Mutual coupling analysis for 2*2 MIMO antenna using DGS

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Abstract - *Mutual coupling significantly lowers MIMO (multiple input multiple output) antennas' system performance and radiation patterns. In this paper, mutual coupling analysis of two element MIMO antenna operating at 28 GHz with various spacing between them is carried out. The analysis was done with and without applying DGS to the proposed structure. The spacing of λ/2, λ/4 and λ/8 is considered between the antenna elements for mutual coupling analysis, where λ is the wavelength at frequency of 28GHz. It has been found that mutual coupling is greater when there is less space between the two antenna components, i.e., the mutual coupling obtained is greater when the spacing between the antenna elements is λ /8 in both the presence and absence of DGS. All the simulations carried out in this work has been done on HFSS v.15.0 tool.*

Key Words: MIMO Antenna, Mutual Coupling, DGS, Inter element spacing, Reflection and Transmission Co-efficient.

1. INTRODUCTION

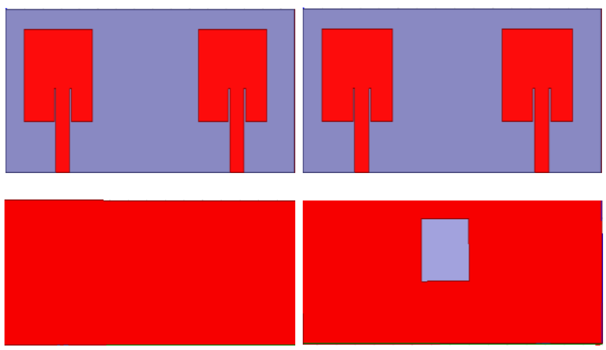
Numerous disciplines, including realistic Ultra High Definition, Artificial Intelligence, Block-chain, and Internet of Things services like Smart Cities, Smart Transportation, and Smart Grids, will be much improved as a result of the phenomenal rise in mobile data speeds brought on by 5G. Carriers are likely to employ the 28, 38, and 73 GHz bands, which will be made accessible for future technologies, as the mobile industry moves toward using the millimeter-wave spectrum. Multiple-input-multiple-output (MIMO) technology can be used to accomplish these goals [1].

MIMO (multiple input multiple output) antenna is represented by M*N, where M represent multiple antennas at transmitter side and N represent multiple antennas at receiver. Isotropic antenna radiates signals in all directions equally but in case of point-to-point communication like satellite, radar applications need to send signals in only one direction for that purpose researchers start designing the MIMO antenna. Two things need to maintain while designing MIMO antennas are spacing and feeding method. As separation between antennas get decreases the mutual coupling between them got increases. The presence of this mutual coupling reduces the radiation pattern, increases the co-channel interference and changes the input characteristics of the antenna. So, to overcome this drawback there are many technologies like EBG structure [2], PCR method [3], 3D EIW cells [4], DGS [5], and other hybrid techniques [6]. In this paper, we used DGS (defective ground structure) because it is easier to design, and cost required for designing purpose also less compared to other methods.

In this work, the mutual coupling analysis of 2*2 rectangular patch antenna with inter-element spacing of λ/2, λ/4 and λ/8 respectively is done using Defective Ground Structure (DGS), where λ is a wavelength at frequency of 28GHz. The antenna was built on RT duroid and has a compact dimension of 15.7 x 5.8 x 0.5 mm^3. The antenna operates at 28 GHz (27.22 to 28.84 GHz) satisfying the need of future 5G applications.

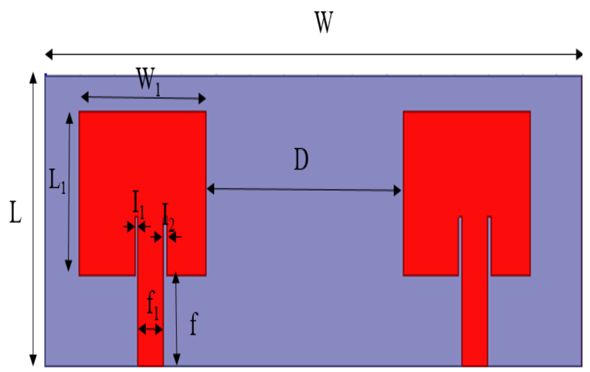
2. ANTENNA CONFIGURATION

The Proposed configuration of 2*2 MIMO antenna is illustrated in Fig 1. The antenna is built on RT duroid with a thickness h = 0.5mm and relative permittivity $\varepsilon_r = 2.2$ with compact dimension of 15.7 x 5.8 mm^2. The proposed structure mainly consists of two rectangular patches placed apart from each other used as a single MIMO antenna as shown in Fig 1. The inset feed method is used to excite the proposed antenna. Firstly, an antenna with full ground plane is designed at 28GHz with S11 < -10 dB, as shown in Fig 1(a), and corresponding mutual coupling has been analyzed. Next, the antenna with partial ground plane (DGS) is designed with same frequency of 28GHz, as shown in Fig 1(b), and the corresponding mutual coupling parameter is analyzed. The detailed dimensions of the antenna designed in this work are tabulated in Table 1 and its point by point dimensions are presented in Fig 2

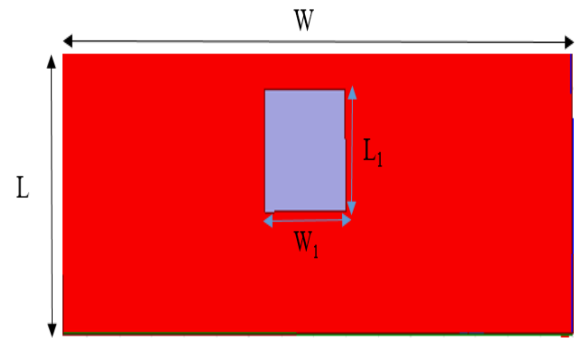


(a) (b)

Fig -1: Proposed 2*2 MIMO Antenna: (a) Without DGS and (b) With DGS



(a)



(b)

Fig -2: Proposed 2 * 2 MIMO Antenna with DGS: (a) Radiating Patch (b) Ground Plane.

Table -1: Detailed Dimension of proposed antenna

Parameter	Dimension (mm)
W	15.7
W_1	3.7
L	5.8
L_1	3.2
D	5.3
F	1.8
F_1	0.75
I_1,I_2	0.1
P	1.7

3. DESIGN ANALYSIS

In this work the mutual coupling between the patches of 2*2 MIMO antenna is analyzed by varying the distance between them(D) in both cases of with DGS and without DGS.

Without DGS:

The patches are placed apart at a distance of λ/2, λ/4 and λ/8 respectively, where λ is the wavelength of operating frequency at 28GHz. At first case, when D=λ/2 the Reflection co-efficient S11 obtained is -42.32 dB and transmission co-efficient S12, which represents mutual coupling is -40.0382. At second case, when D=λ/4 S11 obtained is -35.443 dB and S12 is -43.3795. At third case, when D=λ/8, S11 obtained is -52.3425 dB and S12 is -22.27 dB. The corresponding S11 and S12 plots are shown Fig 3 and Fig 4 respectively.

With DGS:

As shown in Fig 5 and Fig 6, by applying DGS to the antenna designed with D=λ/2, S11 obtained is -39.1895 dB and S12 is -36.5569. At second case, when D=λ/4 the S11 obtained is -38.4209 dB and S12 is -42.1844. At third case, when D=λ/8 the S11 obtained is -41.8286 dB and S12 is -21.1390 dB.

By the analysis shown above it is observed that, as distance between the elements of MIMO antenna gets reduces, the mutual coupling between them increases.

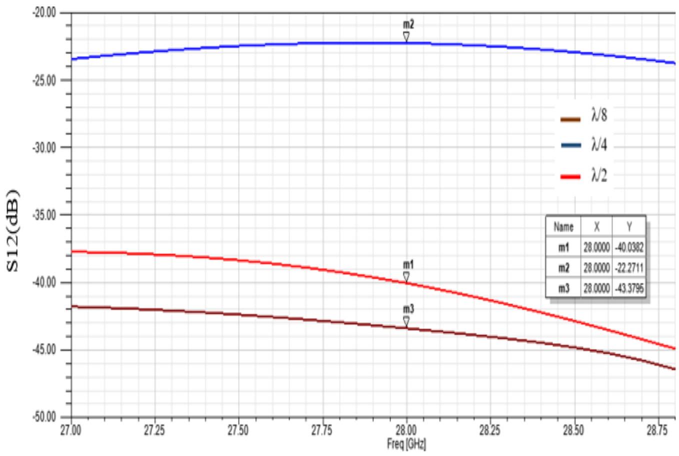


Fig -4: S12 plots of proposed 2*2 MIMO Antenna without DGS for various inter element spacing.

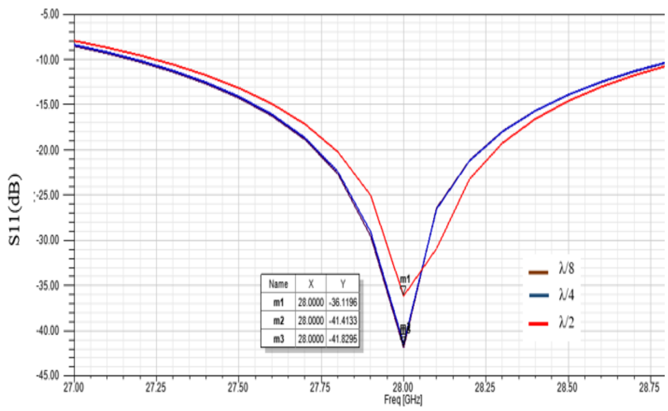


Fig -5: S11 plots of proposed 2*2 MIMO Antenna with DGS for various inter element spacing.

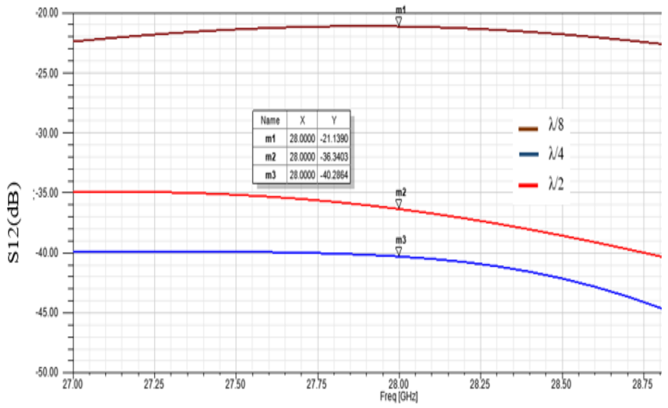


Fig -6: S12 plots of proposed 2*2 MIMO Antenna with DGS for various inter element spacing.

4. RESULTS AND DISCUSSIONS:

The Table summarizes the overall results obtained from proposed 2*2 MIMO antenna. As discussed above the antenna operates at 28GHz with spacing of λ/2, λ/4 and λ/8 respectively. The better S11 was obtained by spacing of λ/8 between the elements of MIMO antenna, i.e., -52.34 dB was obtained without DGS and while applying DGS a maximum S11 is -41.82 dB. The more mutual coupling which is represented in terms of S12 parameter is observed at by spacing of λ/8. In order to show the significance of proposed structure, the VSWR, gain and directivity was found and is illustrated in Table 2. The VSWR values obtained lies nearer to 1 which shows that better impedance matching was obtained. The gain of 6.03, 6.18, and 5.99 was obtained without DGS with inter element spacing of λ/2, λ/4 and λ/8 respectively, the gain of 6.04, 6.17 and 6.06 was obtained with DGS with inter element spacing of λ/2, λ/4 and λ/8 respectively. Similarly, directivity of 6.07, 6.21, and 6.05 was obtained without DGS with inter element spacing of λ/2, λ/4 and λ/8 respectively, the directivity of 6.07, 6.20 and 6.11 was obtained with DGS with inter element spacing of λ/2, λ/4 and λ/8 respectively.

The 3D polar plot of proposed antenna with and without applying DGS for various inter element spacing is shown in Fig 7.

Table 2: Summarized Results of Proposed Antenna

Parameters	Without DGS			With DGS		
	λ/2	λ/4	λ/8	λ/2	λ/4	λ/8
S11(dB)	-42.32	-35.44	-52.34	-39.18	-38.42	-41.82
S12 (dB)	-40.03	-43.37	-22.27	-36.55	-42.18	-21.13
VSWR	1.01	1.03	1.00	1.02	1.02	1.01
Gain (dB)	6.03	6.18	6.06	6.04	6.18	5.99
Directivity(dB)	6.07	6.21	6.05	6.07	6.20	6.11

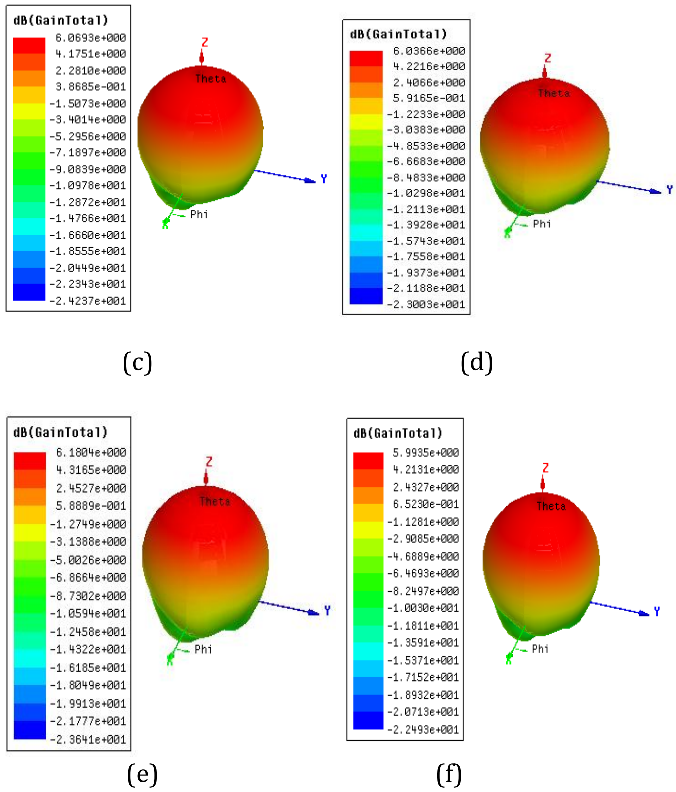


Fig -7: 3D Polar plot of Proposed Antenna: (a) (b) and (c) are without DGS, (d) (e) and (f) are with DGS: (a) and (d) for λ/2 spacing, (b) and (e) for λ/4 spacing, and (c) and (f) for λ/8 spacing.

3. CONCLUSIONS

In this paper, a 2*2 MIMO antenna is designed operating at a center frequency of 28 GHz for 5G applications. The mutual coupling of two antenna elements was analyzed with respect to various distance between them and further the antenna is analyzed by applying DGS. Along with mutual coupling, the analysis of reflection co-efficient, VSWR, gain and directivity for various cases was done in this paper. It is observed that the mutual coupling is more when distance between the two antenna elements is less i.e., the mutual coupling obtained is more when the spacing between the antenna elements is λ/8 in both with and without DGS condition. The results confirm that the antenna operates well because better S11, acceptable gain and directivity, and stable radiation pattern was obtained.

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