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A Triband CPW fed MIMO Antenna with Enhanced Isolation using Defected Ground Structure (DGS)

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ABSTRACT

A co-planar waveguide fed 2X1 MIMO micro strip patch antenna is designed and the optimum isolation between the antenna elements is being obtained by using the Defected Ground Structure (DGS).The proposed antenna best operates at three resonant frequencies 3.5 GHz, 8.3 GHz and 10.9 GHz as the antenna exhibits good isolation(S12),above 20 dB and the maximum isolation obtained is 29.3 dB at 3.12 GHz in the range 2-12 GHz.Also the return loss associated at these resonant frequencies is in permissible limits (|S11| < -10 dB). The other simulated parameters such as envelop correlation coefficient (ECC), voltage standing wave ratio (VSWR), Gain, Radiation Patterns of the designed MIMO antenna are also discussed in this work.

***KEYWORDS:** Co-planar Waveguide, MIMO, Defected Ground Structure (DGS), Isolation, Return loss*

1. INTRODUCTION

In this ever changing modern world there is always a greater demand for the reliable communication technology. The more its reliable the more it gets demanded. And this is one of the main characteristics which make the MIMO (Multiple Input Multiple Output) technology trending in this modern world. The need for the MIMO technology is best described by the disadvantages or the drawbacks of the wireless system which include co-channel interference,fading of signal with long distances,limited bandwidth,unreliability etc.The advantage of MIMO is best described by the spatial diversity and the spatial multiplexing which ensures the high data rate and the reliable data transmission,quality of service and wide coverage of signal.By Using coplanar waveguide there are many advantages which includes easy integration with active and passive elements.CPW will helps in improving the matching of characteristic impedance which in turn reduces the return loss.Many research journals on the performance of CPW fed MIMO antennas were published and one among them is a journal on Dual-band MIMO coplanar waveguide-fed-slot antenna for 5G communications[2] and one more reference journal is on Grounded Coplanar Waveguide-fed Compact MIMO Antenna for Wireless Portable Applications[3]. Micro strip patch antennas are commonly used in MIMO network due to the advantages of it can be effectively coordinated with microwave integrated circuits (MICs).Capable of double and triple frequency operations,light weight ,low creation cost and less space so that it can provide compactness to the MIMO network.Micro strip patch MIMO antennas exhibit good performance in WLAN applications[4] DGS (Defected ground structure) is one of the techniques used in MIMO antenna networks.The advantages of using DGS in MIMO networks includes enhancement of isolation between antenna elements[7],band width expansion[5] and also reduces the mutual coupling.DGS helps MIMO antennas to perform well for various applications such as WiMax[5],5G millimeter wave applications[6] .

There are good number of articles and works on the CPW fed MIMO antennas with different aims and achievements.Some of them which are closely related to this work are ,'Two port CPW fed MIMO antenna with wide bandwidth and high isolation for future wireless applications'[8] in which the small extended stub structures are used to improve the isolation above 20 dB,'Compact CPW-Fed ultrawideband MIMO antenna using hexagonal ring monopole antenna elements'[9] in which the circular arcs shaped grounded stubs are used to enhance the isolation which achieved in keeping the isolation above 15 dB, 'Compact CPW-fed UWB MIMO antenna with a novel modified Minkowski fractal defected ground structure (DGS) for high isolation and triple band-notch characteristic'[10] in which the isolation is improved from 14.71 to 21.81 dB by the addition of parallel rectangular strips at the back side of the antenna.

In this work the single basic antenna is selected from [1]. A 2x1 basic MIMO antenna with overall size 50 mm X 25.5 mm is designed and the simulation results are discussed and isolation between the antenna elements obtained is ranged from 10.8 dB to 22.1 dB within 2-12 GHz and the defected ground structure is deployed between the two antenna elements which helped to enhance the isolation range from -13.8 dB to 29.3 dB within 2-12 GHz and the gain provided with this frequency range is 2.5 dBi to 4.7 dBi.

2.DESIGN OF MIMO ANTENNAS

Design of basic CPW Fed MIMO Antenna

Multiple Input Multiple Output is the technique used in the modern antenna system to enhance the data rates over the user when the input is taken from antenna to get the output signal over multiple channels.It provides high quality of service and wide coverage.There is signal fading problem in wireless channel, to overcome this problem, use MIMO antenna.There are several design challenges for MIMO antennas. It includes integration of multiple antenna elements in a single antenna system,to maintain the compactness of the antenna,to reduce the mutual coupling between the antenna elements. The prototype of the single element base antenna is Coplanar waveguide fed ultra-wideband antenna was designed which is taken from journal [1]. The alignment of ground and substrate in the same plane is known as Coplanar. The Coplanar waveguide is a planar transmission line, which is widely used for microwave IC design. The advantages of coplanar waveguide are broadband performance, low dispersion.

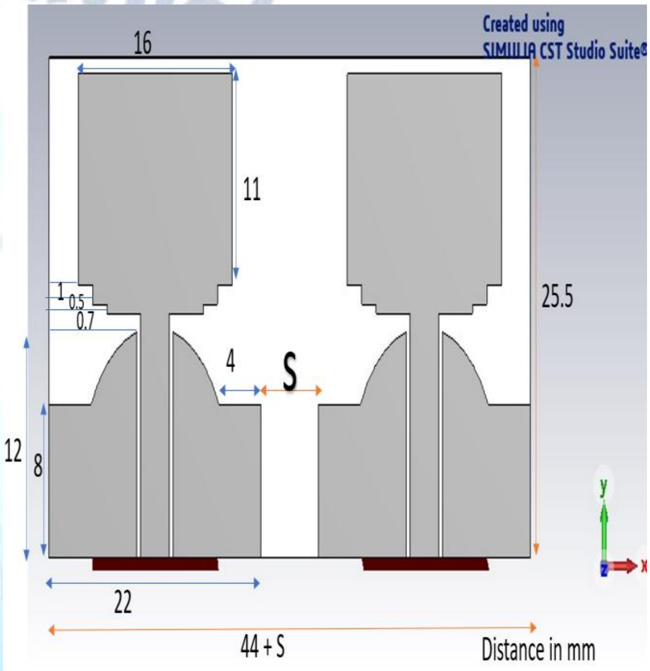

Fig. 1. Design of basic CPW Fed MIMO Antenna

The design and simulation of MIMO antenna are done on computer simulation technology software. The separation between the antenna elements is denoted by S. In this work the value of S is taken as 6 mm. The components of MIMO antenna are substrate, patch and ground. For 6 mm separation MIMO antenna, the dimensions of substrate are 50 mm long, 25.5 mm width and 1.4 mm height. The dimensions of patch are 16 mm long, 12.5 mm width and 0.02 mm height. The dimensions of ground are 22 mm long, 8 mm width and 0.02 mm height.

The properties of FR-4 (lossy) are Epsilon is 4.3 and Mu is 1. FR means flame retardant which means heat resistant. The properties of PEC (perfect electrical conducting material) are idealized material which exhibits infinite electrical conductivity and zero resistance. The materials used in the design of MIMO antenna are FR-4 (lossy), PEC (perfect electrical conducting material). For designing of substrate FR-4 (lossy) material used and for designing of patch and ground, uses PEC (perfect electrical conducting Material).

Design of basic CPW Fed MIMO Antenna with Defected Ground Structure (DGS)

To get better simulation results of MIMO antenna, Defected Ground Structure (DGS) method is preferable. The purpose of DGS is to decrease Mutual coupling of two antennas and increase isolation of MIMO antenna. Designing DGS in between 6mm separation of MIMO antenna. DGS is a purposefully created defect on the ground plane of a printed microstrip board. It is typically created in the form of an etched-out pattern on the ground plane. DGS is a simplified form of Electromagnetic Band Gap (EBG) structure. It is used to suppress the mutual coupling between adjacent element for improving the radiation characteristics of the microstrip patch antenna. The defects on the ground plane disturb the current distribution of the ground plane and it absorbs the surface waves.

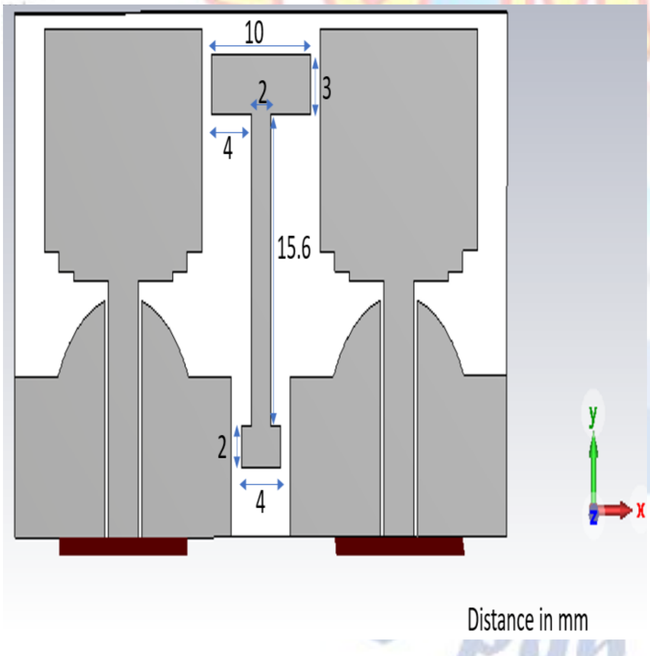

Fig. 2. Design of basic CPW Fed MIMO Antenna with Defected Ground Structure (DGS)

The materials used to design the DGS are PEC (perfect electrical conducting material). The dimensions of DGS design are 4 mm long, 2 mm width, and 0.02 mm height at bottom of DGS. 2 mm long, 15.6 mm width, and 0.02 mm height at middle of DGS and 10 mm long, 3 mm width, and 0.02 mm height on top of DGS.

From the designing of DGS, it improves the isolation of MIMO antenna and decreases the mutual coupling between two antenna elements. For all the operating frequencies, i.e., 3.52 , 8.37 , 10.95 GHz both the S11 and the S12 are optimum i.e S11 is less than -10 dB and is S12 less than -20 dB.

3. SIMULATION RESULTS

In the previous section the design of CPW fed MIMO antenna and the design of the same along with the defected ground structure are described. The simulation parametric results of both the designs such as S12(Isolation), S11(Return loss), ECC, Gain are discussed. The introducing of DGS between the antenna elements has the effect on the surface current flow of the elements. Since the DGS is symmetrical about the antenna elements the parameters S11 and S22 are equal and likewise the S12 and S21 parameters. The results are described in a way by giving the effect of DGS on the basic MIMO antenna.

S parameters (Isolation and Return loss)

Fig.1 shows the s-parameters graph of basic MIMO antenna in terms of decibel(dB) versus frequency (GHz) and the fig.2 represents the same thing for the DGS MIMO antenna. It is clearly noticed that in fig.1 the S12 curve is in between -10 dB and -20 dB lines from 2 GHz to 12 GHz where as in the fig.2 it is observed that S12 curve is almost in between -20 dB and -30 dB lines from 2 GHz to 12 GHz that infers the introduction of DGS has enhanced the isolation between the antenna elements but it is not a constant improvement at all the frequencies. The maximum isolation achieved out of this work is 29.3 dB for the DGS MIMO antenna at 3.2 GHz. The return loss(S11) curve of basic MIMO antenna in fig.1 infers that return loss is high upto 3 GHz and then it is nearly constant of around -10 dB from 4 GHz to 9 GHz followed by a low loss from 10 GHz to 12 GHz. In fig.2 the return loss is above -10 dB almost from upto 7 GHz and then it falls to nearly -40 dB.

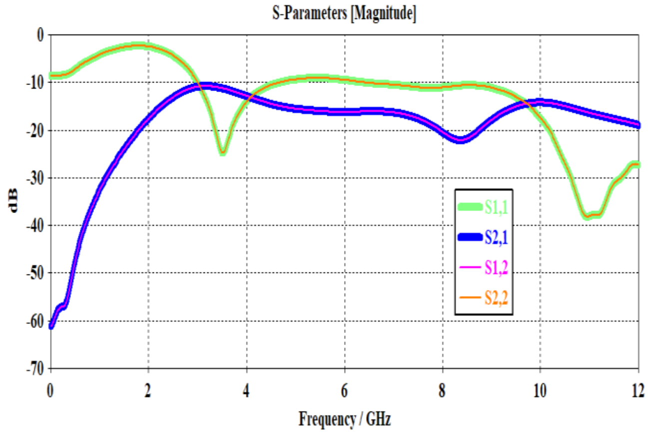

Fig. 3. S parameters of Basic MIMO antenna

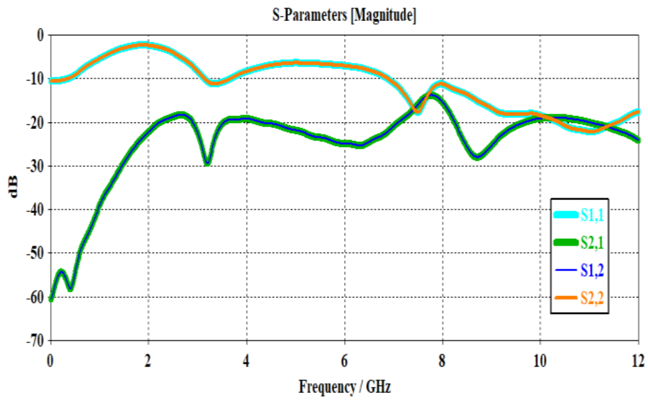

Fig. 4. S parameters of DGS MIMO antenna

Gain

Fig.3 and fig.4 represent the gain of basic MIMO antenna and DGS MIMO antenna respectively as Gain(dBi) versus Frequency (GHz) graph. The maximum gain for the basic MIMO antenna obtained is approximately 4.3 dBi at around 8.3 GHz where as for the DGS MIMO antenna the maximum gain obtained is approximately 4.7 dBi at around 8.3 GHz.The effect of DGS over gain is positive at certain frequencies like 8.3 GHz and 11 GHz.

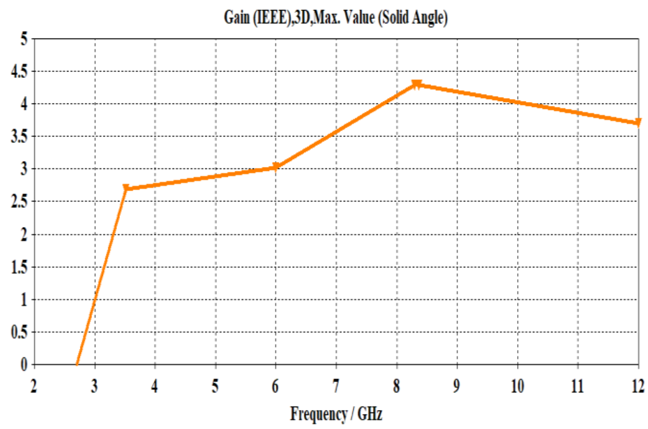

Fig. 5. Gain of Basic MIMO antenna

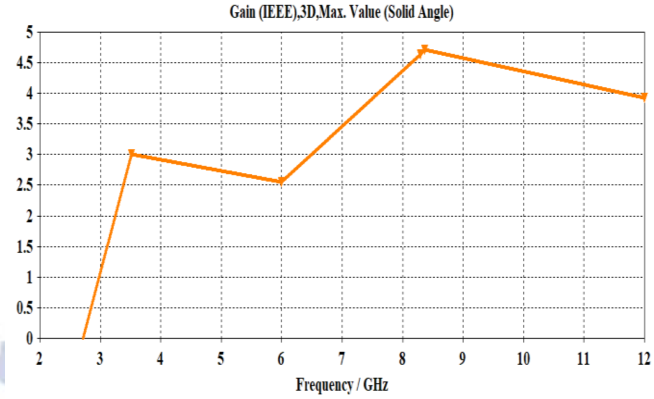

Fig. 6. Gain of DGS MIMO antenna

Voltage Standing Wave Ratio (VSWR)

The VSWR is almost less than 2 for the basic MIMO antenna from 3 GHz to 12 GHz which is proving by the fig.5 and from the fig.6 it is indicating that the VSWR is somewhat fluctuating between 2 and 3 but it is less than 2 at most of the frequencies.

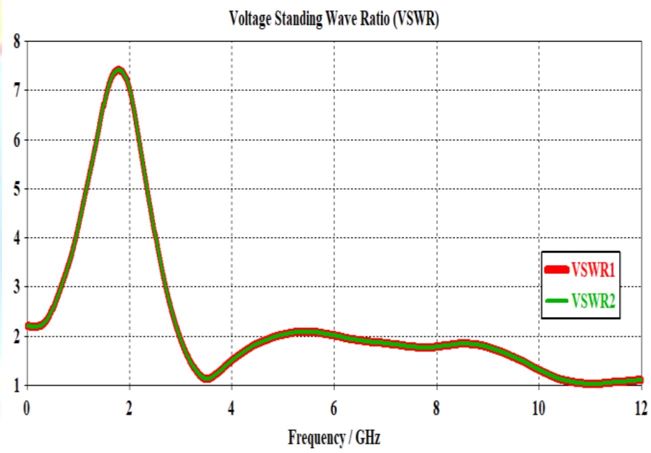

Fig. 7. VSWR of Basic MIMO antenna

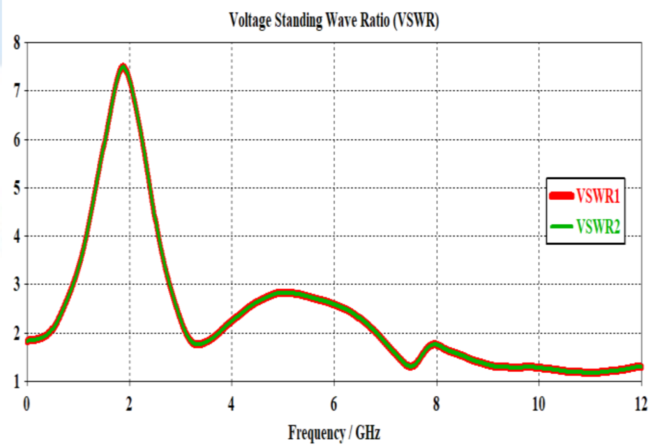

Fig. 8. VSWR of DGS MIMO antenna

Envelop Correlation Coefficient (ECC)

The fig.7 represents the envelop correlation coefficient (ECC) of the basic MIMO antenna and the maximum value is 0.015 which is a very small value obtained at around 5.7 GHz and the fig.8 represents ECC graph of the DGS MIMO antenna in which the maximum value is 0.013 obtained at 7.9 GHz which is even smaller than that of the basic MIMO antenna.

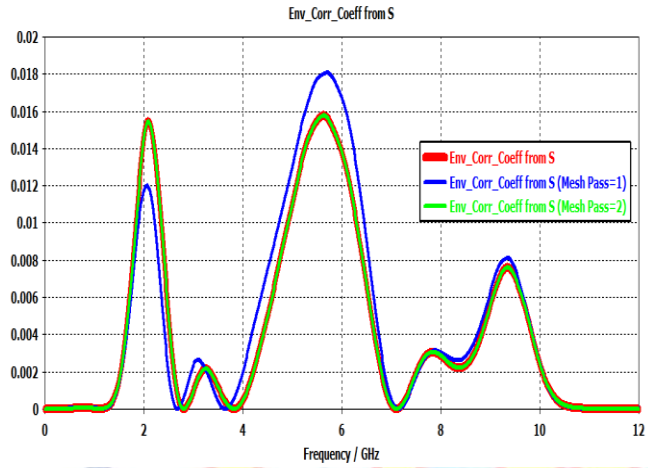

Fig. 9. ECC of Basic MIMO antenna

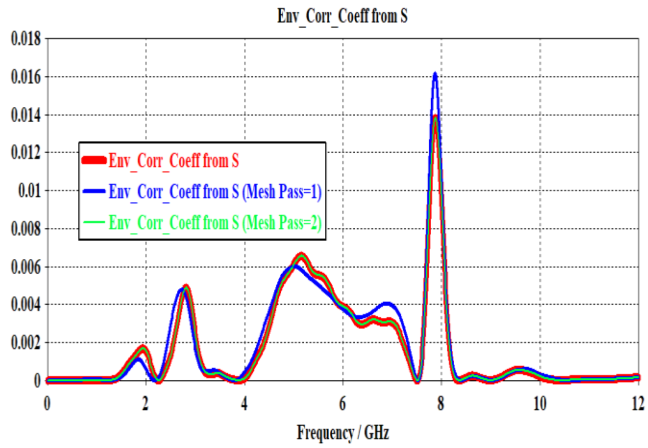

Fig. 10. ECC of DGS MIMO antenna

Radiation Patterns

The fig.9, fig.10 and fig.11 show the farfield radiation patterns of the proposed antennas. At lower frequencies the radiation is omnidirection and the same is shown in fig.9 and at 3.52 GHz frequency. At around 8.5 GHz there is a bidirectional radiation and at around 10.9 GHz the radiation is multidirectional which are shown through the fig.10 and fig.11 respectively.

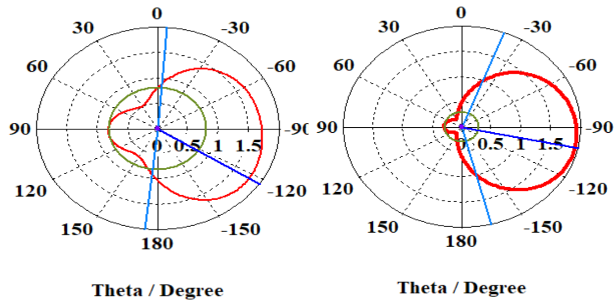

Fig. 11. Basic MIMO (left), DGS MIMO (right) at f=3.5GHz

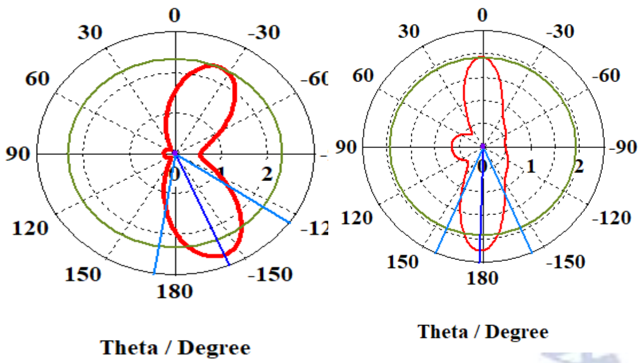

Fig. 12. Basic MIMO (left), DGS MIMO (right) at f=8.3GHz

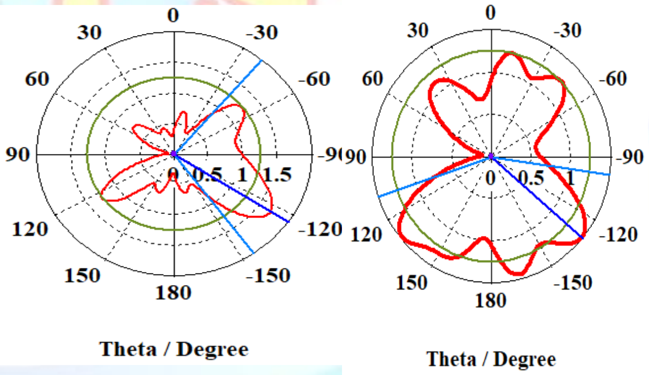

Fig. 13. Basic MIMO (left), DGS MIMO (right) at f=10.9GHz

Surface Current Distribution

The intensity of surface current is more for the basic MIMO antenna .With the integration of DGS the intensity of the surface current is reduced.For instance,from fig.14 and fig.15,it is observed that the surface current of basic MIMO antenna at 3.5 GHz is absorbed by the DGS which reduces the surface current distribution on the second antenna element.All the surface current distributions shown here are due to port1 (left antenna element) excitement and its effect on the port2(right antenna element) and the DGS.Fig.16 and fig.17 shows the surface current distribution for the basic and the DGS MIMO antennas respectively at 8.3 GHz.Fig.18 and fig.19 shows the surface current distribution for the basic and the DGS MIMO antennas respectively at 10.9 GHz.

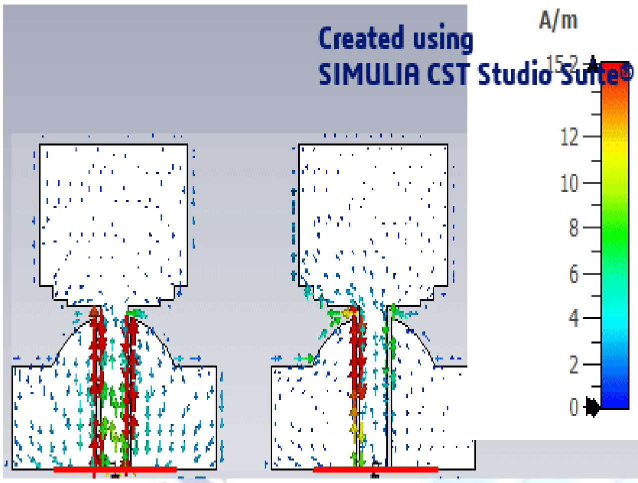

Fig. 14. Surface current distribution of Basic MIMO antenna at 3.5 GHz

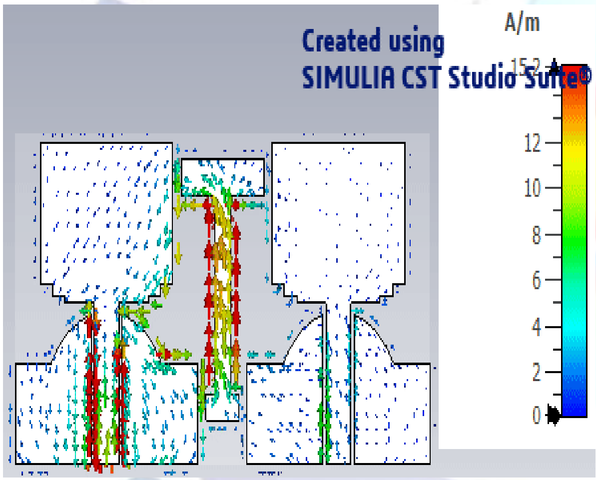

Fig. 15. Surface current distribution of DGS MIMO antenna at 3.5 GHz

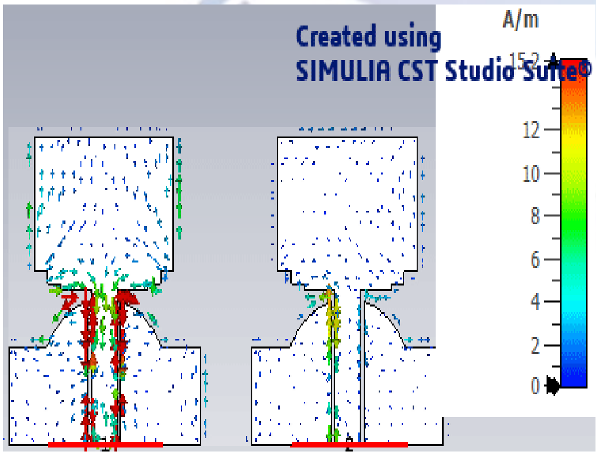

Fig. 16. Surface current distribution of Basic MIMO antenna at 8.3 GHz

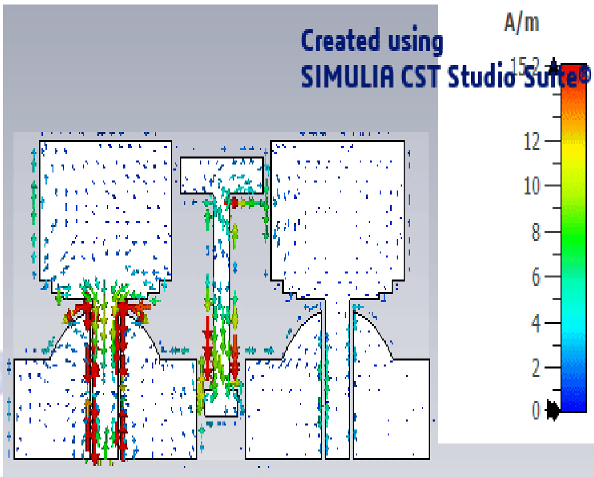

Fig. 17. Surface current distribution of DGS MIMO antenna at 8.3 GHz

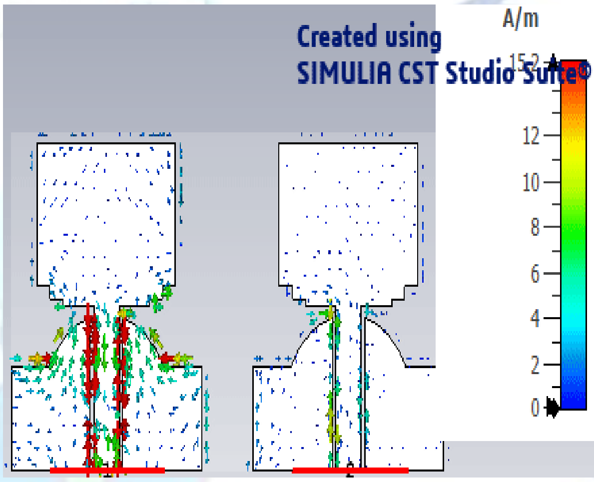

Fig. 18. Surface current distribution of Basic MIMO antenna at 10.9 GHz

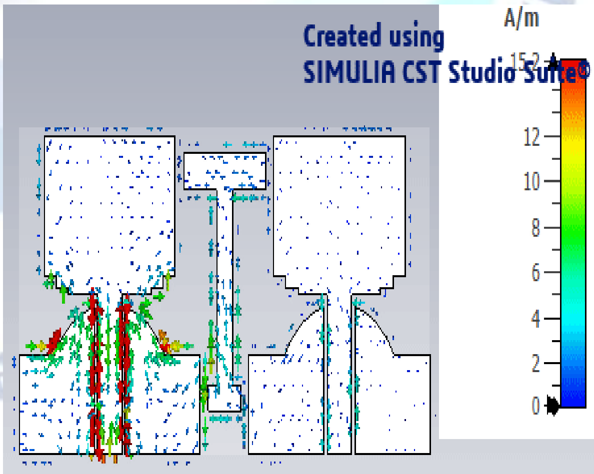

Fig. 19. Surface current distribution of DGS MIMO antenna at 10.9GHz

4.SUMMARY

This section consists the summary of the simulation results from the Table 1 which describes the total work at a glance in an understanding manner.The three frequencies 3.52 GHz, 8.37 GHz and 10.95 GHz are taken as resonant frequencies and the work of enhancing the isolation is concentrated at these frequencies and the DGS is designed in such a way that it ensures the optimum results at all the resonant frequencies that chosen.The following table gives the comparison of S parameters between the basic and the DGS MIMO, also,the other parameters such as VSWR,Gain,ECC are also compared. At 3.52 GHz the isolation is enhanced from -11.30 dB to - 20.17 dB and the maximum isolation provided is -29.3 dB at 3.2 GHz and the gain is also improved from 2.68 dBi to 3.01 dBi and the return loss is less than -10 dB for both the antennas. The isolation is optimized to -22.80 dB at 8.37 GHz and maximum is at 8.7 GHz which is -28 dB and the gain is improved to 4.70 dBi and at 10.95 GHz the isolation is enhanced to -20.02 dB and the gain to 4.14 dBi.

Resonant Frequency (GHz)	MIMO Type	S11 (dB)	S12 (dB)	VSWR	Gain (dBi)	ECC
3.52	Basic	-24.7	-11.30	1.12	2.68	0.00100
	DGS	-10.72	-20.17	1.82	3.01	0.00034
8.37	Basic	-10.67	-22.17	1.82	4.29	0.00220
	DGS	-13.01	-22.80	1.57	4.70	0.00001
10.95	Basic	-38.20	-16.30	1.02	3.86	0.00001
	DGS	-22.09	-20.02	1.17	4.14	0.00004

5.CONCLUSION

In this work the two MIMO antennas are designed and the simulated results are discussed. The isolation between the antenna elements of the basic MIMO antenna gets enhanced and optimized to less than -20 dB at the resonant frequencies 3.52 GHz,8.37 GHz and 10.95 GHz and the return loss is also under 10 dB which infers that the proposed DGS MIMO antenna best suits for the wireless applications operating at frequencies around 3,8 and 11 GHz.Also the proposed DGS MIMO antenna is compact and can be integrated within the communication systems easily as it can occupy less space.The proposed antenna is suitable for applications which require S-band frequencies (2-4 GHz) as it contains frequencies around 3.5 GHz particularly the maximum isolation, 29.3 dB, obtained at 3.2 GHz and this applications include such as navigational assistance,inflight Wi-fi,surface ship radar. The other two frequency bands,8.37 GHz and 10.95 GHz, comes under the X-band frequency range 8-12 GHz.The maximum isolation obtained within this range is 28 dB at 8.7 GHz.The proposed antenna is suitable for X-band applications such as satellite and terrestrial communications and also for civil and government radar applications.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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