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Rectangular MIMO Antenna System with Defected Ground Structure to Enhance Bandwidth for WLAN Applications

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Abstract: ***This document we presented four element rectangular microstrip MIMO (Multiple Input Multiple Output) antenna for WLAN (Wireless Local Area Network) applications by using complimentary octagon split ring defected ground structures (COSRDGS) to enhance the bandwidth. The effect of adding defected ground structure has been studied. The proposed antenna designed by using FR-4 substrate with 4.4 dielectric constant and overall antenna dimension is 62.8X60X1.6mm^3. The proposed antennas were simulated and fabricated and both results give good agreement between them. The proposed antennas resonate at 5.9GHz with -19.41dB, and it supported bandwidth 322MHz and date rate up to 7.9Gbps. The performance of the proposed simulated and fabricated antenna is explained in terms of return loss, gain, radiation pattern, VSWR (Voltage Standing Wave Ratio), Mutual coupling coefficients (MCC) and Envelope correlation coefficients (ECC).***
Keywords: ***MIMO, WLAN, Microstrip Patch Antenna, COSRDGS, ECC***

I. INTRODUCTION

Legacy antennas cannot be effectively and efficiently used in future 5G systems. Antenna systems are closely linked to the architectural implementation of the RF front end. Open-loop and recently available tunable closed-loop systems are state-of-the-art today. However, so far, tunable systems are available only for some antenna types and are still fairly large and expensive. In 5G systems, the aim is to provide solutions and develop steerable, bandwidth and multiband antennas systems dealing with the challenges for future multi-band/multi-mode terminals and infrastructures.

In recent wireless communication developments, antennas may be required to have diverse data rate. Combining several single antenna elements in an array can be a feasible way of meeting this requirement [1]. The data rate of the array can be changed by modifying the 'array factor' [2]. However, in an antenna array, mutual coupling effect between antenna elements can limit the performance of pattern diversity [3]. Although the element spacing can be increased to reduce coupling, this can allow unwanted grating lobes to occur and may exceed the practical aperture size limitations, resulting in unsuitability for some applications.

The evolving 5G cellular wireless networks are predicted to overcome the fundamental limitations of existing cellular networks, for example, giving higher data rates, excellent end-to-end performance, and user-coverage in hot-spots and crowded areas with lower latency, energy consumption, and cost per information transfer [4]. So there is a great demand for MIMO antennas in the fields of wireless communications, satellite communications, radar, 5G, and so on, and although the research on MIMO antennas only began in recent years, it has attracted a great deal of interest [5–9].

In the following section of this paper will describe the conventional rectangular MIMO microstrip patch antenna as well as proposed rectangular MIMO microstrip patch antenna loaded with complementary octagon split ring defected ground structure. The effect of complementary octagon split ring defected ground structure also discussed. The both type antennas are simulated and fabricated by using FR-4 substrate with relative permittivity of 4.4. The performance of the antennas, in terms of return losses, radiation patterns and gains, mutual coupling VSWR and envelope correlation coefficient, has been studied and then summarized the antenna result with final conclusion.

II. GEOMETRY STRUCTURE OF CONVENTIONAL MIMO ANTENNA

The conventional simulated and fabricated WLAN MIMO antennas are illustrated in Fig.1 and Fig.2 respectively. The antennas are printed on FR-4 substrate with relative permittivity 4.4 a loss tangent 0.1 and thickness is 1.6mm and antennas with edge to edge separation of $\lambda/4$ (where λ is the free space wavelength) maintained because if the antennas are placed close to each other resulting

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in high correlation between the antenna elements, and therefore poor diversity and separate feeding ports for all individual antennas. The overall size of the antenna is 62.8X60X1.6mm^3 and dimensions of the antenna are shown in table1and table2 respectively.

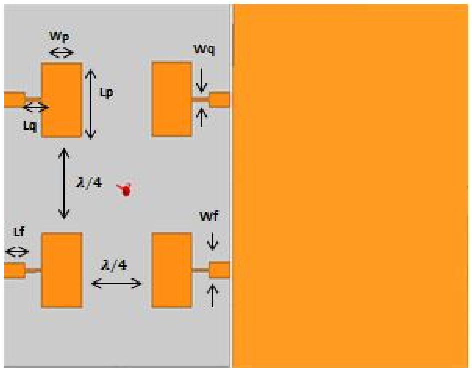

Fig. 1 A simulated conventional MIMO Antennas top and bottom view

Fig. 2 A fabricated conventional MIMO Antennas top and bottom view

Parameters	Dimensions (mm)
Width of the Patch Wp	11.35
Length of the Patch Lp	15.25
Width of the Quarter wave transformer Wq	3.05
Length of the Quarter wave transformer Lq	6.15
Width of the feed line Wf	0.5
Length of the feed line Lf	4.9

Table1: Single Antenna Dimensions

Parameters	Dimensions(mm)
Length of the substrate	62.8
Width of the substrate	60
Antenna between edge separation	λ/4
Height of the substrate	1.6

Table 2: 2X2 MIMO Antenna Dimension

Fig.3 shows the simulated and measured reflection coefficients for the conventional MIMO antenna. Simulated and fabricated results give good agreement between them is -21.3dB at 5.9GHz with a frequency bandwidth of 204MHz (WLAN frequency band) and it supported data rate is 5Gbps as per the Shannon channel capacity. Fig.4 shows VSWR of conventional MIMO antenna is less than 1.2 hence it shown good amount of power transfer along the antennas.

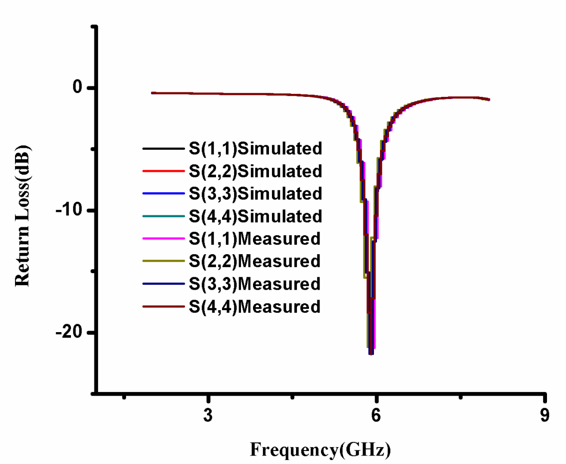

Fig.3: Return loss of conventional MIMO Antenna

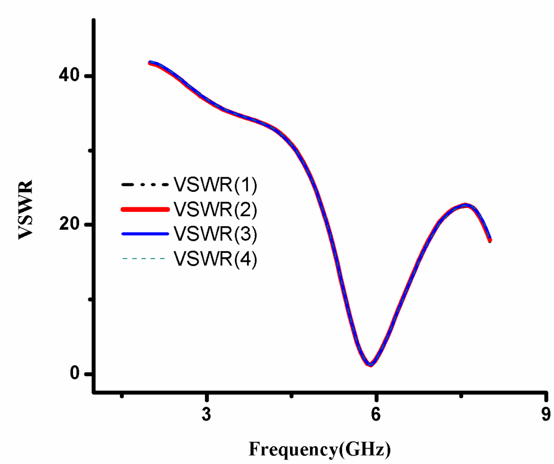

Fig. 4: VSWR of conventional MIMO antenna

Fig.5 shows that the gain is better than 5.69dBi with antenna efficiency of 98.03% at 5.9GHz. Fig.6 shows that the mutual coupling between ports 1and 2 is better than -20.9dB at 5.9GHz.

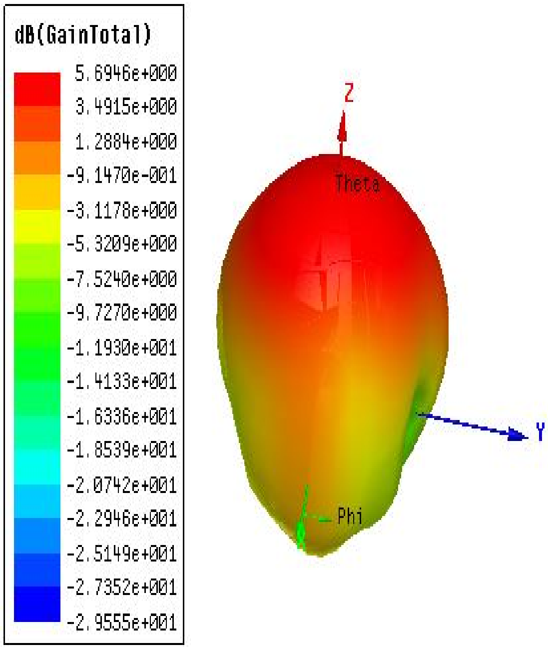

Fig.5: Gain of conventional MIMO antenna

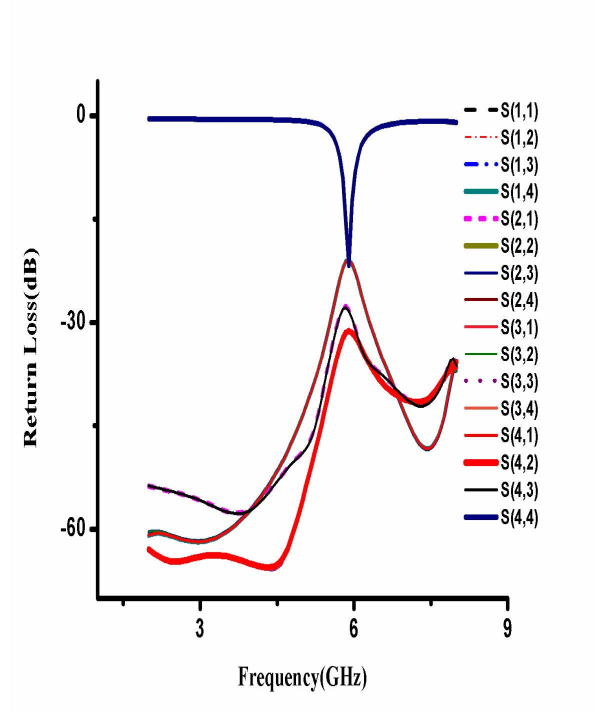

Fig. 6: Mutual Coupling of conventional MIMO antenna

Fig.7 and Fig.8 shows the meandering of the surface current and radiation pattern of the conventional MIMO antenna.

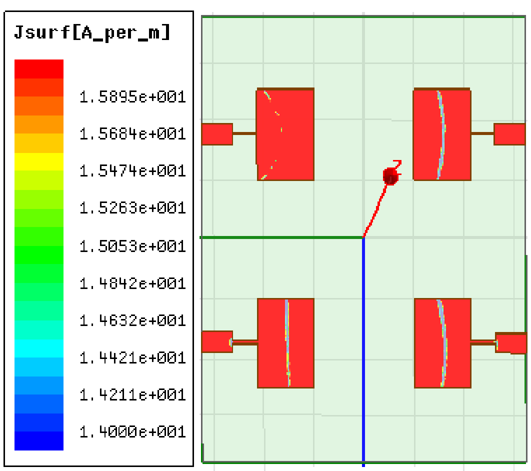

Fig.7: Surface current of conventional MIMO antenna

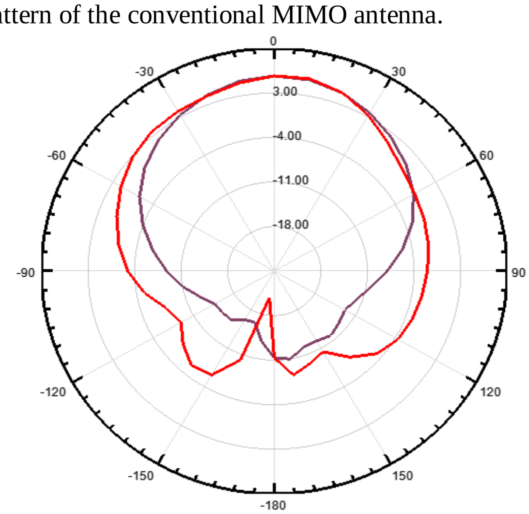

Fig. 8: Radiation pattern of conventional MIMO antenna

III. GEOMETRY STRUCTURE OF DEFECTED GROUND STRUCTURE MIMO ANTENNA

Ground plane modifying technique is also one of the popular techniques to obtain the multiband effect as well as bandwidth enhancement. The example techniques are ground plane aperture (GPA), ground plane lossy aperture (GPLA), and defected ground structure (DGS) (Zakaria, Z., et al., 2012). A compact multiband antenna also can be obtained by embedding suitable slots like rectangular, meander line, split ring resonator slot, and other structure in the radiating patch location (Mahatthanajatuphat, C., et al., 2007, Lee, E.C., et al., 2011, Radonic, V., et al., 2012).

There are few slot antenna designs for the bandwidth enhancement and also for size reduction functions have been wide studied such as in the papers (Noghabaie, et al., 2013, Aziz, et al., 2013). The slot antennas designed capability to exist the multiband and dual-band for the wireless communication system. Split ring resonator (SRR) structure is categorized as the left handed material (LHM) beside photonic band gap (PBG) (Goswani, K., et al., 2011), electronic band gap (EBG) (Kanso, A., et al., 2011) and also artificial magnetic conductor (AMC) (Abu, M., et al., 2010). The first structure of a split ring resonator design is a combination of wire and edge couple split ring resonator (EC-SRR) structure by (Pendry, J.B., et al., 2000) and (Smith, D.R., et al., 2000). This SRR has the capability to produce the negative dielectric constant (permittivity) and negative permeability in the patch antenna design. The other example of SRR antenna is in these papers: (H. Nornikman, O.T. Kean, A.B. Hisham, A.A.M.Z. Abidin, S.W. Yik, O.M. Azlishah, et al., 2014)

In this paper, the authors had been added the complementary octagon split ring resonator to investigate the effect of this structure on the rectangular microstrip MIMO antenna. The OCSRDGS it contains of two same shape rings with different length and width. Fig.9 shows the OCSRDGS structure, Table 3 shows the dimension of the OCSRDGS structure.

Table3: Dimension of unit cell OCSRDG structure

Parameters	**Dimensions(mm)**
Length of Substrate *'Ls'*	10
Width of Substrate *'Ws'*	10
Thickness of substrate 't'	1.6
Sides of octagon S1, S2, S3,S4	4, 3.5, 2.8,2.3
Gap 'g'	0.3
Distance between octagon (d)	0.845
Width of the ring (w)	0.6

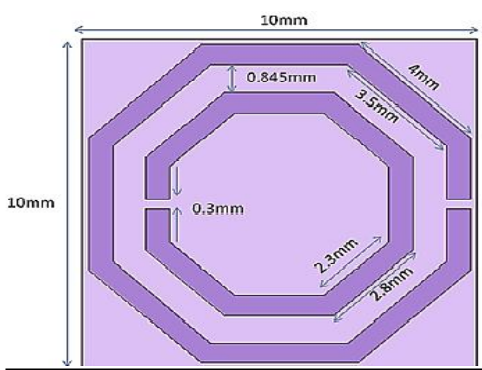

Fig.9: The unit cell OCSRDG structure

The edge couple complementary octagon split ring resonator is etched at the ground plane of the rectangular patch antenna. Studying parametric method and find out the best suitable place to etch the ground plane by using OCSRDGS structure. Hence the proposed antenna were simulated and fabricated are shown in Fig.10 and Fig.11 respectively.

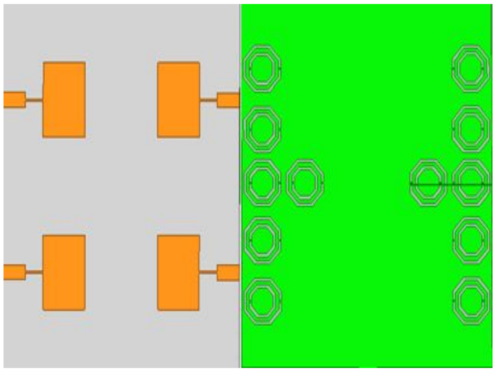

Fig. 10 A simulated proposed MIMO Antennas top and bottom view Fig. 11 A fabricated proposed MIMO Antennas top and bottom view

Fig.12 shows the simulated and measured reflection coefficients for the proposed MIMO antenna. Simulated and fabricated results give good agreement between them is -19.48dB at 5.9GHz with a frequency bandwidth of 322MHz (WLAN frequency band) and it supported data rate is 7.9Gbps as per the Shannon channel capacity. Fig.13 shows VSWR of proposed MIMO antenna is less than 1.2 hence it shown good amount of power transfer along the antennas. Fig.14 shows that the gain is better than 4.74dBi with antenna efficiency of 94.03% at 5.9GHz, but compare with conventional MIMO antenna, the proposed antenna gain is reduced because of etching the ground plane by defected ground structures hence we need some more parametric study to increase gain. Fig.15 shows that the mutual coupling between ports 1and 2 is better than -21.6dB at 5.9GHz, because of the defected ground structure it avoided the interference between the antenna each other hence mutual coupling is reduced compare to conventional antenna. Fig.16 and Fig.17 shows the meandering of the surface current and radiation pattern of the proposed MIMO antenna. The correlation coefficient can be computed from S parameter using the following formula [9] Fig.18 shows envelope correlation coefficient (ECC) of the proposed MIMO antenna. As can be seen, the envelope correlation of this structure is less than 0.001. Hence we concluded that very small channel capacity loss in the rich environment of multipath.

$$\rho_{i,j} = \frac{\left|S_{ii}^{*}S_{ij}+S_{ji}^{*}S_{jj}\right|}{(1-|S_{ii}|^2-|S_{ji}|^2)(1-|S_{jj}|^2-|S_{ij}|^2)}$$

Fig.19 shows return loss comparison of conventional MIMO antenna with proposed MIMO antenna, due to defected ground structure proposed MIMO antenna bandwidth enhanced to 322MHz. and summarized the results in table 4

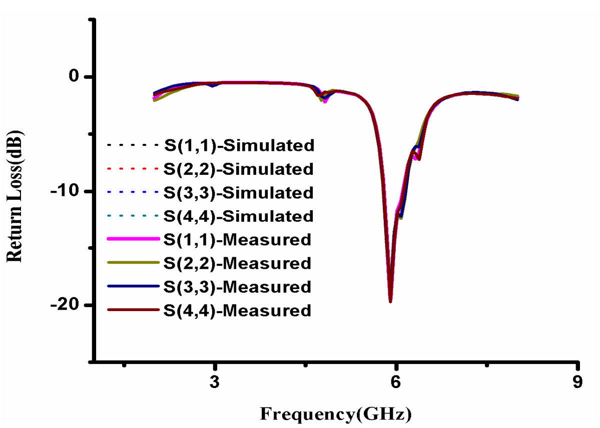

Fig.12: Return loss of proposed MIMO Antenna

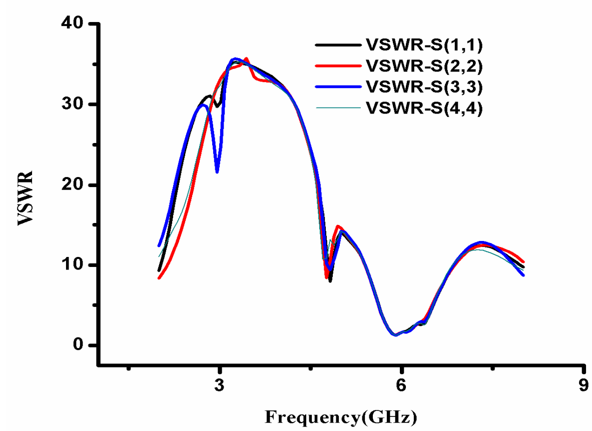

Fig. 13: VSWR of proposed MIMO antenna

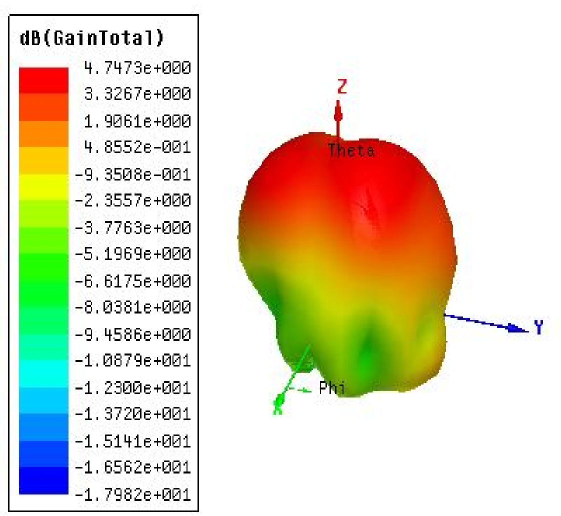

Fig.14: Gain of proposed MIMO antenna

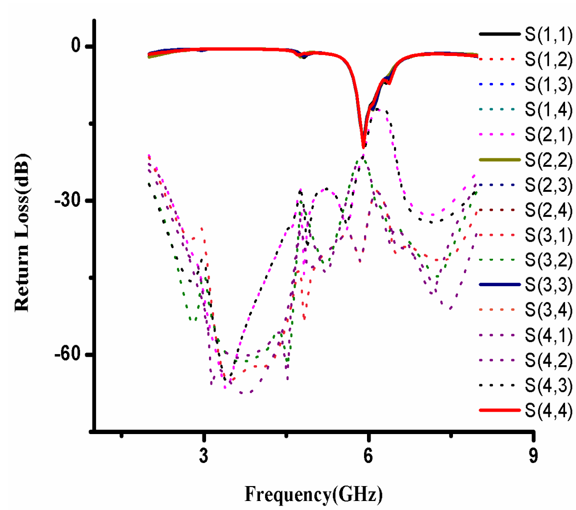

Fig. 15: Mutual Coupling of proposed MIMO antenna

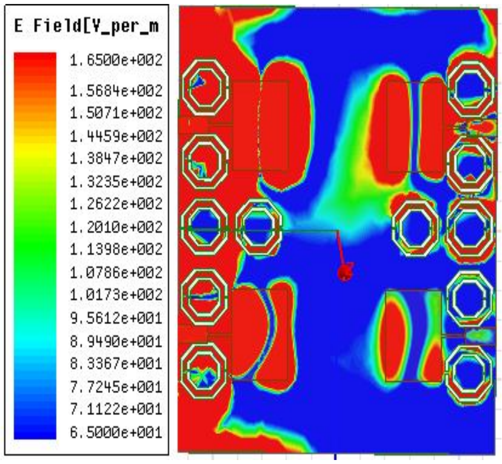

Fig.16: Surface current of proposed MIMO antenna

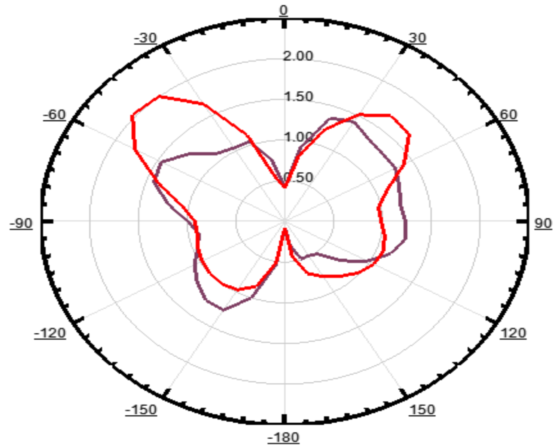

Fig. 17: Radiation pattern of proposed MIMO antenna

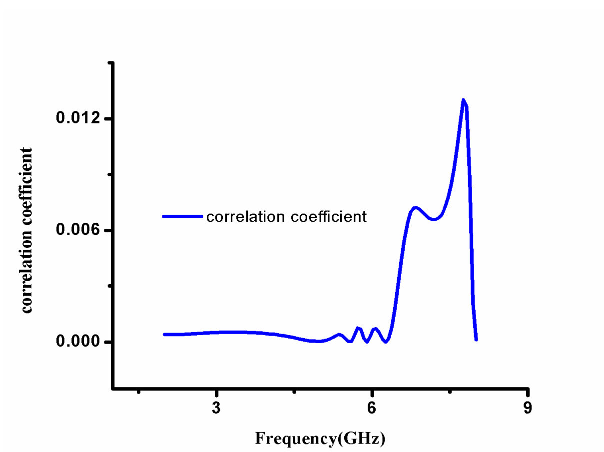

Fig.18: Correlation Coefficients of conventional MIMO Antenna

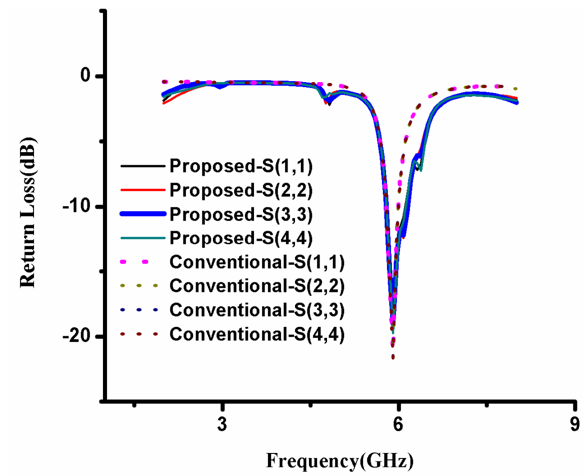

Fig.19: Return loss of conventional and proposed MIMO Antenna

SL.NO	PARAMETERS	CONVENTIONAL ANTENNA	PROPOSED ANTENNA
01	Return Loss	-21.3dB	-19.48dB
02	Bandwidth	204MHz	322MHz
03	Gain	5.69dB	4.76dB
04	VSWR	1.2	1.2
05	Mutual Coupling	-20.9dB	-21.6dB

Table4: Result summary

IV. CONCLUSIONS

The design and characteristics of a rectangular microstrip MIMO antenna with defected ground structure is presented for Wireless Local Area Network (WLAN) operation. With the optimized antenna geometry, the proposed antenna offers a measured impedance bandwidth over 322MHz which is enough to cover WLAN band. The proposed rectangular microstrip MIMO antennas with defected ground structure provides good performances in terms of good return loss, radiation patterns characteristics and envelop correlation coefficients. It can be predicted that, the designed rectangular microstrip MIMO antennas with defected ground structure has excellent can be investigated, which is very useful for wireless communication application.

V. ACKNOWLEDGMENT

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