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A Metamaterial based Defected Ground Antenna for IEEE P802.11ax Applications

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ABSTRACT

A sub-6-GHz / 5G spectrum band antenna for IEEE std P802.11ax is presented and analyzed in this letter. An antenna entrenched with a rectangular reflector patch with a metamaterial is designed using various substrate material and comparison is made and found that FR4 substrate material shows the better results in both simulation and in testing. The ground layer of the proposed antenna is an imposed with quarter wave defected architecture (QWDA). The proposed antenna proves its operation at Sub-6 GHz band centered at 3.5 GHz the obtained simulated return loss of proposed antenna provides evidence that less deviation in signal. The proposed geometry is validated by fabricating and testing the antenna prototype.

Keywords: QWDA, DGS, FR4, Narrow bandwidth and IEEE.

INTRODUCTION

The recent trend in wireless communication is the usage of sub-6 GHzin 5G technologies [4]. Sub-6 GHz is considered as the primary working frequency band of the 5G network. The frequency range of Sub-6 GHz is less investigated in recent literatures and mm-wave frequency range is investigated more in past literatures. In this proposed paper, the sub 6 GHz antenna is investigated[1, 2] and the presented antenna supporting sub-6 GHz comes under the IEEE std P802.11ax applications [4] and to satisfy the requirement of Quality of Service the IEEE P 802.11 ax std can improve the average transmission latency and this is considered as the major mechanism [18] for its high data rate in signal transmission and it helps to manage the interference in dense deployment scenario [19]. The novel antenna design process concentrates on the substrate selection, ground architecture and radiating patch design to achieve the IEEE std P802.11axoperating standards [17]. In the transceiver the substrate material used will plays a prominent role in mechanical support and helps in its frequency resonance. The dielectric constant and tangent loss are the two most important parameters to be considered for substrate material [10]. In this proposed work the substrate

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material used are Arlon, RT duroid, Glass, FR4 [14, 4].The basic working concept of meta-material based radiating patch is presented in this paper. It is an artificial material engaged in antenna design in the patch or ground layer to reduce the radiation emission and enhance the SNR (Signal to Noise Ratio) performance. The composition of meta-material is metal, polymer or any other dielectric materials [8]. Meta-material is a Greek word, the term Meta means beyond normal (or) something advance. This material is designed to obtain the physical properties that do not exist in nature. Artificial materials realized by tremendously high permittivity or permeability is also considered as [10] meta-materials and it is not a commonly available natural material [14]. Metamaterials are generated by arranging microstructures that are called as atoms or cells. This type of materials used to obtain miniaturization. The electromagnetic property of these meta-materials can be described by the Maxwell's equation [11], and the new budding technology called DGS isimplemented for dealing various performance parameters of microwave circuits. It has been used in MSPA for enhancing the bandwidth and gain and to suppress the higher mode harmonics [7]. The usage of this technique helps to design, fabricate and easy to realize[6] the equivalent circuit and the undesired high cross-polarization can be reduced by integrating the DGS techniques [9].

DESIGN&RESULTS ANALYSIS

The antenna design and optimization are carried out using the3-D full-wave simulation software ANSYS HFSS 3-D mode antenna simulator are used to design and to simulate the high-frequency components, such as antennas and RF/microwave components and multiple performance parameters.

Designing the antenna with a meta-material structure can improve the performance of the simple patch antenna. Meta-material structures have been used in patch of proposed antenna along with DGS to realize high performance parameters in*IEEE P802.11ax* applications. The design of proposedDefected Ground Structure based Meta-material Patch Antenna is represented in figure 2 with dimension and the overall dimension of the proposed design is $24.6 \times 22.6 \times 0.8\ mm^3$. The important aspect in the proposed design is inset feed has been used and it is noted with care because feeding technique helps the antenna to match impedance easily. The inset feed line of length 7mm and width 4mm is used in this design.For rectangular micro-strip antenna, the transmission line model considers the attenuation of signal.

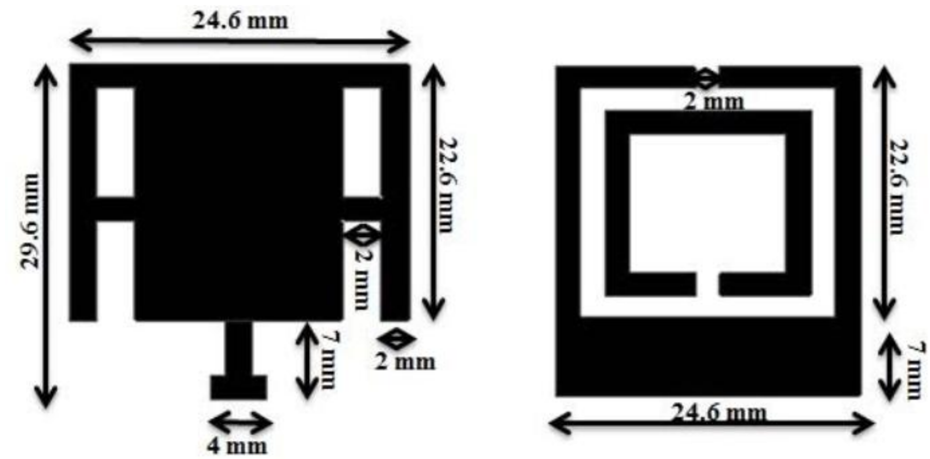

Figure 1. Design of proposed antenna describing top and bottom view with dimensions

To design an antenna substrate selection plays a prominent role because resistance can be increased by the antenna material, so in this section the proposed antenna design is going to be compared with various substrate materials so in this section here we used are Arlon, FR4, RT duroid, glass and it is initially simulated using HFSS software with placing single simulated comparative S parameter graph which gives the detail comparative graphical representation of proposed antenna. This comparison is done for the presented geometry to know which substrate material gives the better results in simulation and to consider the final design for the fabrication.From the obtained comparative simulation results of S parameter for each substrate only FR4& Arlonsubstrate material resonates at IEEE std P802.11ax application band and other substrate antenna resonates at 4 to 4.9 GHz with very high deviation in signal transmission. From the given S parameter below only the FR4 substrate material gives the minimal deviation in signal transmission so from the comparison analysis the FR4 substrate material antenna shows better results. This FR4 substrate material based antenna took as a final design and it is going to be fabricated and tested in real time using the VNA.

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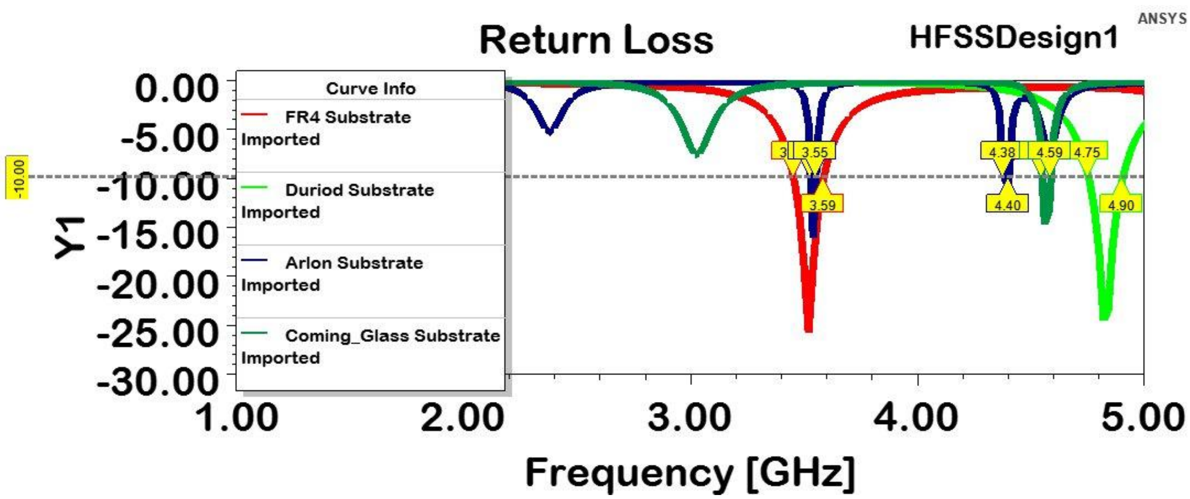

Figure 2 S parameter comparison graph for all substrate materials

Substrate Material	Dielectric Constant	Resonated Frequency	Simulated Return Loss	Simulated Gain
RT duroid	2.2	4.8 GHz	-22dB	6 dB
FR4	4.4	3.52 GHz	-25.73 dB	6.4 dB
Glass	5.7	4.58 GHz	-15 dB	2.18 dB
Arlon	10.2	3.55 GHz	-16dB	4.87 dB

Table 1 Represents the simulated Results & Resonated Frequency for each Substrate Material

The Table 1 Represent the simulated Results & Resonated Frequency for each Substrate Material which is used in proposed design. In the upcoming section all the parameters for FR4 material based antenna design is analyzed using the ANSYS HFSS software version 20.

The designed antenna return loss for FR4 material is maintained as a more negative value so the antenna has a low reflection of signalstheproposed antenna reflection coefficient is obtained from the simulation using the HFSS software. The transceiver is showing active response in frequency centered at 3.5 GHz with corresponding RL of -25.73 dB. As shown in Figure 3.

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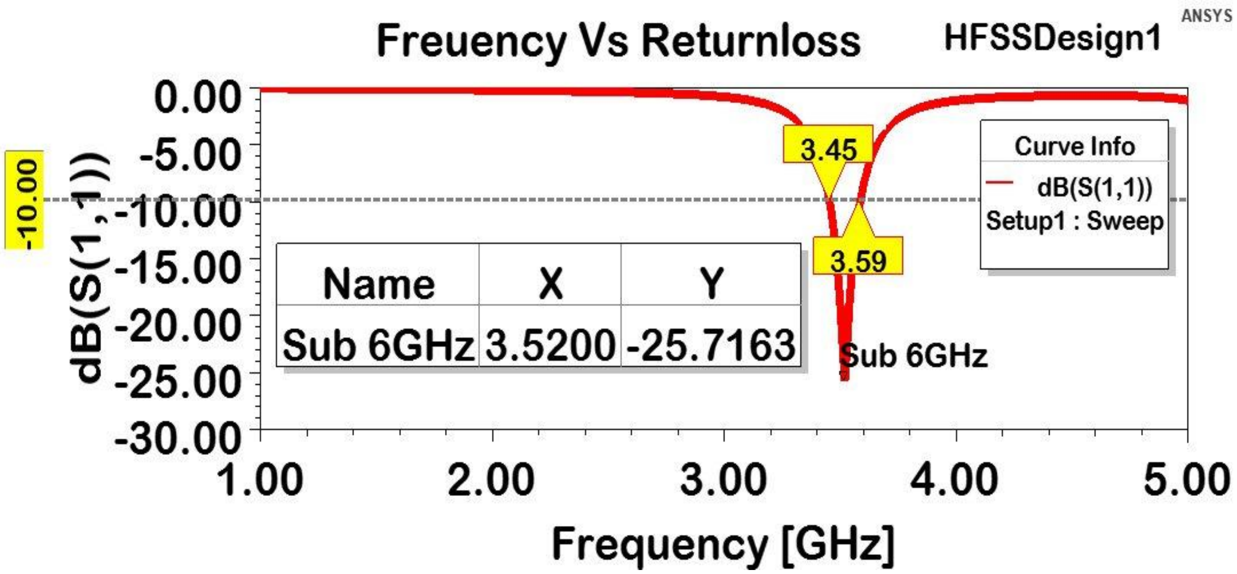

Figure 3. Simulated S_{11} parameter

Voltage Standing Wave Ratio (VSWR) range of proposed antenna lies near unity, which describes the impedance matching of antenna to the transmission line. The observed VSWRvalue proves that the given input signal is completely radiated by the antenna without any reflection.The VSWR range of the designed rectangular patch meta-material antenna is shown in Figure 4.

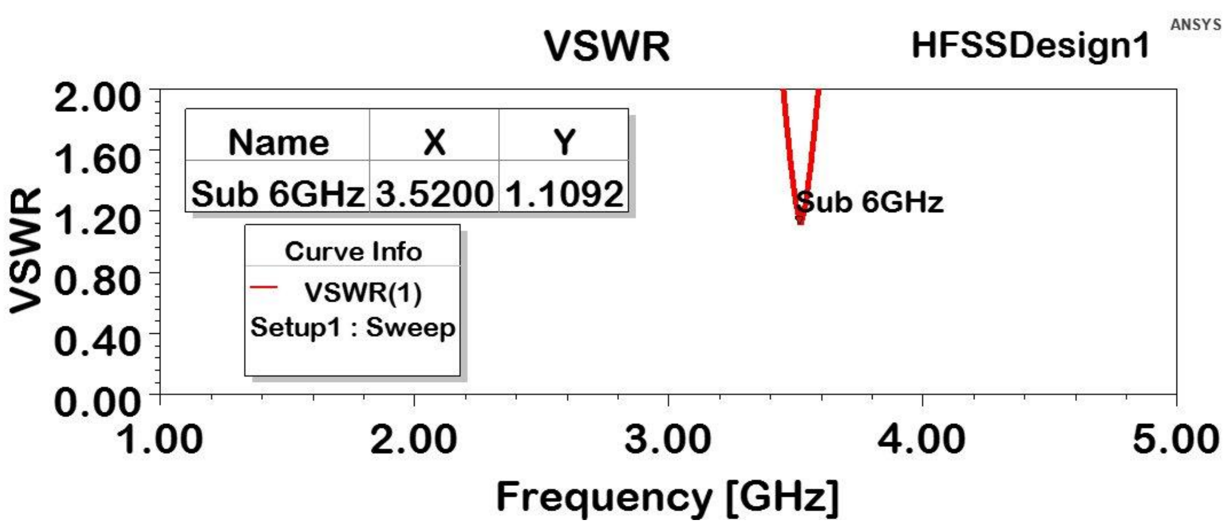

Figure 4. VSWR of Proposed antenna

The impedance plot is used to solve the problems arises with transmission lines and matching circuits, it visualize the impedance of a transmission line transceiver system as a function of frequency and it displays various parameters. The figure 4 represents the smith-chart plot of the

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proposed antenna where admittance, impedance parameters are plotted and analyzed.

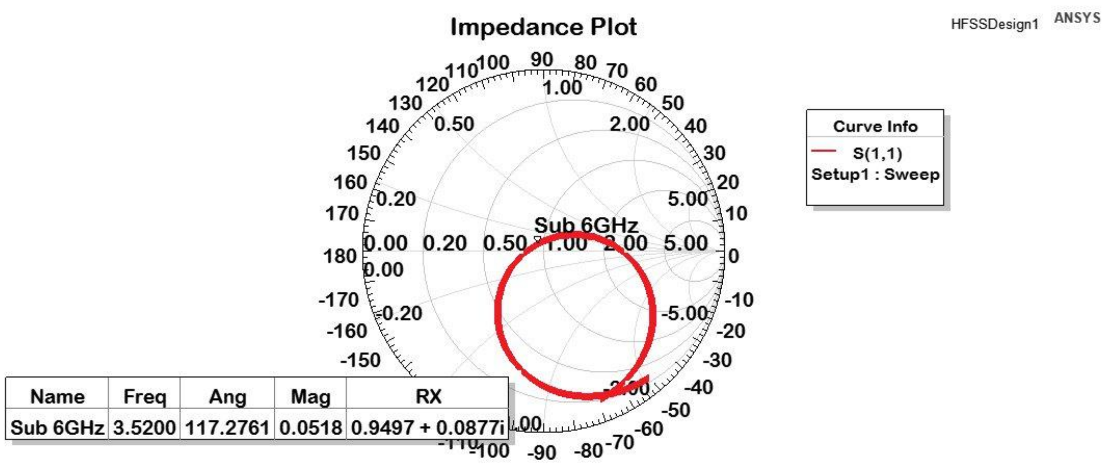

Figure 5. Represents the Impedance plot of proposed antenna

The gain of designed antenna is 6.4dB and it is measured using the 3D polar plot. Directivity is the measure of the degree to which the antenna radiates in a single direction and. The directivity of the designed antenna is 6.7dB.From the obtained value of gain and directivity, the efficiency of the designed rectangular patch meta-material antenna is 95 %. The gain and directivity of Defected Ground Structure based Metamaterial Patch Antenna is shown in Figure 6.

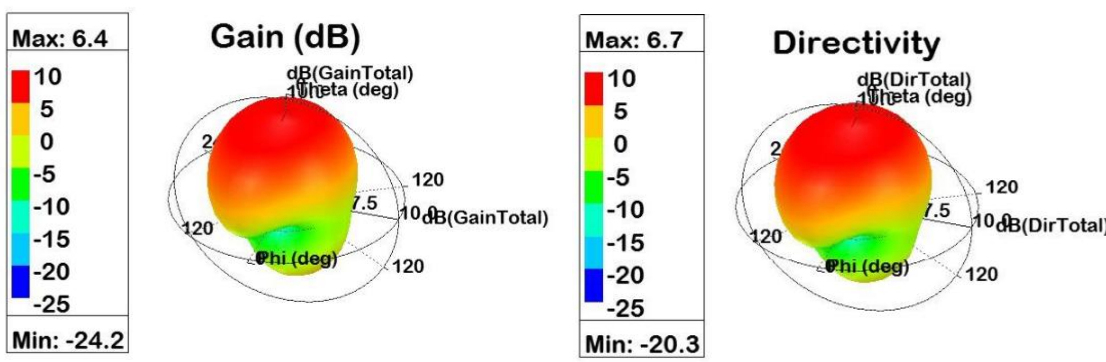

Figure 6. Gain and Directivity Plot

The observed radiation pattern shown in Figure 7 illustrates the radio waves from the antenna in different directions at different angles in the space surrounding the radiating element. In every antenna, the near end radiation is always zero and far end forms the fan shape radiation pattern. The radiation patternis said to be power radiated by an antenna, the angle of power variation is observed in thefar-end of the antenna.In micro-strip antenna radiation pattern is broad, radiating

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power is low and bandwidth is narrow

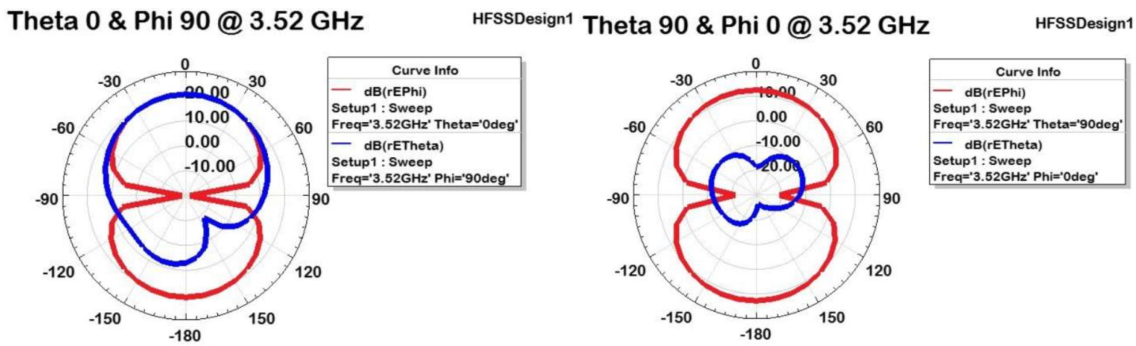

Figure 7. Radiation Pattern of Proposed Antenna

The FBR is defined as the ratio of power gain between the forward and backward directional of transceiver. This ratio compares the gain in specified direction and this is expressed in dB and this graph is analyzed by comparing the gain of designed transceiver in specified direction using HFSS. The figure 8 represents the front to back ratio of designed transceiver.

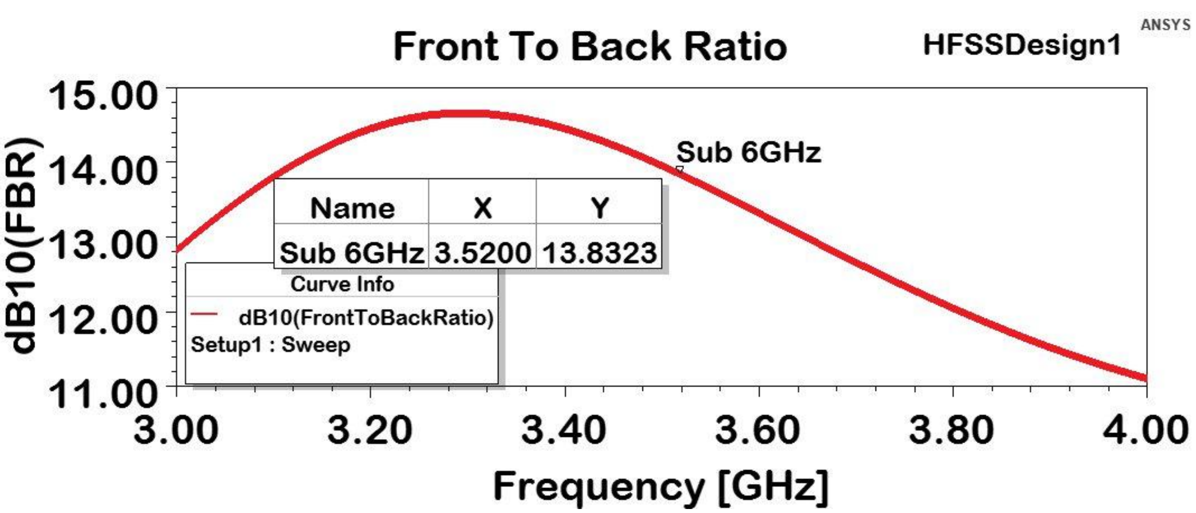

Figure 8. Represents the FBR of Proposed Antenna

Radiation efficiency is defined as the ratio of power dissipated into space to the net power delivered to the antenna by transmitter circuits. By implementing various optimization techniques such as metamaterial in antenna so it provides good radiation efficiency values which is analyzed from the simulated graph given below.

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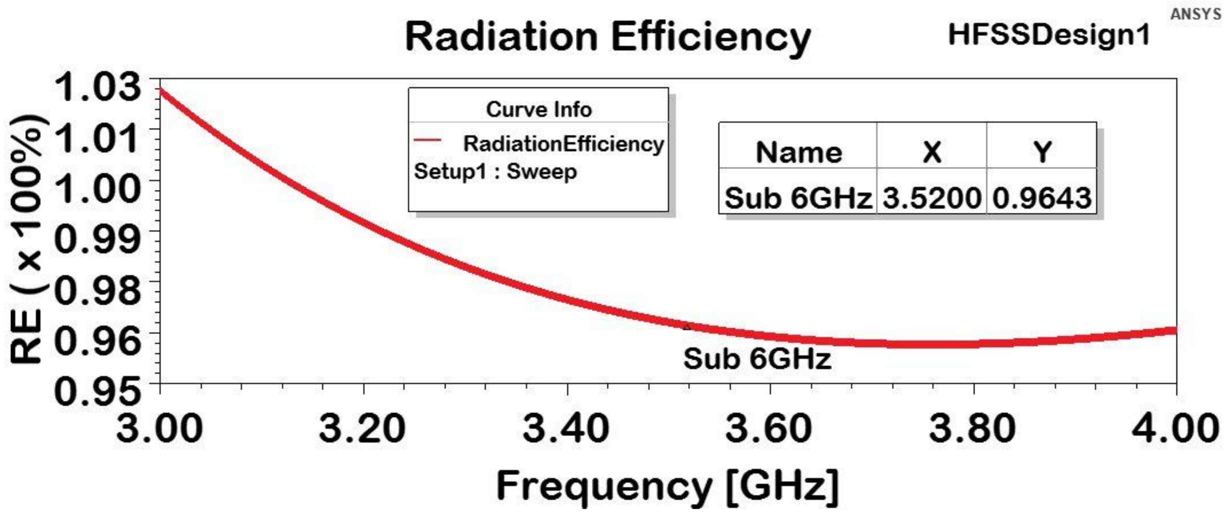

Figure 9 Represents the Radiation efficiency of the Antenna

Radiation intensity of an antenna is closely related to the direction of the focused beam and efficiency of the beam towards the particular direction and it is described as the power per unit solid angle. The figure 8 represents the radiation intensity of the proposed transceiver.

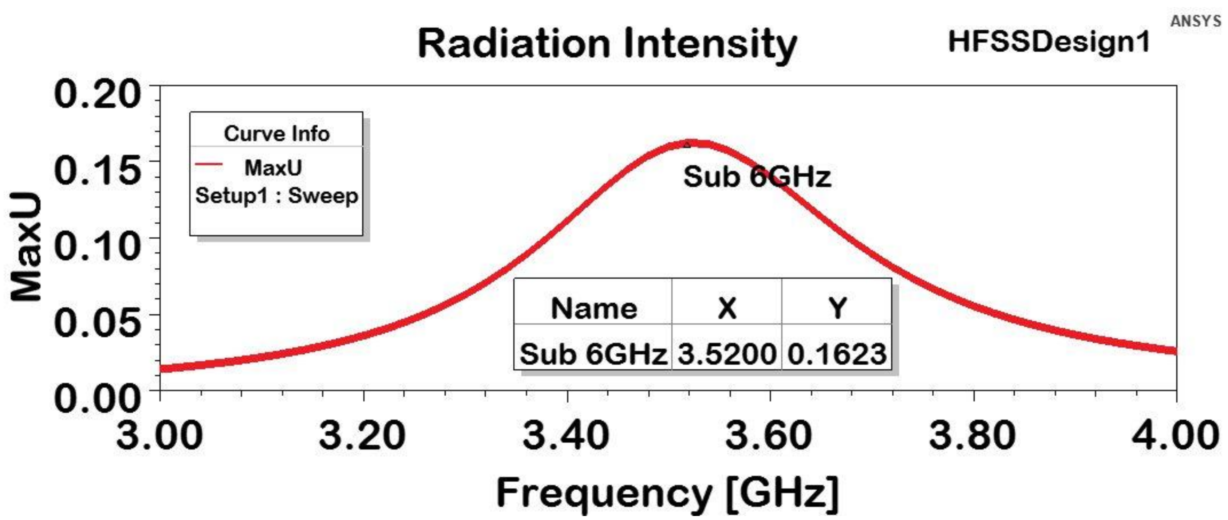

Figure 10 Represents the Radiation intensity of the Antenna

The below table gives the correct accurate value of accepted and radiated power in resonated frequency which is obtained from the simulated results using HFSS software and the obtained simulated results also shown in the figure 9 (a) & (b).

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Frequency	3.52 GHz	
Radiated Power	**27.9 dBm**	**0.6166 Watts**
Accepted Power	**29.9 dBm**	**0.9772 Watts**

Table 2 Represents the Power level for proposed antenna

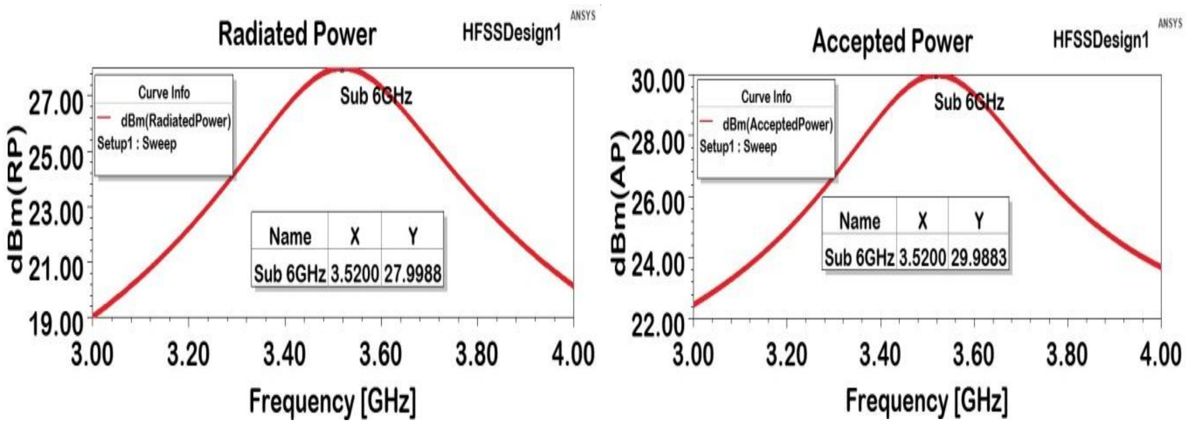

Figure 11 (A) Represents the Radiated Power & (B) Represents the Accepted Power for proposed antenna

A prototype of the fabricated antenna is displayed in the below. The realtime antenna is fed by an SMA connector for applying the excitation signal and to practically measure parameters with a network analyzer.

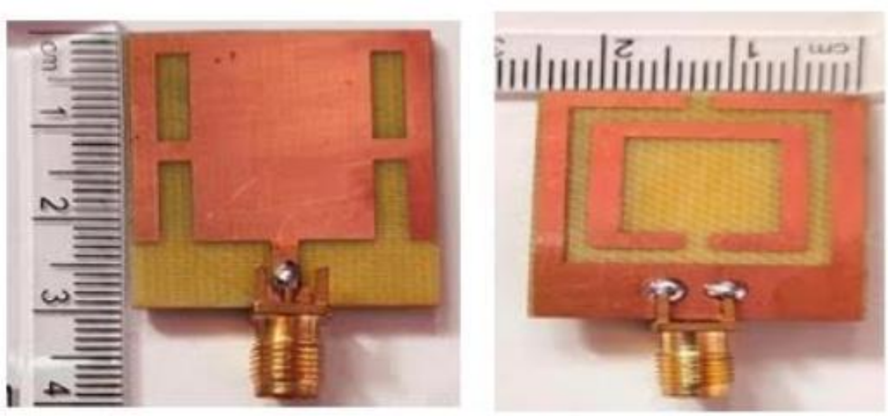

Figure 12 Represents the Prototype of proposed antenna

The result of defected ground structure based metamaterial patch antenna is presented in Table 3.

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S.No	Performance parameters	Numerical results with units
1.	Resonant Frequency	3.52 GHz
2.	Return Loss	-25.7 dB
3.	VSWR	1.1
4.	Specific Absorption Rate (SAR)	0.72 W/Kg

Table 3. Performance parameters of proposed antenna

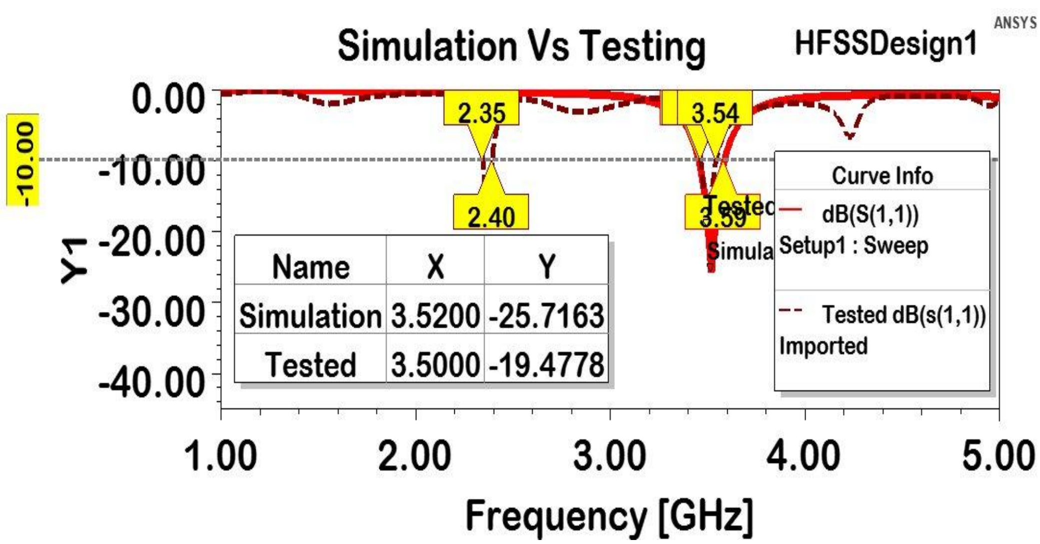

Figure 13.Compression graph of Simulated Results and Tested Results

The analysis of fabricated antenna is carried out in a standard testing environment. The comparison of measured and simulated return loss is shown in Figure 13. The tested result proves that the proposed antenna can operate at Sub-6 GHz with high gain in compact dimensions. The deviation in measured and simulated results is due to fabrication and soldering issues.

CONCLUSION

Our proposed antenna design in FR4 material bears the advantages such as compact size, narrow band resonance and support for future 5G wireless applications according to IEEE standard and ITU standard norms. The observed gain of the proposed antenna is 6.4 dB while operating in the sub-6-GHz band and the resultant efficiency of the designed antenna is 95% in real time operations. The simulation results prove the efficiency of designed antenna with compressed dimensions due to use ofreflectorstructure metamaterial patch and defected ground structure. The proposed design will play a major role in *IEEE P802.11ax*applications without any compromise in gain and efficiency

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