W7	2
W2	1.9	W8	2
W3	3.3	L7	4
L3	2.6	L8	10
W4	2	L9	15
L4	1.7	R	2
W5	4.5		

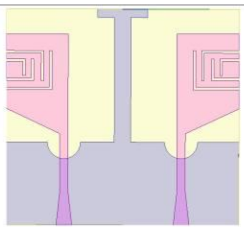
Table 1 : optimised values of proposed antenna.



(a)



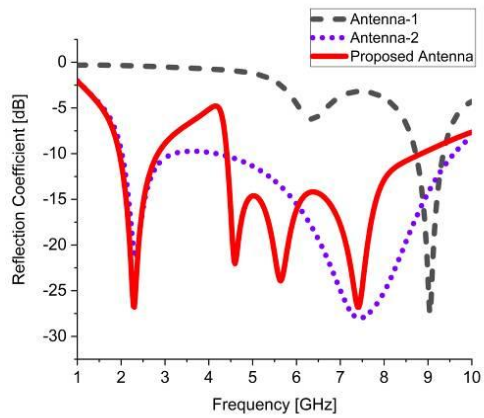
(b)



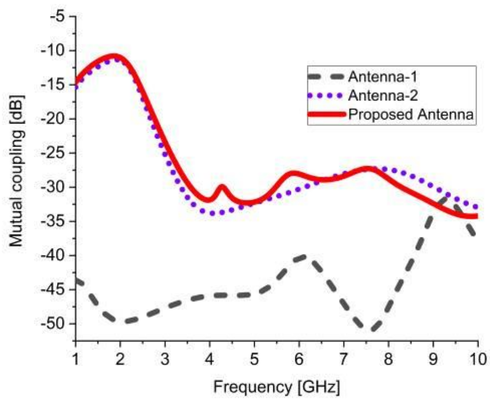
(c)

Figure 3: Evolution of proposed antenna. (a) Antenna 1 with normal ground and without Semi square SRR. (b) Antenna 2 with defected ground and without semi square SRR. (c) Proposed antenna.

Antenna-1 do not have any slots on the patch and has normal ground due to which a narrow band existed.In Antenna-2,due to its ground geometry,the impedance bandwidth has been improved which led to ultra-wideband(UWB).The proposed antenna , which has semi square SRR slots in it has an ultra-wideband with a notch band in the impedance bandwidth.The notch band in a result of placing the semi square split ring resonator(SRR) from 2.84GHz to 4.41GHz.



(a)



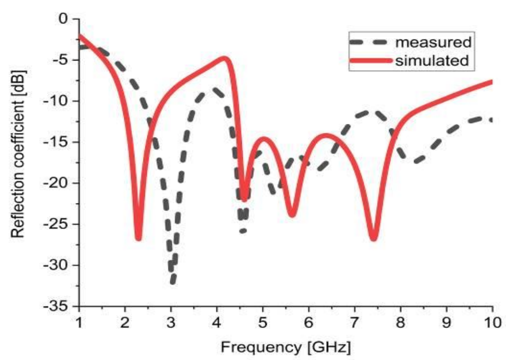
(b)

Figure 4: S parameters. (a) Reflection Coefficient S11 of Antenna 1, Antenna 2 and proposed antenna. (b) Mutual Coupling S12 of antenna 1, antenna 2 and proposed antenna.

III. RESULTS AND DISUSSION

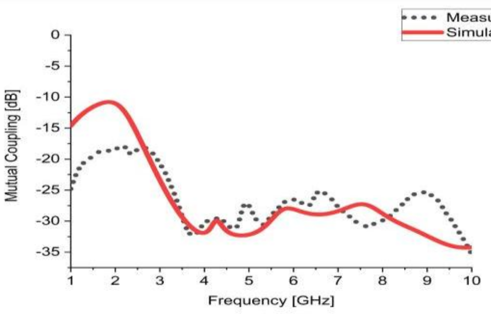
A. Scattering parameters

S-parameters is define relation between two or more ports in two port system. The antenna proposed has the s-parameters as shown in Figure 5.. The band below S_{11}=-10dB or the impedance bandwidth from 1.96GHz to 8.83 GHz with a notch band from 2.84GHz to 4.41GHz which is includes IEEE S-band frequency range. The isolation or mutualcoupling is less than-11dB.



(a)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



(b)

Figure 5: S-parameters (a) measured and simulated reflection coefficient S_{11}. (b)Measured and simulated reflection coefficient S_{12}

The S-parameters are analyzed by varying different antenna parameters such as port width (W2), ground length (L8) and width of rectangular T-stub (W7). The parametric analysis for variable port width from 1.3mm to 2.2 mm is done and the reflection coefficient and mutual coupling of each iteration is shown in Figure 6.For port width of 1.3mm the impedance bandwidth is 5.94GHz (i.e. 1.92GHz-7.87GHz) and notch band is 3.01GHz-4.44GHz.

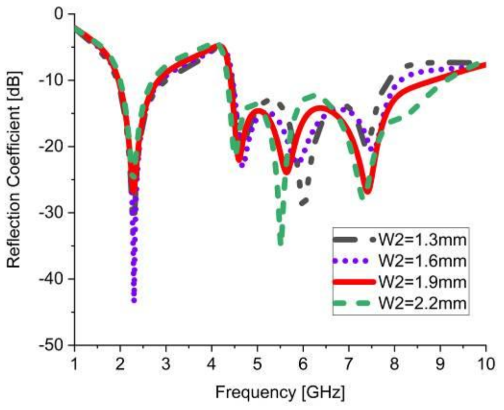
For port width of 1.6mm the impedance band width is 6.18GHz (i.e. 1.95GHz-8.13GHz) and notch band is 2.96GHz-4.46GHz.For port width of 1.9mm the impedance band width is 6.89GHz (i.e. 1.96GHz-8.85GHz) and notch band is 2.71GHz-4.41GHz.

For port width of 2.2mm the impedance band width is 7.14GHz (i.e. 2GHz-9.14GHz) and notch band is 2.72GHz-4.35GHz.The mutual coupling between two ports is more than -10dB.The reflection coefficient and mutual coupling for variable port width is shown in Figure 5.

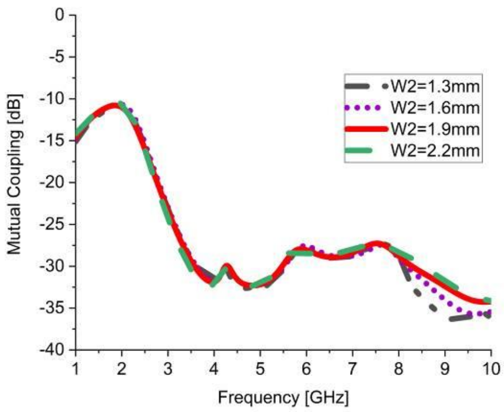
The reflection coefficient and mutual coupling of each iteration for the parametric analysis of variable length of rectangular part of ground from 6mm to 14mm is done and is shown in Figure 6.

The impedance bandwidth is very narrow bandwidth of 430MHz (i.e. 1.67GHz-2.10GHz) for length of 6mm.At length of 8mm; there are 3 bands at 2.06GHz with impedance bandwidth of 580MHz, at 4.5GHz with impedance bandwidth of 290 MHz and at 5.68GHz with impedance bandwidthof 510 MHz.

At the optimum ground length (i.e. 10mm) ultra-wideband with impedance bandwidth 6.89GHz (i.e. 1.96GHz-8.85GHz) and notch band 2.71GHz-4.41GHz is achieved.



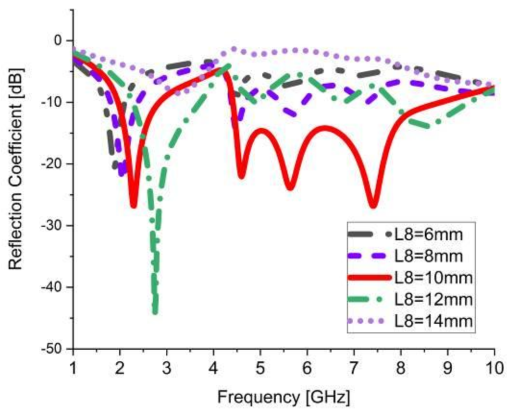
(a)



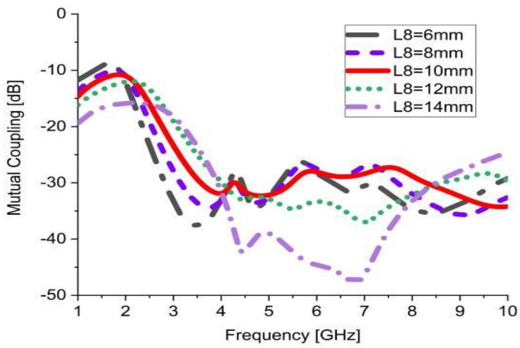
(b)

Figure 6: S parameters of the proposed antenna when port width is varied. (a) Reflection Coefficient S_{11}. (b) mutual Coupling S_{12}.

For ground length of 12mm there are dual bands, one at 2.74GHz with impedance band width of 1.44GHz and another at 8.48GHz with impedance bandwidth of 1.62GHz. The reflection coefficient and mutual coupling for variable length of ground is shown in Figure 7.



(a)



(b)

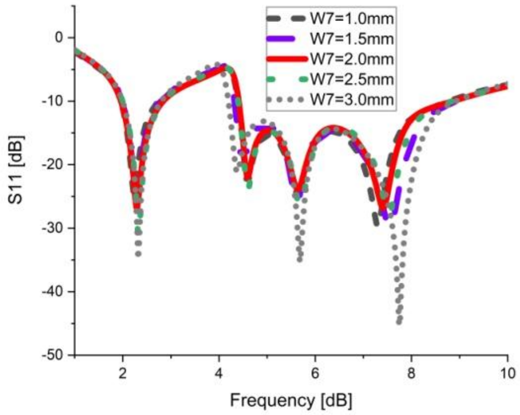
Figure 7: S parameters of the proposed antenna when ground length varied. (a) Reflection Coefficient S_{11}. (b) Mutual Coupling S_{12}.

Similarly, the width of the rectangular T-shaped stub is also varied from 1mm to 3mm and the corresponding reflection coefficient and mutual coupling are shown in Figure 8.

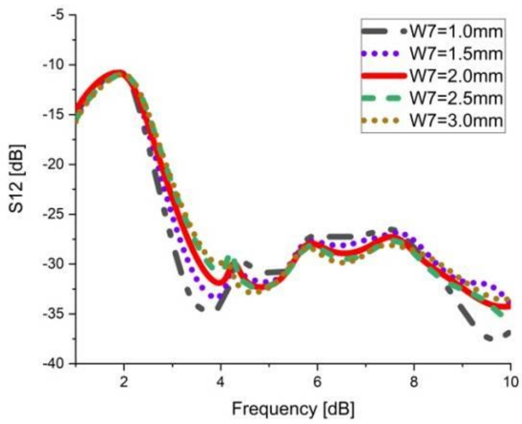
The impedance bandwidth and notch bands are approximately same and all of them have an ultra-high bandwidth, but the reflection coefficient and mutual coupling are found to be very low when the width of the T-shaped stub is more.

As the length of the stub is more, then the coupling effect of the radiating elements on the stub is observed to be less. Similarly when the width of the stub is decreased, then the coupling effect of the radiating elements is more on the stub.

High reflection coefficient is observed at 5.68GHz and 7.76GHz is less than -35dB and -45dB respectively at 3mm width.



(a)

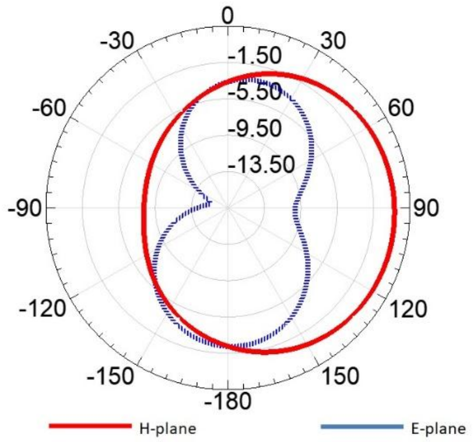


(b)

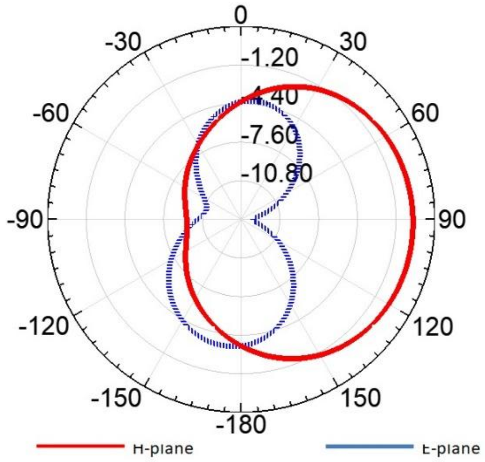
Figure 8: S parameters versus of the proposed antenna when width of the ground stub is varied. (a) Return loss S_{11}. (b) Isolation S_{12}.

B. Radiation patterns:

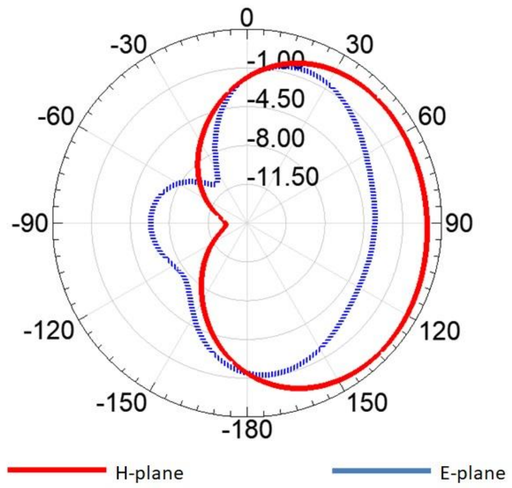
The radiation pattern is simulated at 7GHz, 7.3GHz (resonant frequency) and 8.8 GHz. The gain are found to be 0.91dB, 0.40dB and 1.75dB respectively. The radiation patterns at 7GHz,7.3GHz,8.8GHz are shown in Figure 9.



(a)



(b)

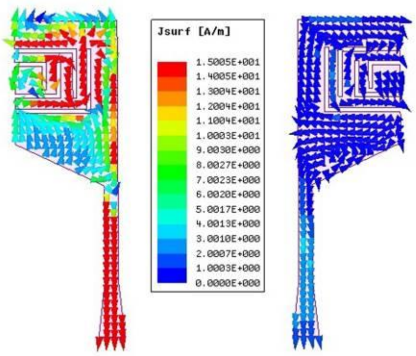


(b)

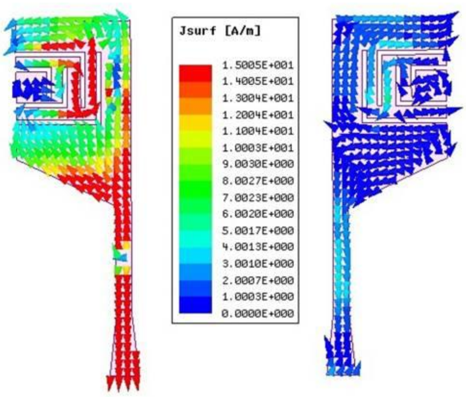
Figure 9: Radiation patterns (a) 7 GHz (b) 7.3 GHz (c) 8.8 GHz

C.Current distributions

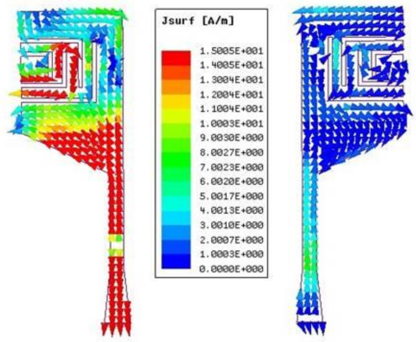
The current distributions at different frequencies are shown along with their directions. In Figure 10, the first port is excited while the second is kept un operational. The blue color in second port indicates that no current flows in second port when first port is excited. It indicates that the two radiating elements are highly isolated and mutual coupling effect is negligible.



(a)



(b)

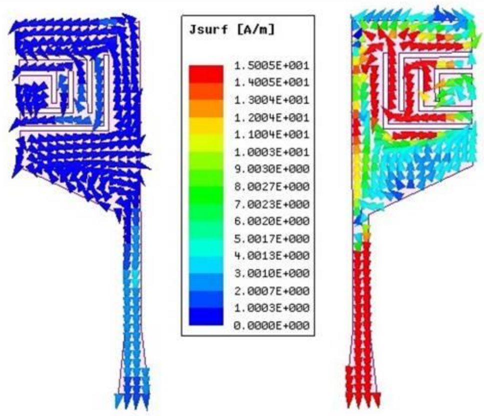


(c)

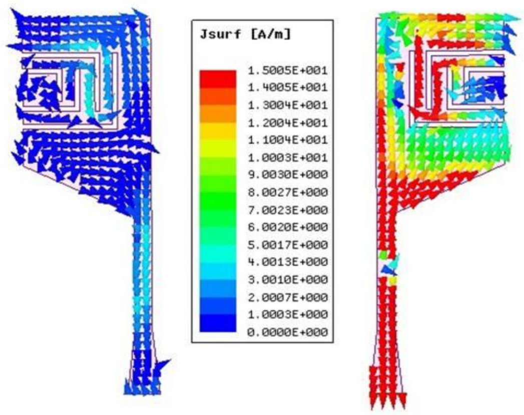
Figure 10: Current distributions when port-1 is excited (a) 4.6 GHz (b) 5.6 GHz (c) 7.4 GHz.

As depicted at 4.6GHz currents are distributes across the four slits of the semi square SRR in alternating directions. At 5.6GHz, currents are distributed across slits 3 and 4 which indicate that these slits are responsible for resonating at 5.6GHz.Now at 7.4 GHz currents are distributed across slits 1 and 2 which indicate that the resonant frequency 7.4GHz is dues to these slits

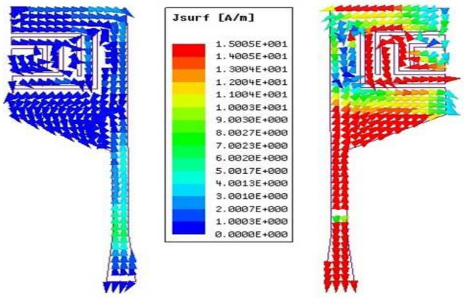
Similarly the current distributions when port 2 is excited are shown in the Figure 11.



(a)



(b)



(c)

Figure 11: Current distributions when port-2 is excited (a) 4.6 GHz (b) 5.6 GHz (c) 7.4 GHz.

D. Envelope Correlation Coefficient:

In higher data rate applications such as WIFI and LTE we use MIMO technology. Wheneverthe term MIMO appears then there exists envelope correlation coefficient (ECC).It correlates the radiating elements or simply says the independency of one radiating element on another.

The feasible value for ECC is below 0.5.So any value below 0.5 is acceptable. Above 0.5 is considered to be bad. A value below 0.3 is optimum and best suited for wireless applications. High isolation has less ECC value and vice versa. Zero ECC mean that both the radiating elements are purely independent of each other. The ECC is calculated based on the formula shown below.

$$\mathrm{ECC} = \frac{|S_{11}^{*}S_{12} + S_{21}^{*}S_{22}|^2}{\left(1-\left(|S_{11}|^2+|S_{21}|^2\right)\right)\left(1-\left(|S_{22}|^2+|S_{12}|^2\right)\right)}.$$

The ECC for the proposed antenna is shown in Figure 12.the ECC of the simulated design is below 0.3 which is optimum value and the best value is found to be 0.0001.

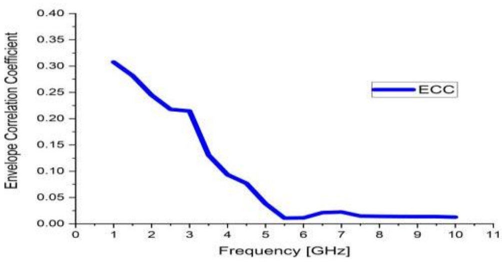


Figure 12: Envelope correlation coefficient (ECC) of proposed antenna.

E. Diversity Gain:

Diversity gain is the measure of reduced transmitted power while using a diversity scheme in any wireless communication. It increases the signal-to-noise ratio (SNR) corresponding to the diversity technique used. It is calculated mathematically based on the formula shown below.

$$\mathrm{DG} = 10\sqrt{1-\mathrm{ECC}^2}$$

The diversity gain plot versus frequency is shown in Figure 13.

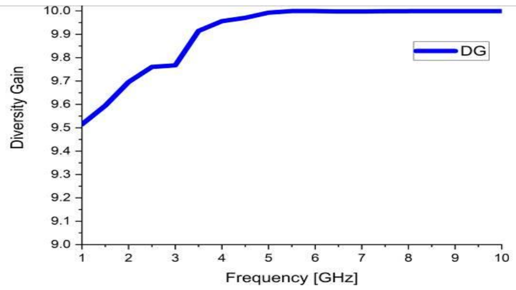


Figure 13: Diversity gain of proposed antenna

The diversity gain is found to be above 9.6 in the working band from 1.96GHz to 8.83GHz which is very optimal value.

IV. CONCLUSION

A band notched UWB MIMO antenna is designed and implemented in this article. The proposed antenna works from 2-9GHz which almost covers all commercial applications of UWB technology and notches in the band 2.84GHz-4.41GHz which include WIMAX band. The proposed antenna consists of a compact size of 26×28mm^2 which is etched on the FR4 substrate. The antenna has ECC < 0.3, diversity gain>9.8 with a stable radiation pattern. Thus the proposed antenna is a good candidate for UWB and MIMO applications.

REFERENCES

1. Yi Zhao, Fu-Shun Zhang, Li-Xin Cao, and Deng-Hui Li, "A Compact Dual Band-Notched MIMO Diversity Antenna for UWB Wireless Applications," in *Progress In Electromagnetics Research C*, Vol. 89, 161–169, 2019.
2. Ma, T.-G. and S.-K. Jeng, "Planar miniature tapered-slot-fed annular slot antennas for ultrawideband radios," *IEEE Transactions on Antennas and Propagation*, Vol. 53, No. 3, 1194–1202,Mar.2005.
3. Yang, Y., Q. Chu, and J. Li, "Dual band-notched ultra wideband MIMO antenna array," *2013 IEEE International Wireless Symposium (IWS)*, 1–4, Beijing, 2013.
4. Y.V.N.R.Swamy.Banothu,P. Siddaiah,"Designing a Compact MIMO Antenna by Inserting SRR Element to Improve the Performance"*SPACES-2018*, Dept. of ECE, K L Deemed to be UNIVERSITY.
5. Rajashekar G P, Usha Rani M A, "Design of MIMO Antenna with High Isolation using Split Ring Resonator" ,in *International Research Journal of Engineering and Technology (IRJET)* Volume: 04 Issue: 05 | May -2017.
6. D. Sarkar and K.V. Srivastava, "Compact four-element SRR-loade dual-band MIMO antenna for WLAN/WiMAX/WiFi/4G-LTE and 5G applications,"*ELECTRONICS LETTERS* ,7th December 2017 Vol. 53 No. 25 pp. 1623–1624.
7. Li, J., Q. Chu, and T. Huang, "A compact wideband MIMO antenna with two novel bent slits," *IEEE Transactions on Antennas and Propagation*, Vol. 60, No. 2, 482–489, Feb. 2012.
8. Ren, J., W. Hu, Y. Yin, and R. Fan, "Compact printed MIMO antenna for UWB applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 13, 1517–1520, 2014.
9. Zhu, J., S. Li, S. Liao, and Q. Xue, "Wideband low-profile highly isolated MIMO antenna with artificial magnetic conductor," *IEEE Antennas and Wireless Propagation Letters*, Vol. 17, No. 3, 458–462, Mar. 2018.
10. Toktas, A., M. Yerlikaya, K. Sabanci, A. Kayabasi, E. Yigit, and M. Tekbas, "Reducing mutual coupling for a square UWB MIMO antenna using various parasitic structures," *2017 10th International Conference on Electrical and Electronics Engineering (ELECO)*, 982–986, Bursa, 2017.
11. Iqbal, A., O. A. Saraereh, A. Bouazizi, and A. Basir, "Metamaterial based highly isolated MIMO antenna for portable wireless communication," *Electronics*, Vol. 7, No. 10, 2018.
12. Sokhi, I. K., R. Ramesh, and K. Usha Kiran, "Design of UWB-MIMO antenna for wireless applications," *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 962–966, Chennai, 2016.
13. Joo, E., K. Kwon, J. Park, and J. Choi, "On-body UWB MIMO antenna for UWB application," *2013 Asia-Pacific Microwave Conference Proceedings (APMC)*, 1130–1132, Seoul, 2013.

14. Zhang, L., W. Liu, and T. Jiang, "A compact UWB MIMO antenna with high isolation," *2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*, 913–914, Fajardo, 2016.
15. Liu, Y. and Z. Tu, "Compact differential band-notched stepped-slot UWB-MIMO antenna with common-mode suppression," *IEEE Antennas and Wireless Propagation Letters*, Vol. 16, 593–596,2017.
16. Kang, L., H. Li, X. Wang, and X. Shi, "Compact offset microstrip-fed MIMO antenna for bandnotched UWB applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 14, 1754–1757, 2015.
17. Gao, P., S. He, X. Wei, Z. Xu, N. Wang, and Y. Zheng, "Compact printed UWB diversity slot Antenna with 5.5-GHz band-notched characteristics," *IEEE Antennas and Wireless Propagation Letters*, Vol. 13, 376–379, 2014.
18. Zhu, J., et al., "A dual notched band MIMO slot antenna system with Y-shaped defected ground structure for UWB applications," *Microwave and Optical Technology Letters*, Vol. 58, No. 3, 626–630, 2016.
19. M. Venkateswara Rao, B.T.P. Madhav, T. Anilkumar, B. Prudhvi Nadh," Metamaterial Inspired Quad Band Circularly Polarized Antenna for WLAN/ISM/Bluetooth/WiMAX and Satellite Communication Applications", in *International Journal of Electronics and Communications*,reference: AEUE 52545.
20. B. T. P. Madhav,M. Venkateswara rao,Anilkumar Tirunagari," Conformal Band Notched Circular Monopole Antenna Loaded with Split Ring Resonator",*Springer Science+Business Media*, LLC, part of Springer Nature, Wireless Pers Commun https://doi.org/10.1007/s11277-018-5890-312 june,2018.
21. B T P Madhav, M Vamsi Krishna Chaitanya Reddy,M Venkateswara Rao, C Mohan Krishna, P Chandan Raj, G Jaya," Quad Band Filtenna Using Split Ring Resonatorsto Notch Unwanted Frequenciesin Medical Application Bands",*Journal of Theoretical and Applied Information Technology*,15th May 2017. Vol.95. No 9.
22. T V Ramakrishna, B T P Madhav, M Venkateswara Rao, A Babu Rao, A Sunaina, A Avinash, B Shivani," SRR Loaded Half-Mode Substrate Integrated Waveguide Monopole Slot Antenna for Multiband Applications", International Journal of Engineering & Technology, 7 (1.1) (2018) 560-564
23. T. Ramakrishna, B. Madhav, N. Kiran, B. Sravani, N. Vamsi, and K. Yamini, "Frequency Reconfigurable Antenna for Ku-Band Applications," ARPN Journal of Engineering and Applied Sciences, ISSN, vol. 6608, pp. 6527-6532, 1819.
24. D. S. Rao, J. L. Narayana, "Microstrip Parasitic Strip Loaded Reconfigurable Monopole Antenna," ARPN Journal of Engineering and Applied Sciences, ISSN, vol. 6608, pp. 1-7, 1819.
25. B T P Madhav, A Manikanta Prasanth, Sreeramineni Prasanth, Batchu Mohan Sai Krishna, Devani Manikantha, Usirika Sharmila NagaSai, "Analysis of Defected Ground Structure Notched Monopole Antenna", ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, Vol. 10, No. 2, Feb-2015, pp 747-752.
26. Harish Kaza, Thanneru Kartheek, Novel Printed Monopole Trapezoidal Notch Antenna with S-Band Rejection, Journal of Theoretical and Applied Information Technology, ISSN: 1992-8645, Vol 76, No 1, 2015, Pp 42-49.
27. P.Lakshmikanth, Kh Takeshore, Printed Log Periodic dipole antenna with Notched filter at 2.45 GHz Frequency for wireless communication applications, Journal of Engineering and Applied Sciences, ISSN: 1816-949X, Vol 10, Issue 3, Aug-2015, pp 40-44. DOI: 10.3923/jeasci.2015.40.44.
28. D S Ram Kiran, Novel compact asymmetrical fractal aperture Notch band antenna, Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, Vol 27, Issue 2, December 2015, pp 1-12.
29. M L S N S Lakshmi, Habibulla Khan, Novel Sequential Rotated 2x2 Array Notched Circular Patch Antenna, Journal of Engineering Science and Technology Review, ISSN: 1791-2377, Vol 8, issue 4, Dec-2015, pp 73-77.
30. D S Ramkiran, Kankara Narasimha Reddy, Shaik Shabbeer, Priyanshi Jain, Saggurthi Sowmya, Coplanar Wave Guide Fed Dual Band Notched MIMO Antenna, International Journal of Electrical and Computer Engineering (IJECE), ISSN: 2088-8708, Vol. 6, No. 4, August 2016, pp. 1732-1741.
31. Y. S. V. Raman, Analysis of Circularly Polarized Notch Band Antenna With DGS, ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 17, September 2016.
32. Allam Vamsee Krishna, Planar Switchable Notch Band Antenna with DGS for UWB Applications, Lecture Notes in Electrical Engineering, ISSN: 1876-1100, Vol 434, 2017, pp 509-518.
33. S.S. Mohan Reddy, P. Mallikarjuna Rao, B. Prudhvi, Design and Analysis of Circular Notch Band DGS Monopole Antenna, Lecture Notes in Electrical Engineering, ISSN: 1876-1100, Vol 434, 2017, pp 409-417.
34. Kosuru Murthy, Kodidasu Umakantham, Korlapati Satyanarayana Murthy, Reconfigurable Notch Band Monopole Slot Antenna for WLAN/IEEE-802.11n Applications, International Journal of Intelligent Engineering and Systems, ISSN: 2185-3118, Vol 10, No 6, Oct-2017, pp 166-173.
35. Vamseekrishna Allam, Defected Ground Structure Switchable Notch Band Antenna for UWB Applications, Smart Innovation, Systems and Technologies, Vol 77, pp 139-145, 2018.
36. T Sai Santosh, M Venkateswara Rao, S Sai Manikanta, K B V Srinivas, J Hanumath Sastry, A Novel Ultra Wideband MIMO Antenna with WIMAX Band Notch Characteristics, Journal of Advanced Research in Dynamical and Control Systems, Vol 9, Issue 14, 2017, pp 2094-2103.
37. B T P Madhav, M Venkateswara Rao, T Anilkumar, Conformal Band Notched Circular Monopole Antenna Loaded with Split Ring Resonator, Wireless Personal Communications, ISSN: 1572-834X, 2018, pp 1-12, https://doi.org/10.1007/s11277-018-5890-3.
38. M Vijaya Lakshmi, P Pardhasaradhi, Circular Monopole Reconfigurable Antenna with Notch Band Filter Characteristics, Journal of Engineering Science and Technology Review, Vol 11, Issue 5, 2018, pp 139-143.

AUTHORS PROFILE

B.Priyadharshini was born in kancheepuram, Tamil Nadu in 1988.She received her B.E from Anna university affiliated college and M.E from Sathyabama University. She has 3 Scopus indexed papers. Currently working as Assistant professor at K L University.

B.T.P Madhav was born in India, AP, in 1981. He received the BSc, MSc, MBA, MTech degrees from Nagarjuna University, AP, India in 2001, 2003, 2007, and 2009 respectively. He got his PhD in the field of antennas from K L University. Currently he is working as Professor and Communication Systems research Head in the Electronics and Communication Engineering. He has published more than 268 papers in International, National journals and Conferences.

M.Hema Sasank was born in Gudiwada,Andhra Pradesh, India, in 1998.He is now pursuing his Bachelor of Technology in the department of Electronics and communication Engineering at K L University. His areas of interests are MIMO antennas and SRR structures.

Mr.M. Venkateswara Rao was born in India in 1992. He received B tech and M Tech specialization in microwave and communication engineering from JNTU Kakinada in the years 2013, 2015 respectively. He currently is pursuing his Ph.D. in Metamaterial Antennas from Antennas and Liquid Crystals Research Centre of ECE department, K L Deemed to be University. He produced 19 publications and interested research topics are Metamaterials, Gain enhancement in broadband and wideband Antennas, circularly polarized antennas

P Vamsi Krishna was born in 1998 at Erraguntlapadu.He is now pursuing bachelor of technology in the department of electronics and communication engineering at K L University. Hisareas of interest include reconfigurable antenna and MIMO antenna**.**

J.J.S.N.S.K.Kavya was born in 1998 at Eluru.She is now pursuing bachelor of technology in the department of electronics and communication engineering at KL University. Her areas of interest include MIMO Antennas.

K.Abhinav Narayana was born in 1998 at Vijayawada. He is now pursuing bachelor of technology in the department of electronics and communication engineering at KL University. His area of interest includes Vehicular communication &MIMO Antennas.