Suppression of Mutual Coupling between Dual Element MIMOAntenna for 5G

R. Darwin, S. Swaati, G. Swathi, R. Vishnu Priya

Abstract: ***5G is the proposed next telecommunication standard beyond the current 4G/IMT-Advance standards,operating from 2GHz-8GHz.Antenna fabrication with reduced mutual coupling is the major challenges.Rectangular Fractal slots are used to enhance bandwidth without any matching element and for goodradiation pattern. In this paper we have designed dual element Multiband MIMO antenna for 5G application which operates in 3.1GHz,3.6GHZ and 3.9GHz with reduced mutual coupling. To analyze mutual coupling, two antennas are placed at a distance of 0.125λ.Various techniques to reduce mutual coupling like Electromagnetic Band Gap(EBG),Meander line,Defective Ground Structure(DGS)are implemented and out of which DGS has better isolation. An isolation of -59dB has been achieved with the DGS structure relative to -29dB without the DGS.***

KeyWords:MIMOAntenna,Mutualcoupling,ElectromagneticBandGap(EBG),Meanderline,DefectiveGroundStructure(DGS),High Frequency StructureSimulator(HFSS).

I. INTRODUCTION

MIMO fractal geometry plays a key role in the area of multiband antenna design. Compared to SISO structure MIMO has better Bit Error Rate, high data rate with Spatial Multiplexing(SM), enhances good coverage with Space Time Block Coding(STBC) and avoids fading. This paper also adds an advantage of reducing the mutual coupling by analyzing various reduction methods and found Defective Ground Structure(DGS) technique better.

II. ANTENNA DESIGN

Frequency of resonance, thickness of substrate, patch length, patch width,slot length, slot width, feed line length, feed line width are the fewparameters that has been considered for the rectangular patch antenna design.

Design equations for the rectangular patch has been mentioned below. FR4 has been used as the substrate for the above mentioned design which has 4.4 dielectric constant, 1.6 mm thickness and 3.6 GHz as resonant frequency.

Patch Width (W):

$$W = \frac{c}{2f0\sqrt{\frac{\varepsilon r+1}{2}}} \quad [1]$$

Patch Effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{w}\right]\hat{}\,\frac{1}{2} \quad [2]$$

Patch Effective length (L_{eff}):

$$L_{eff} = \frac{C}{2f0\sqrt{\varepsilon reff}} \quad [3]$$

Length extension (ΔL):

$$\Delta L = 0.412h\frac{(\varepsilon reff+0.3)(\frac{w}{h}+0.264)}{(\varepsilon reff-0.258)\ (\frac{w}{h}+0.8)} \quad [4]$$

Actual length (L) of patch :

$$L = L_{eff} + 2\Delta L \quad [5]$$

Where,
c = Velocity of light in free space.
h = height of substrate.
ε_r = Relative permittivity.

The length and width of the rectangular patch Antenna thus been calculated to be 35.44mm and 45.64mm respectively.

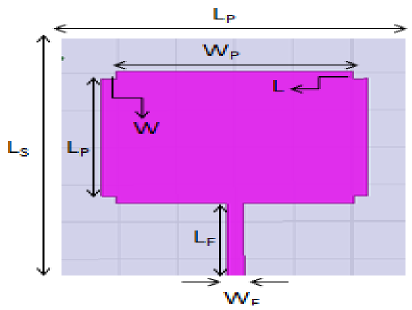

Figure 1:Dimensions of Antenna

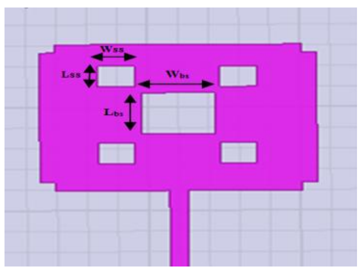

Figure 2:Dimensions of Slots

Design Parameters

S.No	Parameters	Description	Values
1.	L_s	Substrate Length	65 mm
2.	W_s	Substrate Width	60 mm
3.	L_p	Patch Length	35.44 mm
4.	W_p	Patch Width	45.64 mm
5.	L	Slot Length	2 mm

Revised Manuscript Received on December 08, 2018.

R. Darwin, Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.
S. Swaati, Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.
G. Swathi, Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.
R. Vishnu Priya, Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.

6.	W	Slot Width	2.5 mm
7.	L_{ss}	Small slot Length	5 mm
8.	W_{ss}	Small slotWidth of	6 mm
9.	L_{bs}	Big slot Length	10 mm
10.	W_{bs}	Big slot Width	12 mm
11.	L_f	Feed line Length	19.78 mm
12.	W_f	Feed line Width	3 mm

This structure follows 3 iterations and the final MIMO structure is shown below:

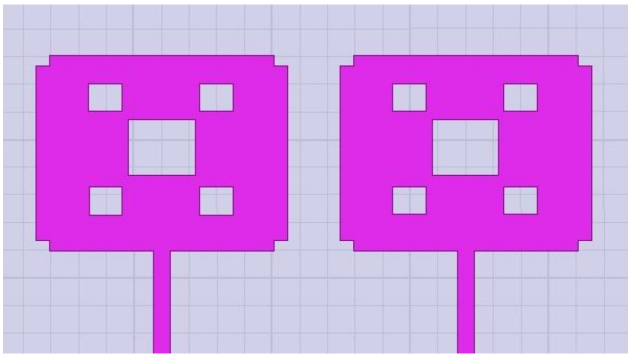

Figure 3:MIMO Antenna

The two antennas are spaced in the distance of 0.125λ which equals 10mm.The length and width of the above shown antenna's substrate is 115mmx65mm.

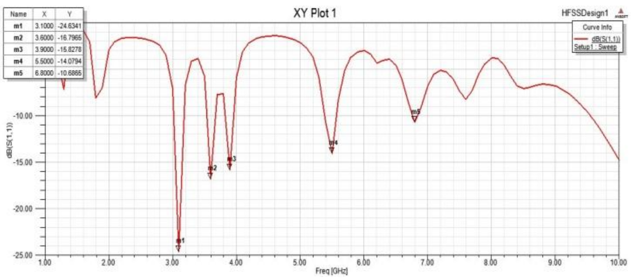

Figure 4:S11 of MIMO Antenna (Simulation)

The above plot gives the return loss of the MIMO antenna.

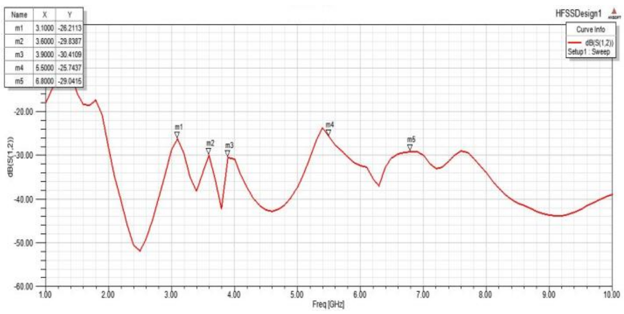

Figure 5: S12 of MIMO Antenna (Simulation)

Because of mutual coupling between the two antennas,an isolation of -29dB is achieved.

III. TECHNIQUES TO REDUCE MUTUAL COUPLING

Mutual coupling betweenadjacent elements is the reason for the degradation in the performance.There existsfew techniques to reduce mutual coupling between radiating elements in MIMO system like EBG,Meander Line and DGS and are analyzed in following sections.

IV. ELECTROMAGNETIC BAND GAP STRUCTURE (EBG)

The EBG structures areused to suppress the surface wavesand thus reduce mutual coupling between radiating elements [4].

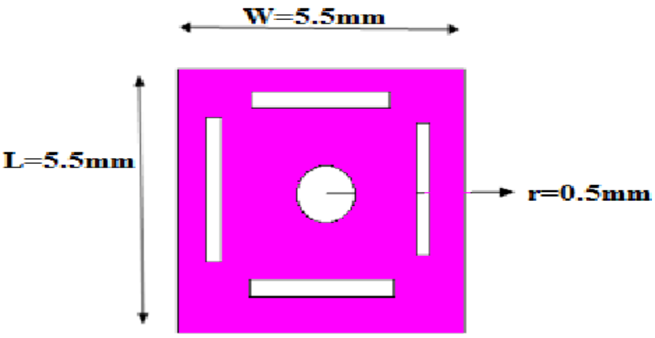

Figure 6:Unit cell of EBG

It makes use of the periodic structures to create a frequency band gap. These periodic structures can suppress surface waves to reduce mutual coupling. Figure 6 depicts the geometry used in the above mentioned design [14]. It consists of slots cut ona plain metal sheet with different shapes. The shapes used here is a rectangle and a circle. Introduction of additional slots gives miniaturization of the structure. In this paper, EBG structures are periodically arranged and introduced between the MIMO antennas to reduce mutual coupling. As per the analysis the designed structure gives the following values for
W=5.5mm, L=5.5mm, r=0.5mm.

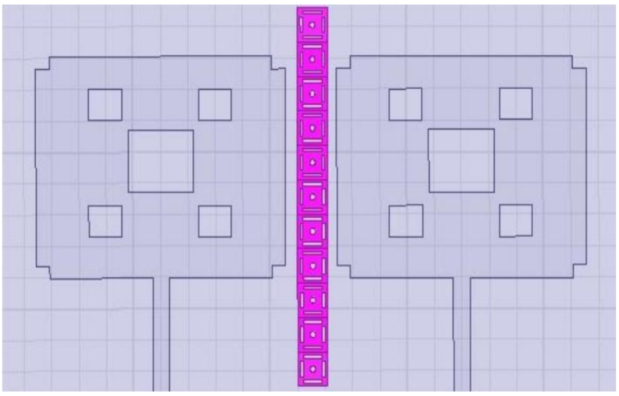

Figure 7 :MIMO with EBG

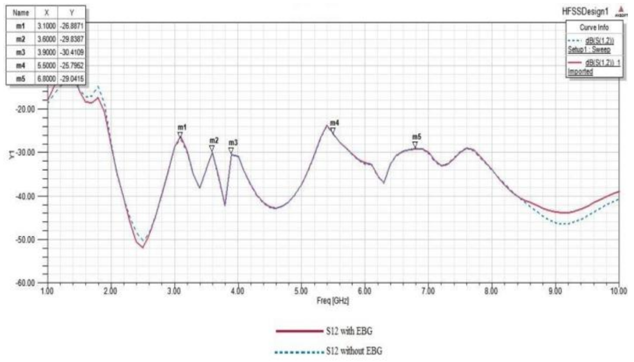

Figure 8: S12 of MIMO With and Without EBG

With the implementation of EBG,there is no greater improvement.Other methods to increase isolation and to reduce mutual coupling is discussed below.

V. MEANDER LINE

Embedding a wire structure onto a dielectric substrateleads to a Meander line antenna. By this property it achieves miniaturization in size.

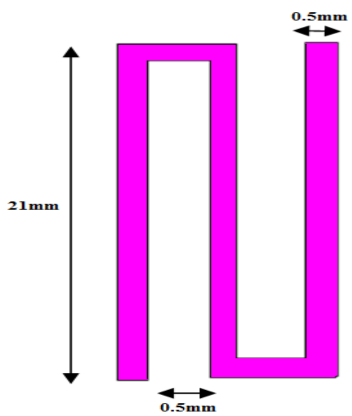

Figure 9: Unit cell of Meander Line

The structure of the meander line used is shown in the Figure 9 with its dimensions.The length,width,spacing between the meander line are 21mm,0.5mm,0.5mm respectively.

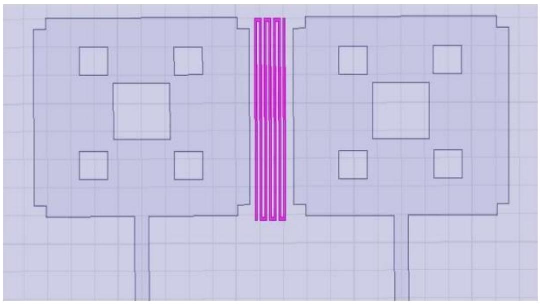

Figure 10: MIMO with Meander Line

A meander line structure is introduced between the radiating antenna elements for better separation with a lower level of cross polar power.

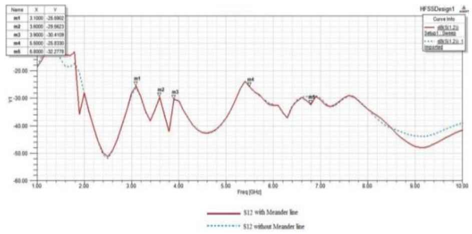

Figure 11:S12 of MIMO With and Without Meander Line

It is found that there is only minimum level of increased isolation with the meander line and further following method will explain the significant increase in isolation and reduction in mutual coupling.

VI. DEFECTIVE GROUND STRUCTURE

The current induced in the ground plane will destroy the isolation between elements in MIMO antenna system [6]. The coupling between the nearby elements can be minimized by altering the geometry of ground plane structure [7]. The band stop characteristics of the DGS will come into handy to prevent the propagation of EM waves which in turn increase mutual coupling. This issue of increased coupling between elements will be addressed by introducing slits and slots on the ground plane [8][9].

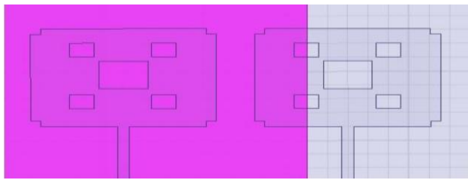

Figure 12: MIMO with DGS

DGS acts as band stop filter and suppresses the higher harmonics[10].In[6]DGS of Wd xLd of dimension 40mmx65mm is removed away under the rectangular patch of dimension 115mmx65mm.Thus it acts as a band stop filter by suppressing the higher harmonics greater than 30 db. The coupling between the two MIMO antennas [13]is thus reduced.

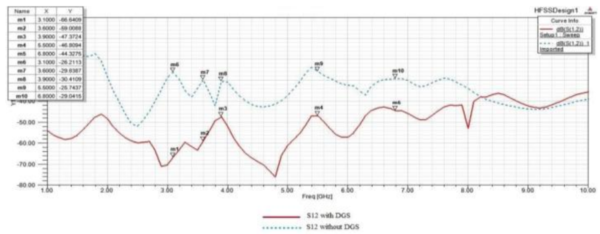

Figure 13: S12 of MIMO With and Without DGS

It is clear from the figure 13,mutual coupling got suppressed and thus an isolation of-59dB is obtained with using DGS,but there is only an isolation of -29dB without using DGS structure[15].Clearly it depicts that DGS plays a major role in reducing mutual coupling than EBG,Meander line.

VII. COMPARISON TABLE

Techniques	Frequencies	S11	S12	Gain
MIMO	3.1GHz	-24.6	-26.2	0.87
	3.6GHz	-16.7	-29.8	
	3.9GHz	-15.8	-30.4	
EBG	3.1GHz	-25.1	-26.8	1.12
	3.6GHz	-16.7	-29.6	
	3.9GHz	-15.9	-30.4	
Meander line	3.1GHz	-24.8	-25.5	1.09
	3.6GHz	-16.8	-29.5	
	3.9GHz	-15.8	-30.2	
DGS	3.1GHz	-25.8	-66.4	1.93
	3.6GHz	-17.4	-59.0	
	3.9GHz	-15.8	-47.3	

VIII. HARDWARE DESCRIPTION

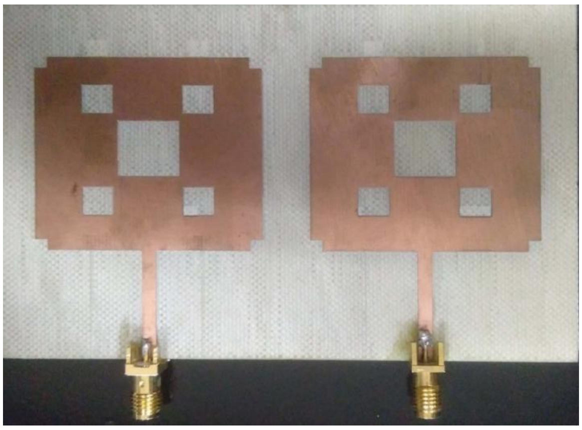

Figure 14:Fabricated Prototype Of The Proposed Design-Top view

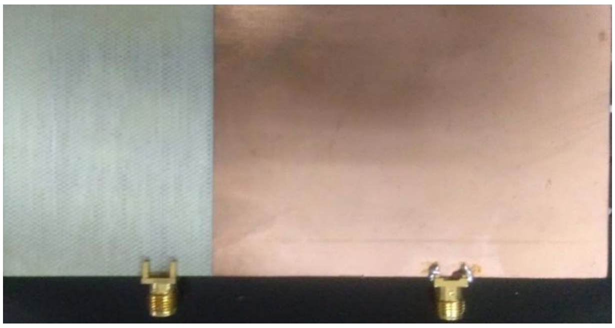

Figure 15: Fabricated Prototype Of The Proposed Design-Rear view

IX. TESTING EQUIPMENT

Figure 16 :Fieldfox Microwave Analyser(VNA) with Fabricated Design

X. HARDWARE RESULTS

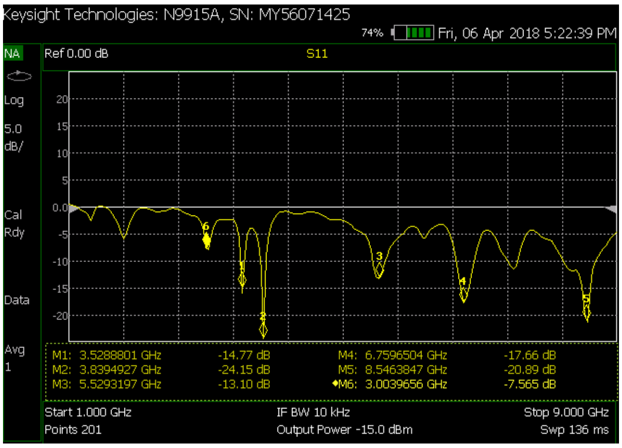

Figure 17: S11 Result of Fabricated Design

In comparison with the simulated results, the fabricated results are found to be same in accordance with frequency.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

XI. CONCLUSION

In this paper various mutual coupling reduction techniqueswith fractal slots of rectangular patch in MIMO antenna has been analyzed. A DGS technique will thus significantly reduce the mutual coupling than the other techniques. It has been observed that there is a decrease in the value up to -59dB using this technique. The structure designed without the above mentioned method experiences a lot of distortion in the observed resultant wave.Antenna analysis shows that the structure with DGS implementation gives improved performance in terms of reduced mutual coupling which leads to better gain and reliability. In addition the results observed in the experimental setup is in close relation with the simulated results.

REFERENCES

1. P. S. R. Chowdary, A. M. Prasad, and P. M. Rao, “Design of modified Sierpinski antenna for WLAN applications,” in 2014 International Conference on Electronics and Communication Systems, ICECS 2014, 2014.
2. R. Choudhary, S. Yadav, P. Jain, and M. M. Sharma, “Full composite fractal antenna with dual band used for wireless applications,” in Proceedings of the 2014 International Conference on Advances in Computing, Communications and Informatics, ICACCI 2014, 2014, pp. 2517–2520.
3. G. J. Foschini and M. J. Gans, “On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas,” Wirel. Pers. Commun., vol. 6, no. 3, pp. 311–335, 1998.
4. D. Sievenpiper, L. Zhang, R. F. Jimenez Broas, N. G. Alexöpolous, and E. Yablonovitch, “High-impedance electromagnetic surfaces with a forbidden frequency band,” IEEE Trans. Microw. Theory Tech., vol. 47, no. 11, pp. 2059–2074, 1999.
5. .R Best and J.D Marrow, “Limitations of Inductive Circuit Model Representations of meander lineantennas”, vol. 1, pp 852-855, IEEE Trans. Antenna and Propagation Society International Symposium,June 2003
6. M. S. Sharawi, “Printed multi-band MIMO antenna systems and their performance metrics [wireless corner],” IEEE Antennas Propag. Mag., vol. 55, no. 5, pp. 218–232, 2013.
7. M. T. Islam and M. S. Alam, “Compact EBG structure for alleviating mutual coupling between patch antenna array elements,” Prog. Electromagn. Res., vol. 137, pp. 425–438, 2013.
8. C. Y. Chiu, C. H. Cheng, R. D. Murch, and C. R. Rowell, “Reduction of mutual coupling between closely-packed antenna elements,” IEEE Trans. Antennas Propag., vol. 55, no. 6 II, pp. 1732–1738, 2007.
9. X. Zhou, X. Quan, and R. Li, “A dual-broadband MIMO antenna system for GSM/UMTS/LTE and WLAN handsets,” IEEE Antennas Wirel. Propag. Lett., vol. 11, pp. 551–554, 2012.
10. D. Guha, S. Biswas, and C. Kumar, “Annular ring shaped DGS to reduce mutual coupling between two microstrip patches,” in Applied Electromagnetics Conference, AEMC 2009 and URSI Commission B Meeting, 2009.
11. A.P. Aparna, A. Chandramouli, Divya Raju, R. Darwin, “Massive MIMO: Implementation and its Challenges”, International Journal of Pure and Applied Mathematics, Volume 117 No. 22 2017, 101-106.
12. R.Elakkiya, N.M.Harshini,G.Karthikeyan, R.Darwin,“GreenRadioCommunicationsNetworks-Implementationand its Challenges”, International Journal of Pure and Applied Mathematics, Volume 118 No.182018,3567-3579.
13. V.Sumitha,A.Sangeetha,P.Priya,N.Porchelvi,“Circular Antenna For Wireless Communication”, International Journal of Innovations in Scientific and Engineering Research (IJISER), Vol 4 Issue 3 MAR 2017/102,pp83-86.
14. R. Darwin, G. Ishwarya, “ Dual Band MIMO antenna using decoupling slots for WLAN applications”, Journal of Advanced Research in Dynamical and Control Systems, pp. 1138-1147, 2017.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication