International Journal of Future Generation Communication and Networking
Vol. 13, No. 3, (2020), pp. 3731–3738

Design of Tri-band MIMO Antenna for wireless Applications to reduce mutual coupling

K.V. Babu[1], M.S.Rao[2], N. Sivaiah[3] and K. Sandhya Rani[4]

[1]Associate Professor, [2]Assistant Professor, [3]Assistant Professor & [4]Assistant Professor
vasubabuece@gmail.com, sreenivas.vvit@vvit.net, sivaiah462@gmail.com, srisandhya1234@gmail.com
Dept. of ECE, Vasireddy Venkatadri Institute of Technology, Guntur, A.P, India.

Abstract

A compact tri-band MIMO multiple rectangular slots antenna is designed with a 40 mm × 20 mm area of defected ground structure. Due to the DGS structure, there is an improvement in the mutual coupling and also improve the bandwidth impedance. The design structure covered the applications of C-band, Wi-Fi and WiMAX with return loss maintained ≤ -10 dB as well as its mutual coupling ≤ -20 dB thought the tri-band resonant frequencies. The VSWR of the tri-band structure maintained ≤ 2 thought the resonant structure. For this structure MIMO parameters like ECC, group delay, directivity, efficiency, and diversity gain also obtained with in the acceptable values of the MIMO design.

1. Introduction

For limited bandwidth resources in the reality and demand for high-speed data communication multiple antennas are proposed that for system performance and spatial freedom. The technique for improving the multipath fading, spatial multiplexing and weak diversity gain are implemented by MIMO design. This design implemented using two or more antennas simultaneously for a radio channel to transmission as well as reception purpose. MIMO technology incorporate the WLAN systems is a combination of IEEE 802.11 ac and IEEE 802.11n. 5G technology for communication purpose have many benefits like higher data rates, bandwidth availability and shorter latency compared to the 4G communication technology. In [1], designed for super-wide band phi-shaped monopole CPW antenna whose isolation is around 25 dB. For extension of UWB applications CPW transparent type antenna designed with a low compact structure [2]. For the applications of super wide-band have a 30 x 45 mm^2 compact antenna designed [3]. For the range of frequency from 3.1 GHz- 10. 6 GHz a planar inverted printed antenna is designed for WLAN [4]. In [5], a semi-ring fed printed antenna designed to achieve the bandwidth ratio 25:1. For a proper spacing between the radiators to reduce the isolation a compact MIMO is designed [6]. Defect in ground plane using a quad element MIMO designed with a compact structure of 40 mm x 50 mm in [7]. A quasi self-complementary radiator is designed for UWB applications to obtain the better isolation [8]. Using access points application and square ring patches of CSRR loaded for four port MIMO system [9, 10]. The novelty of the current MIMO structure is a rectangular slots are cut from the patch to obtain multi-band frequencies and defect in ground structure to improve mutual coupling between the patches. Due to the monopole ground plane and within that using three circular rings there is lot of change the mutual coupling parameter compared to existing systems mentioned in the literature. Table 1 shows the dimensions of the tri-band MIMO structure. Table 2 shows the comparison with other systems mentioned in the references.

ISSN: 2233-7857 IJFGCN

2. Design Structure & Layout

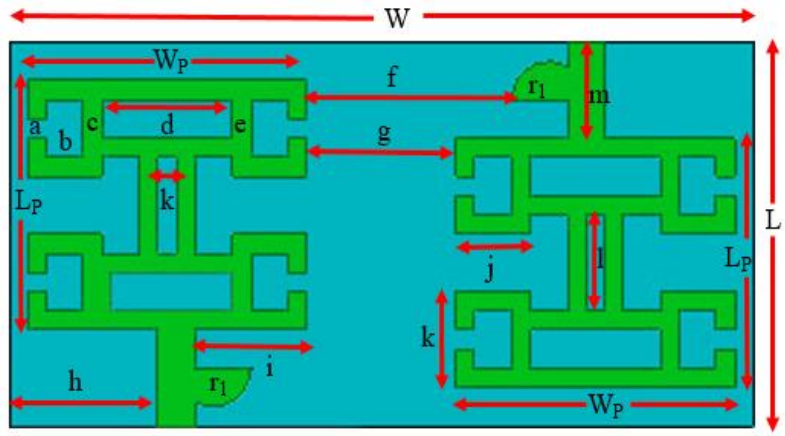


Fig. 1 Front plane

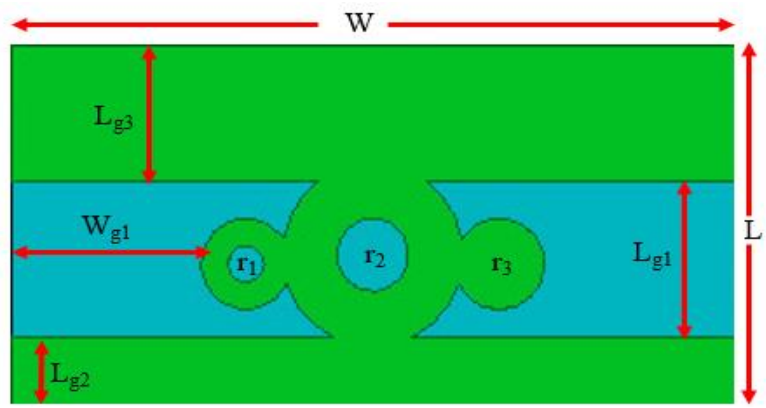


Fig. 2 Back plane

Table 1: Tri-band MIMO structure dimensions are in mm

Parameter	L	W	L_p	W_p	a	b	c	d	e	f	g
Dimensions (mm)	20	40	13	15	1	2	3	7	2	11	8
Parameter	h	i	j	k	l	r_1	r_2	r_3	L_{g1}	L_{g2}	L_{g3}
Dimensions (mm)	8	6	4	5	5	4.1	8	4.8	8.5	4.2	7.3

Fig.1 shows the compact tri-band MIMO structure have a dimensions of 40×20 mm^2 using FR-4 substrate with relative permittivity of 4.4. The length and width of the patches are considered a dimension of 15 mm × 13 mm. The four sides of the square patch at the edges cutting a rectangular slots and transform the same shape with a distance of 8 mm to avoid the interference between the patches it means reduce the mutual coupling between the patches. Fig. 2 shows the back side of the plane which means a ground, it can be considered as a monopole ground plane with DGS structure to improve the bandwidth as well as reduction of mutual coupling in the design. Three circular rings with different radius are considered in the ground plane cut from the full ground plane.

Table 2: Comparison table @ Existing systems

ISSN: 2233-7857 IJFGCN

S.No.	Size (mm^2)	$\|S_{11}\|$	$\|S_{21}\|$	ECC	No. of Ports
[1]	50 × 45	19	21	0.089	2
[3]	40 × 40	17	24	0.097	2
[4]	70 × 35	18	26	0.068	4
[6]	45 × 35	24	19	0.074	2
[8]	65 × 50	21	26	0.093	2
[10]	75 × 40	16	24	0.068	4
Proposed	40 × 20	27.44	33.94	0.019	2
		24.33	26.59	0.054	
		23.58	27.71	0.001	

3. Results Discussion

Fig. 3 shows the comparison of S-parameters for 3.5 GHz, 5.5 GHz and 6.6 GHz frequencies whose $|S_{11}|$ are 27.44 dB, 24.33 dB and 23.58 dB and its corresponding $|S_{21}|$ are 33.94 dB, 26.59 dB and 27.71 dB. Fig. 4 shows the simulated VSWR among the three resonant frequencies which is ≤ 2. Fig. 4 shows the impedance of the current design for real and imaginary parts. For real part which is around 100 ohms and for imaginary part which less than zero ohms. Fig. 6 shows the distribution of surface currents at 3.5 GHZ, 5.5 GHz and 6.6 GHz. Fig. 6 (a) & (b) shows the port 1 is excited for both ground plane as well as back plane. At the bottom side of the slots maximum current flowing through the patch and observed for the bottom side ground plane for the first ring maximum current will flow through that path. Fig. 6 (c) & (d) shows port 1 is excited at 5.5 GHz and port 2 is excited at 6.6 GHz. It observed that the current flow at 5.5 GHz covers the entire patch at edges maximum current and current flows at 6.6 GHz maximum current will flow through the surface of right side edge patches. At the middle point maximum current flows inside the patch equally distributed to corresponding all the patches.

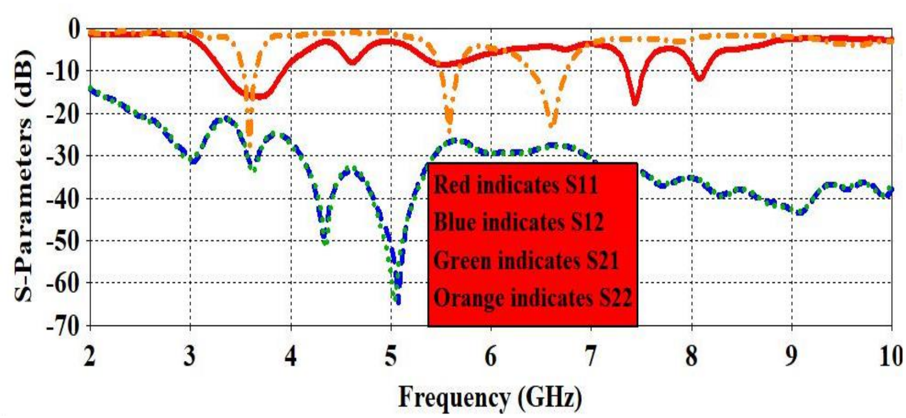


Fig. 3 S-Parameters of Tri-band MIMO structure

ISSN: 2233-7857 IJFGCN

International Journal of Future Generation Communication and Networking
Vol. 13, No. 3, (2020), pp. 3731–3738

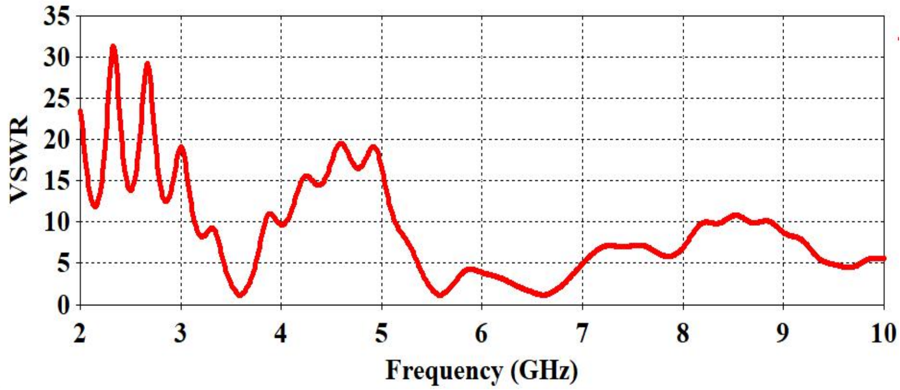


Fig. 4 VSWR of Tri-band MIMO structure

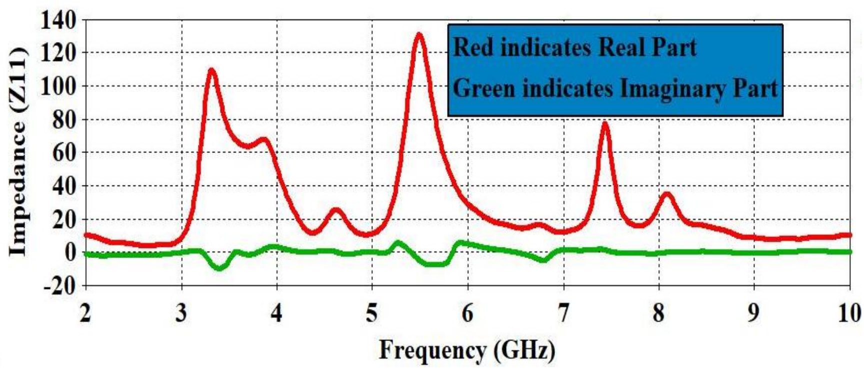
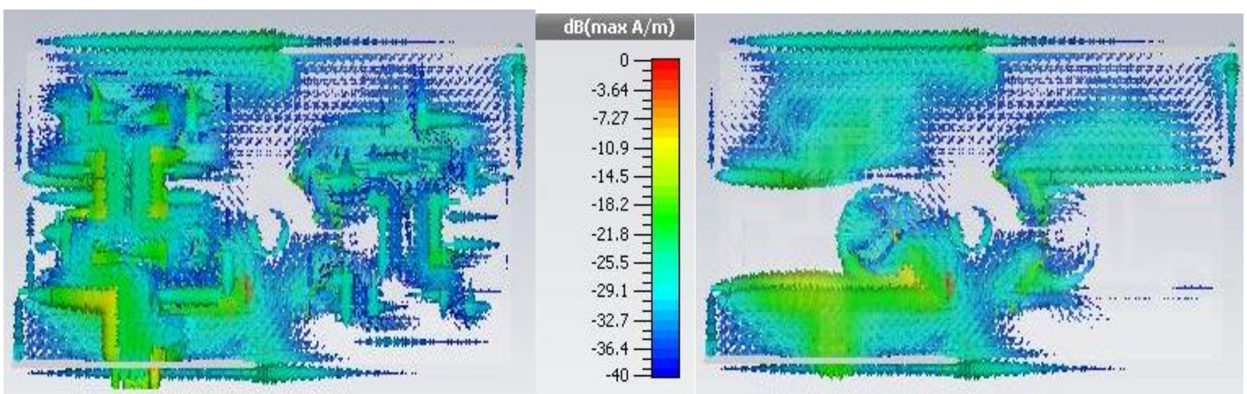
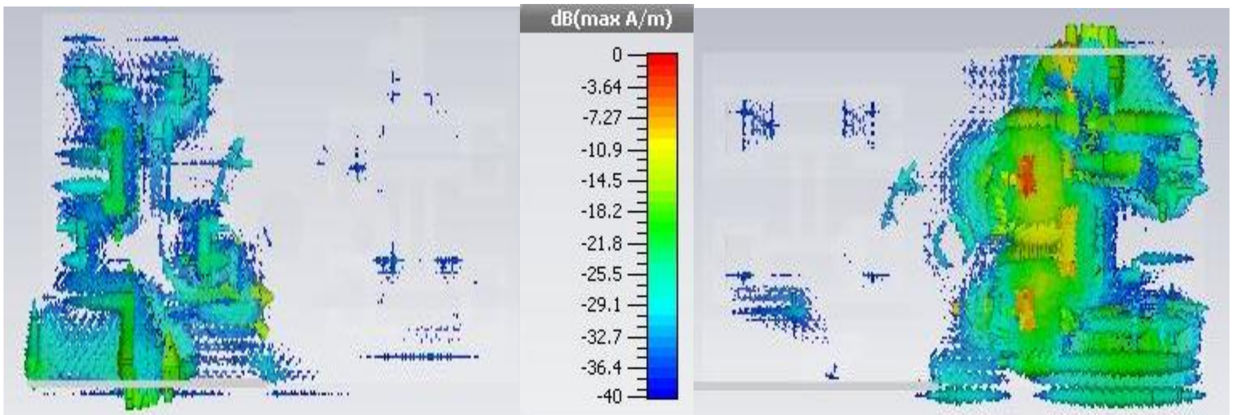


Fig. 5 Impedance of Tri-band MIMO structure



(a) Port 1 is excites at 3.5 GHz front plane (b) Port 1 is excites at 3.5 GHz back plane

ISSN: 2233-7857 IJFGCN



(c) Port 1 is excites at 5.5 GHz front plane (d) Port 2 is excites at 6.6 GHz front plane

Fig. 6 Tri-band MIMO structure Surface Current Distribution

The performance of tri-band MIMO design to evaluate the ECC using S-parameters and far-field pattern using (1) & (2) from [10]

$$ECC = \frac{\left| \iint_{4\pi} \left[E_1(\theta,\phi) * E_2(\theta,\phi) \right] d\Omega \right|^2}{\iint_{4\pi} \left| E_1(\theta,\phi) \right|^2 d\Omega \iint_{4\pi} \left| E_2(\theta,\phi) \right|^2 d\Omega} \quad (1)$$

Where $E_i(\theta,\phi)$ Complex 3-D far-field radiated pattern

The ECC expression using S-parameters

$$ECC = \left| \frac{\iint_{4\pi} \left| S_{11}^{*} S_{21} + S_{21}^{*} S_{22} \right|}{\left[(1-(|S_{11}|^2 + |S_{21}|^2))(1-(|S_{22}|^2 + |S_{12}|^2)) \right]^{1/2}} \right| \quad (2)$$

The diversity gain is evaluated using the relation is

$$DG = 10\sqrt{1-|\rho_e|^2} = 10\sqrt{1-|ECC|^2} \quad (3)$$

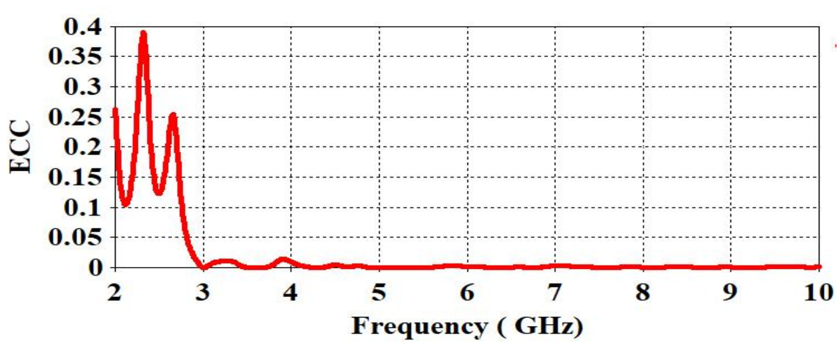


Fig. 7 ECC of Tri-band MIMO structure

ISSN: 2233-7857 IJFGCN

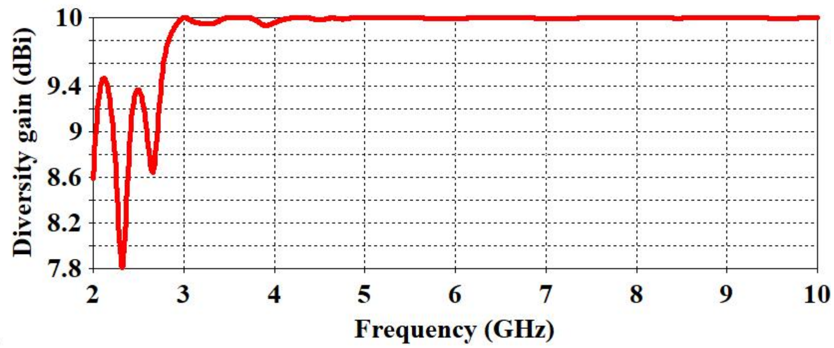


Fig. 8 Diversity gain of Tri-band MIMO structure

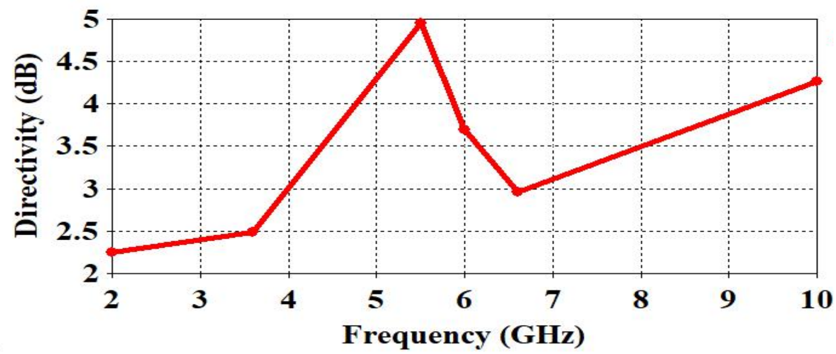
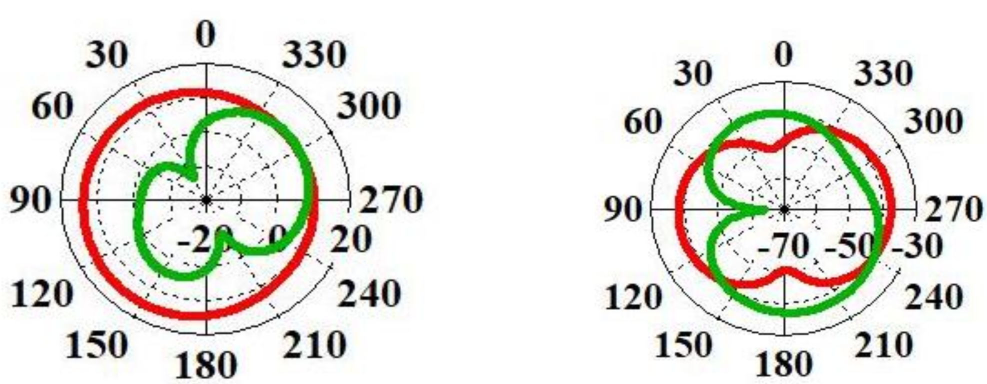


Fig. 9 Impedance of Tri-band MIMO structure

Fig. 7 shows the ECC of the tri-band MIMO structure resonating at 3.5 GHz, 5.5 GHz and 6.6 GHz are 0.019, 0.054 and 0.001 which is acceptable value of the MIMO design. Fig. 8 shows the diversity gain of the proposed structure which is approximately 10 dBi at the resonant frequencies. Fig. 9 shows the directivity of the proposed structure having at the frequencies of 3.5 GHz, 5.5 GHz and 6.6 GHz are 3.68 dB, 4.92 dB and 2.96 dB. Fig. 10 shows the radiation patterns of tri-band MIMO design xz-plane represents its corresponding E-field and similarly yz-plane represents its corresponding H-field. The E-field represents correspondingly approximate bi-directional pattern and H-fields represents approximately omnidirectional pattern.

xz-plane yz-plane



ISSN: 2233-7857 IJFGCN

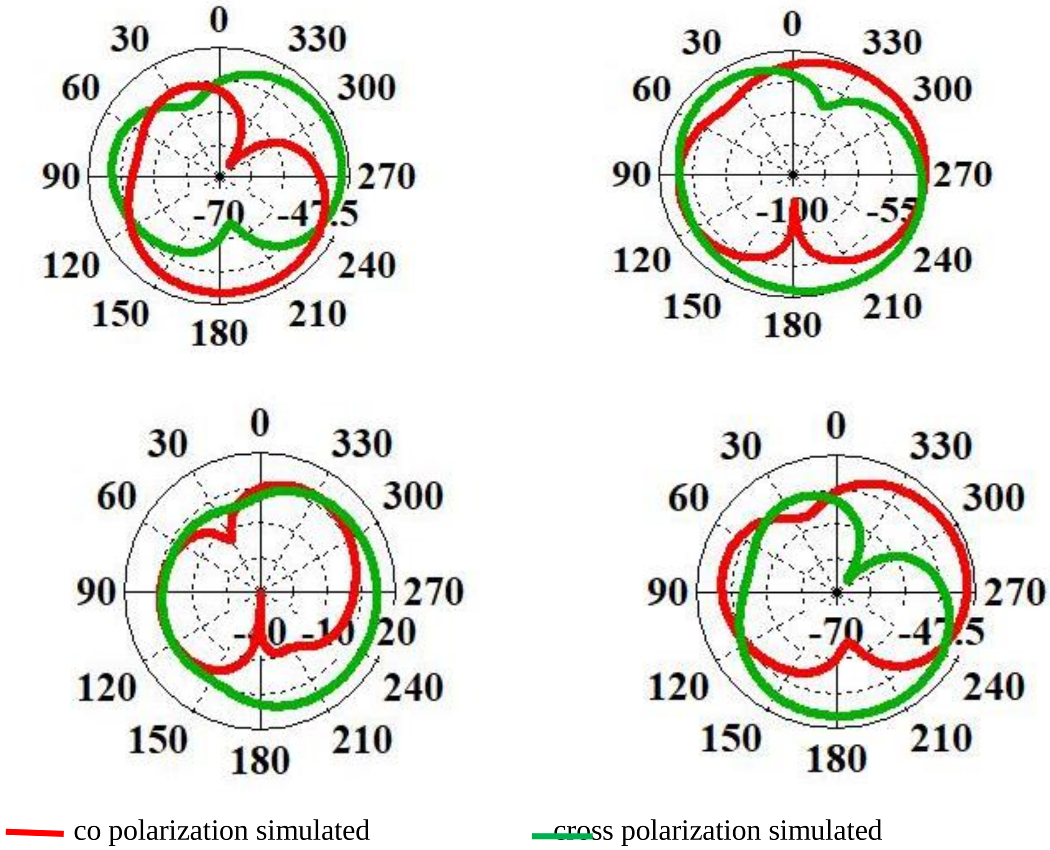


Fig. 10 Tri-band MIMO structure Radiation Patterns at 3.5 GHz, 5.5 GHz and 6.6 GHz

4. Conclusion

In this paper, a compact tri-band MIMO structure with 40 mm x 20 mm have been designed using FR-4 substrate. The tri-band MIMO design have been maintained the $|S_{11}| \leq 10$ dB and $|S_{21}| \leq 15$ dB at the resonant band of frequencies. The VSWR of the corresponding design have been identified which is ≤ 2. The MIMO parameters of the tri-band MIMO structure ECC, diversity gain, directivity and its corresponding radiation patterns at the resonant frequencies have been observed with in the MIMO limited region. Within the corresponded resonant frequencies bidirectional and omnidirectional radiation patterns have been observed in xz-plane and yz-planes

References:

[1]. Singhal, Sarthak, and Amit Kumar Singh. "CPW-fed phi-shaped monopole antenna for super-wideband applications." Progress in Electromagnetics Research 64 (2016): 105-116.

[2]. Hakimi, Shayan, et al. "CPW-fed transparent antenna for extended ultrawideband applications." IEEE Antennas and Wireless Propagation Letters 13 (2014): 1251-1254.

[3]. Chen, Ke-Ren, and Jeen-Sheen Row. "A compact monopole antenna for super wideband applications." IEEE Antennas and Wireless Propagation Letters 10 (2011): 488-491.

[4]. Cheng, Shi, Paul Hallbjorner, and Anders Rydberg. "Printed slot planar inverted cone antenna for ultrawideband applications." IEEE antennas and wireless propagation letters 7 (2008): 18-21.

ISSN: 2233-7857 IJFGCN

[5]. Liu, Jianjun, et al. "Achieving ratio bandwidth of 25: 1 from a printed antenna using a tapered semi-ring feed." IEEE Antennas and Wireless Propagation Letters 10 (2011): 1333-1336.

[6]. Aw, M. S., K. Ashwath, and Tanweer Ali. "A compact two element MIMO antenna with improved isolation for wireless applications." Journal of Instrumentation 14.06 (2019): P06014.

[7] Anitha, R., et al. "A compact quad element slotted ground wideband antenna for MIMO applications." IEEE Transactions on Antennas and Propagation 64.10 (2016): 4550-4553.

[8] Liu, X–L., et al. "A compact ultrawideband MIMO antenna using QSCA for high isolation." IEEE Antennas and Wireless Propagation Letters 13 (2014): 1497-1500.

[9] MoradiKordalivand, Alishir, Tharek A. Rahman, and Mohsen Khalily. "Common elements wideband MIMO antenna system for WiFi/LTE access-point applications." IEEE Antennas and Wireless Propagation Letters 13 (2014): 1601-1604.

[10] Ramachandran, Anitha, et al. "A four-port MIMO antenna using concentric square-ring patches loaded with CSRR for high isolation." IEEE Antennas and Wireless Propagation Letters 15 (2015): 1196-1199.

ISSN: 2233-7857 IJFGCN