Investigation of Placing Defective Ground Structures for Bandwidth Enhancement in Microstrip Patch Antennas

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***Abstract*— Rectangular Micro strip patch antenna with Defective Ground Structures (DGS) is proposed in this paper. The overall dimension of the antenna is (130*130*1.64) mm. The antenna produces resonance at 2.48 GHz, 4.01 GHz and 4.64 GHz which supports WLAN applications. The proposed antenna gives the reflection coefficient of -16.8dB, -36.94dB and -27.73dB respectively in simulation. The directivity values in simulation are 7.7dBi, 3.8dBi and 6.3dBi respectively. The antenna is designed using FR4 substrate with a dielectric constant value of 4.4. By using DGS, bandwidth is enhanced. The various parameters like reflection coefficient, directivity, bandwidth, radiation pattern are simulated using EM simulator.**

***Keywords—DGS (Defected Ground Structure), patch antenna, WLAN, Reflection coefficient* (S_{11}) dB**

I. INTRODUCTION

The defects on the ground plane are called Defected Ground Structures (DGS). This suppresses spurious radiation and mutual coupling and enhances the performance of the antenna as well as filters [1]. To eliminate these problems, Park et al. [2] proposed Defected Ground Structure (DGS) and characterized DGS for single dumbbell shaped defect. The DGS can be considered as a simplified form of EBG structure, which also exhibits a band-stop property [3]. DGS provides a way to microwave researchers of a wide range of applications. Various structures of DGSs have been proposed and characterized. By adjusting the shape of the structure we can attain enhancement of various useful parameters. The development of DGS is thoroughly discussed in [4].

Defective Ground Structures acts as filters which attenuate unwanted frequencies and will make the antenna to resonate in particular desired frequency. Slots or Defective Ground Structures made on the ground plane enhances the performance like Bandwidth, return loss, VSWR. Conventional micro strip patch antennas have limitations like lower bandwidth, polarization problems. There are many number of techniques to improve the performance of the patch antenna using Frequency selective surfaces, Electromagnetic Band Gap Structures (EBG), Photonic Band Gap structures, different feeding structures, stacking many layers etc. Antennas integrated with defected ground structure have attained more fascinating features when compared to other techniques.

DGS has wider advantage when compared to EBG due to its low cost and simplicity. The slots or defects in the ground plane disturb the current distribution changes the characteristics of a transmission line (or any structure) by including some parameters (slot resistance, slot capacitance, and slot inductance) to the line parameters (line resistance, line capacitance, and line inductance). In other words, any defect etched in the ground plane under the micro strip line changes the effective capacitance and inductance of micro strip line by adding slot resistance, capacitance, and inductance. A variety of different shapes of geometries embedded on the ground plane under the micro strip line have been reported in the literature. These shapes include rectangular dumbbell, circular dumbbell, spiral, “U”, “V”, “H”, cross, and concentric rings. Some complex shapes have also been studied which include meander lines, split ring resonators and fractals [5].

The repetition of slots is called periodic structures. Distance between the cells, no of cells placed, are the main parameters which will decide the main parameters, which will decide the performance of micro strip antenna. Dual broadband antenna with rectangular slot has been analyzed for wireless applications [6 & 7]. Effective capacitance and effective inductance of the model are changed by embedding the slots on the ground plane, resulting in shifting of resonance frequency to its lower side. Thus, compactness is achieved by using DGS [8].

A compactness of 30% is achieved by using meandering slots in the ground plane [9]. A “T” shaped slot integrated in the ground plane to achieve the miniaturization and compactness of 80% has been achieved [10].

A dual-band asymmetric slits loaded micro strip patch antenna has been proposed and CP was achieved using DGS in both bands of operation [11]. A compact, DGS monopole antenna has been presented [12], which employs a single L-shaped slot in the ground plane of a conventional circular disc monopole antenna in order to achieve multiband performance. Characterizing Defective Ground Structures is easy when compared to characterizing Photonic Band Gap and Electromagnetic Band Gap structures. Variation in the value of inductance and capacitance will make shift in the frequency either lower or upper side.

II. ANTENNA DESIGN AND ANALYSIS

The antenna is designed with three layers, like ground, substrate and patch. The proposed patch antenna is placed above the substrate. The substrate used here is FR4. The dimension of the ground plane is (130*130) mm and made of copper with thickness 0.035mm. The substrate is with dimension (130*130) mm, with thickness 1.57mm. The dimension of the patch is (36*28) mm and total height of the antenna is about 1.67mm.

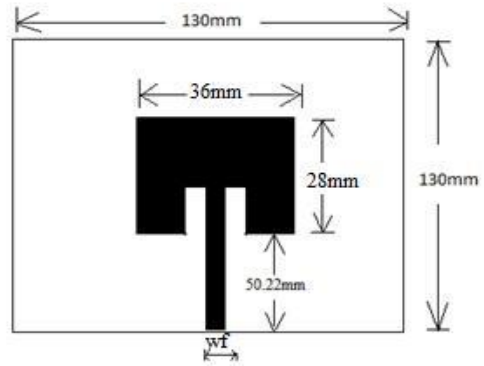

Figure 1. Front view of proposed antenna with Defected Ground Structure.

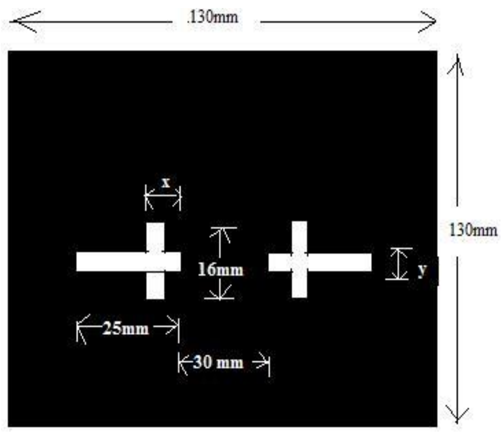

Figure 2. Defective Ground structure of proposed antenna.

The dimension of the defective cell in the diagram drawn above is given as X=8mm and Y=10mm.The white color is defined as substrate and black color shown in the figure is defined as metal. The periodic arrangement of cells in ground will introduce changes in inductance and capacitance which contribute changes in resonance behavior. wf (width of the feed line) is given as 3.16mm.

Since inductance is directly proportional to frequency slot with greater width along X-axis will shift the frequency to the greater side. Similarly, capacitance is inversely proportional to frequency reducing the capacitance value will shift the frequency to the lower side.

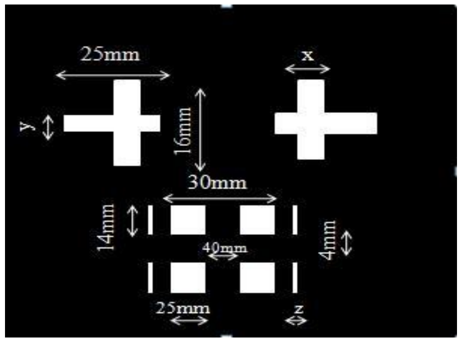

Figure 3. Rectangular slots in ground plane

By placing cross shaped DGS, 156 MHz has been obtained as shown in the figure 4. Figure 3 shows that, by introducing rectangular slot with dimension z=2mm, 184 MHz bandwidth is obtained. Hence, by adjusting the dimensions of the slot current distribution in the ground changes and thereby performance of the patch antenna is enhanced. By changing the dimensions of the slot in the ground plane desired results can be achieved. Capacitance of the antenna can be changed by adjusting the distance between two metals which is separated by a dielectric material. The horizontal slot is always considered as inductor and two metal slots separated by a dielectric acts as a capacitor.

III. RESULTS AND DISCUSSION

The antenna is designed and analyzed for various parameters like directivity, reflection coefficient, and surface current distribution. Figure 4 shows the graph for antenna without DGS.

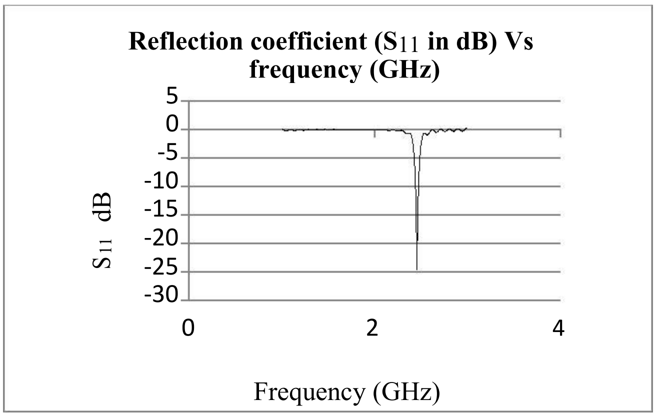

Figure 4. Reflection coefficient (S_{11} dB) vs. Frequency (GHz) for antenna without DGS.

From the normal patch return loss graph single band resonance occurs at 2.48GHz with reflection coefficient of about -24.5dB. This has not reasonable reflection coefficient, directivity and bandwidth hence some modifications are required. To achieve desired response we introduce Defective Ground Structures. Many number of slot structures can be introduced and by changing the dimensions we can enhance the performance.

Only two defective ground cells were introduced. Since it is placed symmetrically on two sides it is known as symmetrically cross shaped slots. By placing defective structures in the ground we have attained three bands with bandwidth of about 56 MHz, 108 MHz and 156 MHz with centre frequency of 2.48GHz, 4.01 GHz and 4.64 GHz respectively.

By introducing rectangular slots along with cross shaped slots, the bandwidth is further increased from 156 MHz to 184 MHz. The proposed antenna is designed with conventional rectangular patch. The design of antenna, reflection coefficient vs frequency graph for the normal patch without defective ground structure and patch with defective ground structure are compared that are shown in the figure 4 & 5. Current distribution in the antenna is shown in the figure 9, 10 & 11, which tells us how antenna resonates. The directivity obtained is about 7.7 dBi, 3.8 dBi, 6.3 dBi respectively which is shown in figure 6, 7 & 8.

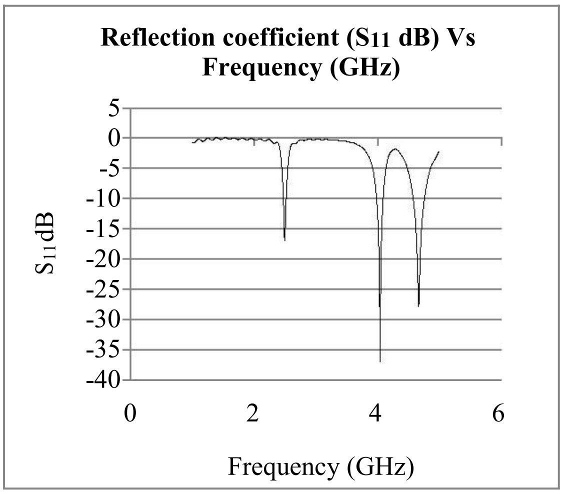

Figure 5. Reflection coefficient (S_{11} dB) Vs Frequency (GHz) for antenna with cross and rectangular slot shaped DGS.

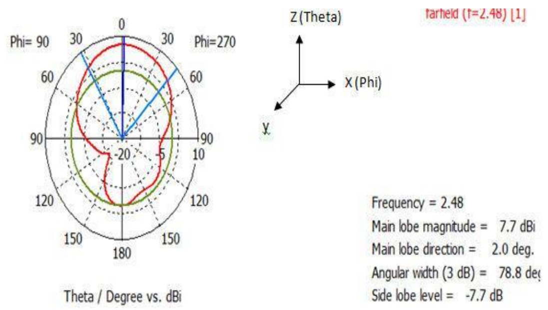

Figure 6. Directivity at 2.48GHz

The directivity obtained is 7.7 dBi

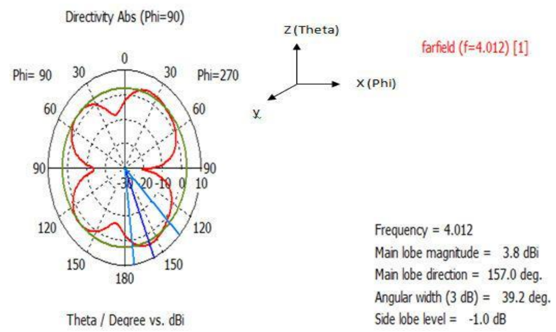

Figure 7. Directivity at 4.012 GHz

The directivity obtained is 3.8 dBi

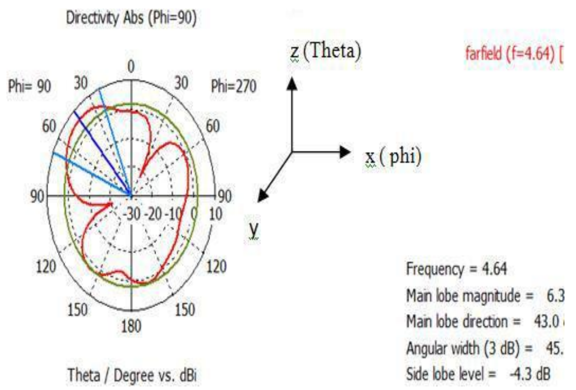

Figure 8. Directivity at 4.64 GHz

The directivity obtained is 6.3dBi.

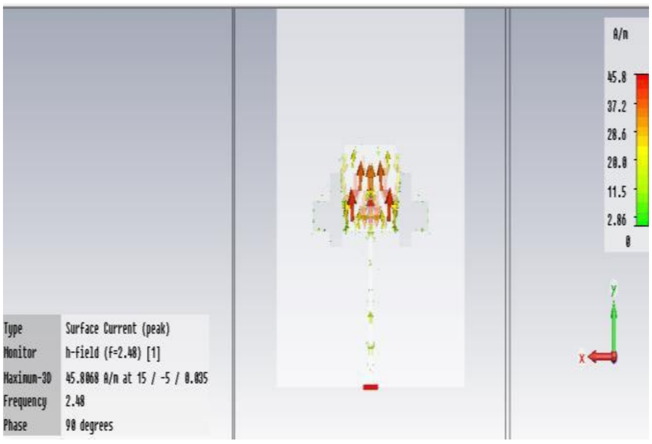

Figure 9. Surface current at 2.48 GHZ

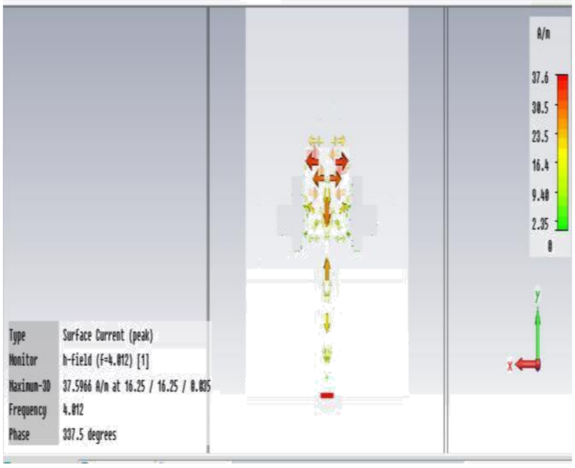

Figure 10. Surface current at 4.012 GHZ

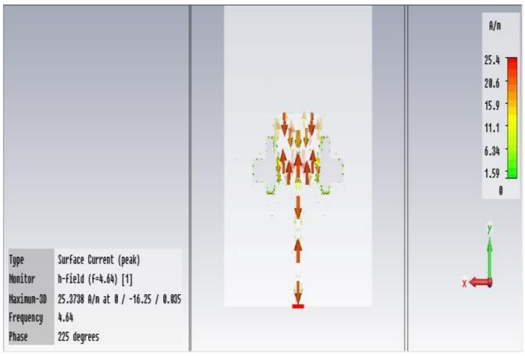

Figure 11. Surface current at 4.64 GHZ

TABLE I. COMPARISON BETWEEN EXISTING AND PROPOSED RESULTS.

Parameters	Proposed system	
	Without DGS	With DGS
Frequency	2.48 GHz	2.48 GHz, 4.01GHz & 4.64 GHz (Triple response)
Reflection coefficient (S_{11} dB)	-24.5 dB	-16.8dB &-36.94dB &-27.73dB
Directivity	7.6 dBi	7.7dBi & 3.8dBi & 6.3dBi
Bandwidth	56 GHz	56 GHZ, 104 GHz, 184 GHz for 2.48 GHz,4.01 GHz & 4.64 GHz respectively. (Triple response)

IV. CONCLUSION

The rectangular shaped patch antenna is designed and simulated with cross shaped Defective Ground Structures. The simulated results shows that the proposed results are good when compared to existing results. The antenna's performance is enhanced without stacking up many layers.

The dimension of the Defective Ground Structures and the patch can be altered such that performance is improved. The extension of this work can be done by placing the Defective Ground Structures above the patch also and integrating it with electromagnetic band gap structures. By characterizing DGS in a better way, greater bandwidth can be obtained such that the antenna can support for 5G applications.

V. REFERENCES

[1] International Journal of Antennas and Propagation Volume 2017 (2017), Article ID2018527,pagehttps://doi.org/10.1155/2017/2018527

[2] J.-I. Park, C.-S. Kim, J. Kim et al., "Modeling of a photonic bandgapand its application for the low-pass filter design," in Proceedings of the Asia Pacific Microwave Conference (APMC '99), vol. 2, pp. 331–334, November-December 1999.

[3] F. Yang and Y. R. Samii, "Electromagnetic Band Gap Structures in Antenna Engineering", Cambridge University Press, Cambridge, UK, 2008.

[4] D. Guha, S. Biswas, and Y. M. M. Antar, Defected Ground Structure for Microstrip Antennas, in Microstrip and Printed Antennas: New Trends, Techniques and Applications, John Wiley & Sons, London, UK, 2011.

[5] H. W. Liu, Z. F. Li, and X. W. Sun, "A novel fractal defected ground structure and its application to the low-pass filter," Microwave and Optical Technology Letters, vol. 39, no. 6, pp. 453–456, 2003.

[6] D.-J. Woo, T.-K. Lee, J.-W. Lee, C.-S. Pyo, and W.-K. Choi, "Novel U-slot and V-slot DGSs for bandstop filter with improved Q factor," IEEE Transactions on Microwave Theory and Techniques, vol. 54, no. 6, pp. 2840–2847, 2006.

[7] H.-J. Chen, T.-H. Huang, C.-S. Chang et al., "A novel cross-shape DGS applied to design ultra-wide stopband low-pass filters," IEEE Microwave and Wireless Components Letters, vol. 16, no. 5, pp. 252– 254, 2006.

[8] D. Piscarreta and S.-W. Ting, "Micro strip parallel coupled-line band pass filter with selectivity improvement using U-shaped defected ground structure," Microwave and Optical Technology Letters, vol. 50, no. 4, pp. 911–915, 2008.

[9] A. M. E. Safwat, F. Podevin, P. Ferrari, and A. Vilcot, "Tunable bandstop defected ground structure using reconfigurable dumbbell shaped coplanar waveguide" IEEE Transactions on Microwave theory and techniques. Vol.54, No.9, September 2006.

[10] S. Dari and S. Sanyal, "Compact sharp cutoff wide stopband low-pass filter using defected ground structure and spurline," microwave and Optical Technology Letters, vol. 48, no. 9, pp. 1871–1873, 2006.

[11] S. Dwari and S. Saral, "Compact wide stopband low-pass filter using rectangular patch compact microstrip resonant cell and defected ground structure," Microwave and Optical Technology Letters, vol. 49, no. 4, pp. 798–800, 2007

[12] S. Dari and S. Sanyal, "Compact sharp cutoff wide stopband microstrip low-pass filter using complementary split ring resonator," Microwave and Optical Technology Letters, vol. 49, no. 11, pp. 2865–2867, 2007.