Patch Antenna for Future 5G Wireless Applications with DGS

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Abstract - A compact size patch antenna resonating at frequency 3.6GHz is presented in this paper. The designed patch antenna is simple in structure and fed using microstrip line. The antenna is designed keeping in mind the specification proposed by Telecom Regulatory Authority of India (TRAI). Proposed antenna shows good results in term of return loss, directivity, VSWR and gain. FR4 is used as a substrate of the proposed patch antenna, while the antenna is simulated using Higher Frequency Structural Simulator (HFSS) software.
Keywords— 5G communications, Patch antenna, Microstrip, defected ground structure, DGS, rectangular patch, HFSS.

I. INTRODUCTION

The present 4G networks are unable to provide instantaneous cloud services, machine to machine communication (M2M), tactile Internet, Internet of things (IoT), enhanced vehicle-to-everything (eV2X), Industrial IOT, Internet of Medical Things (IoMT), Internet of Vehicles (IoV) and communication with robots and drones while guaranteeing quality of service to mobile users. Furthermore, the LTE communication networks are unable to provide high-quality video services to number of mobile cellular users simultaneously. By the year 2025 the total number of connected devices is expected to go beyond 34 billion.

For 5G applications, many frequency spectrum band are proposed by various counties, among them 28GHz, 38GHz, 3.6GHz, V-Band and unlicensed E-Band (71-76GHz, 81-86GHz and 91-93GHz) are the strongly recommended for 5G applications [2].

Federal communication commission (FCC) proposed the frequency band of 27.5- 28.25GHz for 28GHz band spectrum application [6] while the European Telecommunications Standards Institute (ETSI) proposed that for 5G communication antenna must have a bandwidth of 1GHz for S11 return loss less than -10dB [1]. Telecom regulatory authority of India (TRAI) proposed a frequency band of 3.3 - 3.6 GHz for 3.6 GHz spectrum band applications. Keeping in mind these requirements, many Indian researchers designing antennas for 3.6 GHz communication.

A basic rectangular patch antenna is presented in [7] having compact size and significant gain, but the coaxial feed technique is not suitable for applications like cellular mobile device, in [8] another compact size antenna is presented although the antenna has good bandwidth but the antenna gain is less than 3dB, while in [9] antenna has a superior gain but very narrow bandwidth which are against FCC, TRAI and ETSI proposal, in [10] and [11] Planar Inverted F Antenna (PIFA antenna) are presented having wide bandwidth but poor gain.

Another micro strip patch antenna is presented in [12] having a large bandwidth and large gain but the overall size of single patch is not good for handheld device like cellular mobile phone, [13] and [14] present the array antenna for 5G communication having superior gain and wide bandwidth but the overall size of antenna is increased due to formation of array. Keeping these works in view a need for compact size, a higher gain antenna is required for 5G communication using 3.6GHz frequency band spectrum.

Our proposed work is according to the proposal of FCC, TRAI and ETSI and provides a superior gain, required wide bandwidth and compact size with a microstrip line feed that enhances the use of the proposed antenna in small handheld mobile devices. While the use of Defected ground surface (DGS) enhances the parameters of the proposed antenna.

II. ATENNA DESIGN

The antenna considered is a conservative size patch antenna as appeared in Figure 1, the patch is made with FR4 Epoxy material with dielectric constant 4.4 and thickness of 1.6 mm. The ground plane of measurement 38 mm X 48 mm (Lg x Wg), is made using copper.

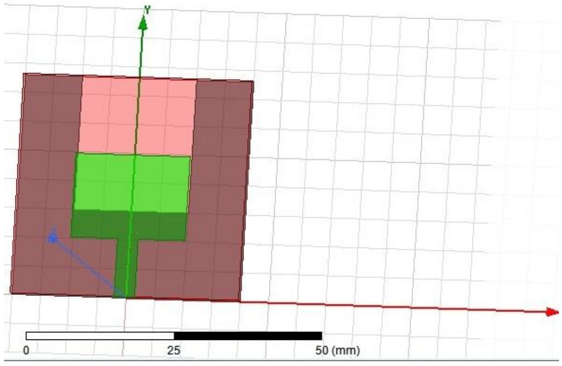

Figure 1. Geometry of Proposed Antenna.

The proposed antenna, as shown in Fig.1, is a rectangular patch antenna of 14.5 mm X 20 mm (Lp x Wp) with feed line of 10 mm X 3.6 mm (Lf x Wf). The ground structure is defected to enhance the performance. The dimensions of rectangular patch antenna are chosen from [3], [5] by using the following formulas.

$$\varepsilon_e = \frac{1}{2}\left(\varepsilon_r + 1\right) + \frac{1}{2}\left(\varepsilon_r - 1\right)\left(1 + 12\frac{h}{w}\right)^{-\frac{1}{2}}$$

for an antenna to radiate as efficiently as possible, W must be equal to λ/2 and is calculated by the relation:

$$\omega = \frac{C}{2f_0\sqrt{\frac{\left(\varepsilon_r + 1\right)}{2}}}$$

Where c is the speed of light in free space The length is given by the relation:

$$L = \frac{C}{2f_0\sqrt{\varepsilon_r}}$$

Where f_0 is the resonance frequency. ΔL and ΔW are the extensions along L and W. The extension of the patch length is calculated by the formula:

$$\Delta L = \frac{h}{\sqrt{\varepsilon_0}}$$

The parameters like Gain, VSWR and Impedance are improved in the proposed patch antenna which is discussed in next section.

III. RESULTS AND DISCUSSION

Simulations of the proposed antenna are carried out using HFSS electromagnetic simulator. The performance of the designed 3.6 GHz patch antenna with DGS and Without DGS are compared.

A. Without DGS

Simulations results of the proposed antenna without DGS. This antenna resonates at 3.5156 GHz. The return loss effect is shown in Figure 2.

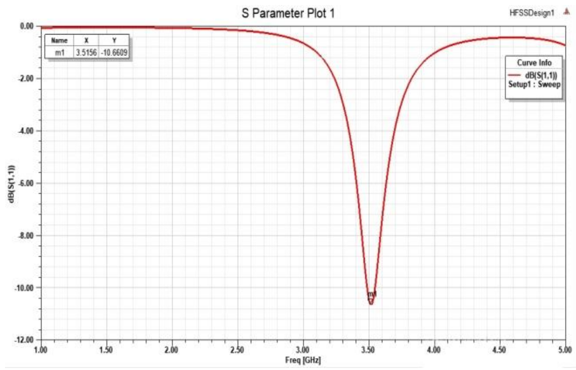

Figure 2. Return Loss.

The value of return loss is -10.66 dB with very narrow bandwidth. The resultant Directivity and gain of the antenna is shown in Figure3 and Figure 4 respectively. The directivity of the patch antenna is 6.35 dB, where as the gain is 4.14 dB.

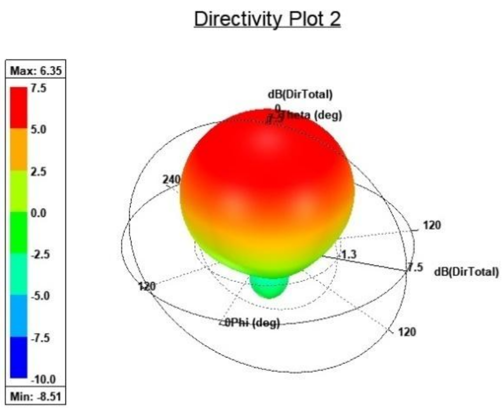

Figure 3. Directivity.

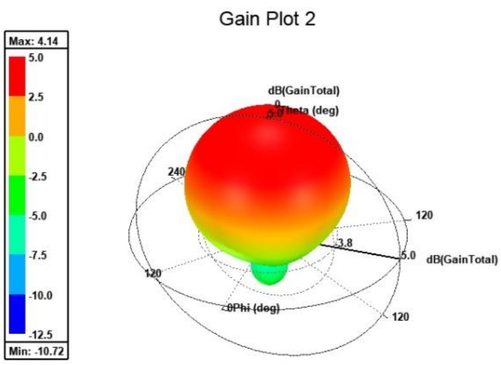

Figure 4.Gain plot.

The VSWR of the antenna is 5.2447 and shown in figure 5. The radiation pattern having a magnitude 2.5954 is shown in figure 6.

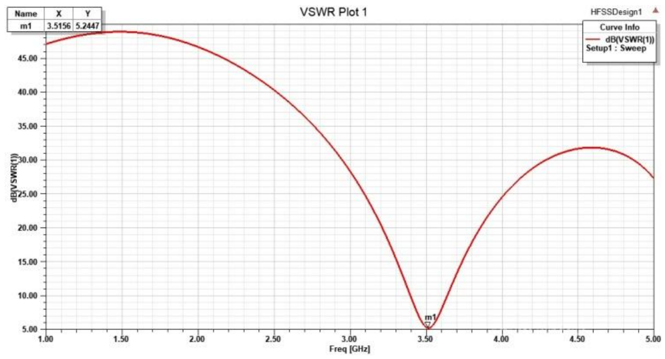

Figure 5. VSWR.

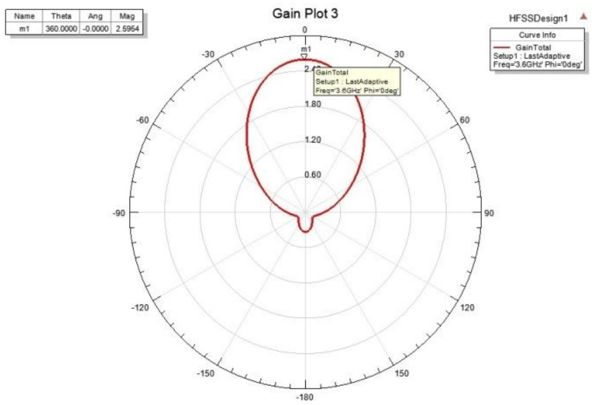

Figure 6. Radiation Pattern.

B. With DGS

Simulations results of the proposed 3.6 GHz antenna with DGS are presented here, as we seen earlier that this antenna enhances the return loss effect as shown in Figure 7.

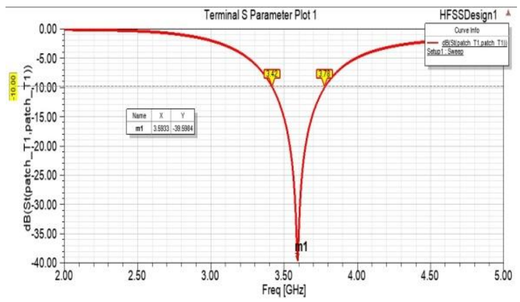

Figure 7. Return Loss of proposed Antenna

The value of return loss is -39.59 dB at 3.59 GHz with bandwidth of 0.36GHz. The resultant directivity and gain of the antenna are shown in Figure 8 and Figure 9 respectively.

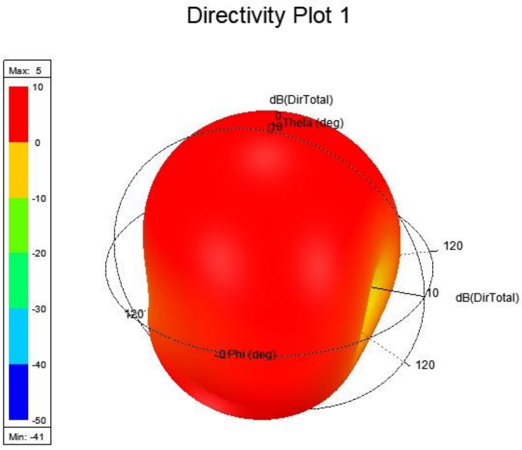

Figure 8. 3D-Directivity plot of proposed Antenna

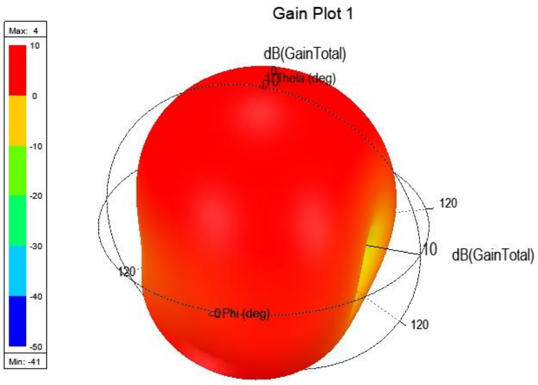

Figure 9. 3D-Gain plot of proposed Antenna

The antenna shows a good value of VSWR as depicted in Figure 5. The value of VSWR at 3.6GHz is reported to be 1.0212.

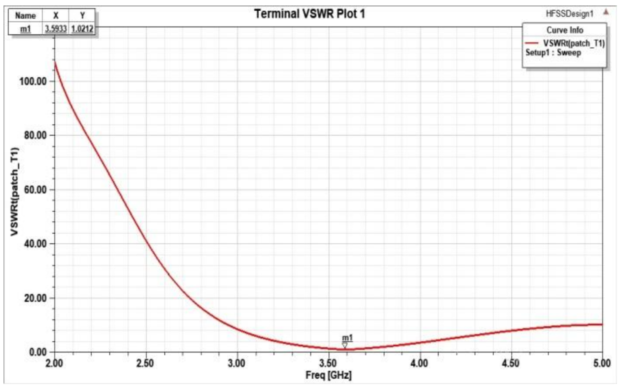

Figure 10.VSWR value of proposed Antenna

The proposed antenna shows a good result in terms of return loss and VSWR. In order to enhance the performance of this antenna slots in patch and ground can be incorporated.

CONCLUSION

The aim of this work is to improve the performance of a patch antenna for 3.6GHz applications using Defected Ground Structure technique (DGS). The return loss of antenna is improved from -10.66 dB to -39.59

dB with a factor of 371%, VSWR parameter is also improved due to the DGS. With these better results, the proposed antenna is well suitable for 5G applications.

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