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Design and Fabrication of Miniaturized Dual-Band Antenna using Split-Ring & Defected Ground Structure for ISM Band Applications

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Abstract- In this paper the design and fabrication of a miniaturized dual band antenna using split ring and modified ground structure for the application of ISM band has been presented. The designed antenna consists of number of slots on patch which forms a split ring, one substrate layer and a common ground plane which is modified accordingly to obtain the desired resonant frequency. The proposed configuration gives a general size diminishment by doing modification in the ground plane. Due to modified ground, efficiency of an antenna is increased. The proposed antenna is designed to operate at 2.45GHz and 5.8GHz. It achieves a return loss of -34.6dB at 2.45GHz and -38.1dB at 5.8GHz. Proposed Antenna has many practical applications like in ISM, WIFI, commercial business, Bluetooth, cordless phone. Voice, video and data communication also uses this frequency band. It is designed with the help of CST microwave studio 2011 software. Same antenna is fabricated and testing has been done. In this paper we have shown the comparison of simulated results and experimental results.

Keywords: microstrip patch antenna, ISM band, design and fabrication.

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DESIGNANDFABRICATIONOFMINIATURIZEDDUALBANDANTENNAUSINGSPLITRINGDEFECTEDGROUNDSTRUCTUREFORISMBANDAPPLICATIONS

Strictly as per the compliance and regulations of:

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Stuti Neha [α], Lavesh Gupta [σ] & Dr. Arun Dev Dhar Dwivedi [ρ]

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I. Introduction

Wireless communication was introduced in 19th century. It has progressed toward becoming fastest growing sector of communication area. In wireless communication data is transmitted and received without using cables and wires. The wireless innovation has changed from analog first generation communication system and is about to an advanced fifth generation. Nowadays, the wireless communication innovation is facing the expanding interest of high transmission data rate, scalability, and efficiency.[1-3] In 1897, Marconi was the first scientist to exhibit that it was conceivable to set up a ceaseless correspondence stream with boats that were cruising forward, the remote innovations that, make progressing correspondence workable for us have been developed strikingly[4-5].

Wireless systems are playing a very important role in industries, medical, and in scientific field. The new age of cost-effective wireless communication innovation has been driven by relatively bringing down equipment and software cost and low power utilization [6-8]. However, these wireless technologies and remote advances have generally low information rate and perform its operation within a closed wireless communication network. These wireless technologies or we can say remote innovations operate or work inside extensive variety of frequency bands called as the ISM radio band [9-11]. ISM refers to Industrial, Scientific, and Medical radio band which are saved for the utilization of industries, scientific, and medical requirements. These frequency bands are unlicensed because it can be exploited according to different regions, by any person. ISM band are accepted band for worldwide operations. The bands which are mostly used are 2.45 GHz, 915 MHz, 868 MHz, and 433.92 MHz in the sward of Internet of Things and home [12-14]. In numerous research papers, antenna was outlined and manufactured to fulfill the coveted outcomes and working recurrence. There were numerous issues and disadvantages of the composed antenna. Some of the issues are antenna large size, its manufacturing cost; one antenna can be connected for just a single application [15-18] etc. To overcome the problem of expansive size of an antenna, applicable for more than one application, dual band antenna, which enhances the conventional patch antenna is required. In this paper the design and fabrication of a miniaturized dual band antenna using split ring and modified ground structure for ISM band application has been presented. We have shown the comparison of simulated results and experimental results.

II. Antenna Design

An efficient technique to build the antenna of large bandwidth is the use of modified ground plane. To include the applications of ISM as a modified ground plane strategy a rectangular patch and a narrow slit is made in the ground plane. In this outline of antenna a ground plane of patch antenna some surrendered shape is presented and relying upon the distinctive measurement, shape, and size of the defect (slots) the shielded current appropriation will get exasperate. The principle point of the proposed work is to upgrade and improve the conventional rectangular patch antenna performance at 2.45 GHz and 5.8 GHz frequency band

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for ISM applications using split ring and modified ground structure. The material utilized for substrate is FR-4 lossy, for ground, and for patch PEC (pure electric conductor) material is used. The parameters of ground, patch and substrate of the proposed receiving wire are calculated using the mathematical formulas of micro strip patch antenna. Fig.1 shows the structure of the proposed antenna and Fig.2 shows the simulated structure of the antenna.

Step 1: Calculation of Width (W)

For an efficient radiator, practical width that leads to good radiation efficiencies is given by:

$$W = \frac{1}{2fr\sqrt{\mu_0 \varepsilon_0}}\sqrt{\frac{2}{\varepsilon r + 1}} \qquad [1]$$

Step 2: Calculation of effective dielectric coefficient (ε_r):

The effective dielectric constant is given by:

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \qquad [2]$$

Step 3: Calculation of effective Length (Leff):

$$Leff = \frac{c}{2f0\sqrt{\varepsilon reff}} \qquad [3]$$

Step 4: Calculation of Length Extension (L):

Before the calculation of "L", ΔL will be calculated by

$$\Delta L = 0.412\,\frac{(\varepsilon reff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{W}{h}+0.8)} \qquad [4]$$

Step 5: Calculation of actual length of patch (L):

Thus, the actual length of the radiating patch is obtained by

$$L = Leff - 2\Delta L \qquad [5]$$

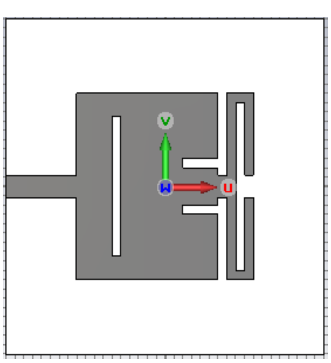
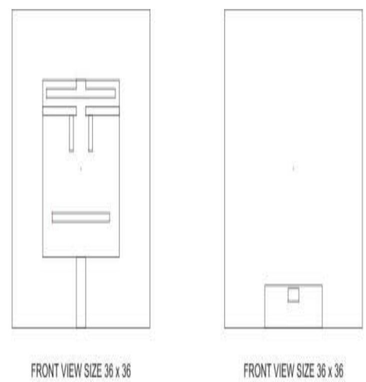
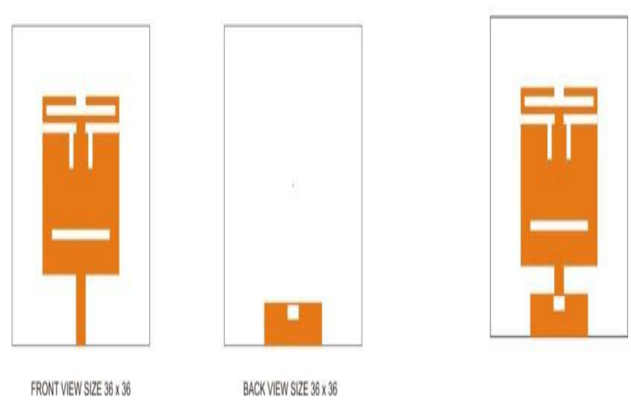


Fig. 1: Proposed design of microstrip antenna

Table 1: Dimensions of designed antenna.

Parameters	Dimension in mm
Width and length of substrate	36 x 36 mm
Dielectric constant	4.3
Material of substrate	FR4
Length and width of ground	36 x 36 mm
Length of modified ground	31.2 mm
Width of modified ground	15 mm
Length of slot in ground(solid 1)	28 mm
Width of slot in ground (solid 1)	2.8 mm
Length of feed line	28 mm
Width of feed line	2.4 mm
Length of slot 1 in patch	15 mm
Width of slot 1 in patch	11 mm





Design parameters were calculated using design equations given from (1) to (5) and listed in Table-1 which were used in simulation.

a) Measured And Simulated Results

i. *Return loss and Antenna Bandwidth*

The measured and simulated return loss characteristics are shown in Fig. 3 (a) and (b) representing that the proposed antenna shows a return loss of -16dB at 2.45GHz and -23.98 dB at 5.8GHz which is a good agreement.

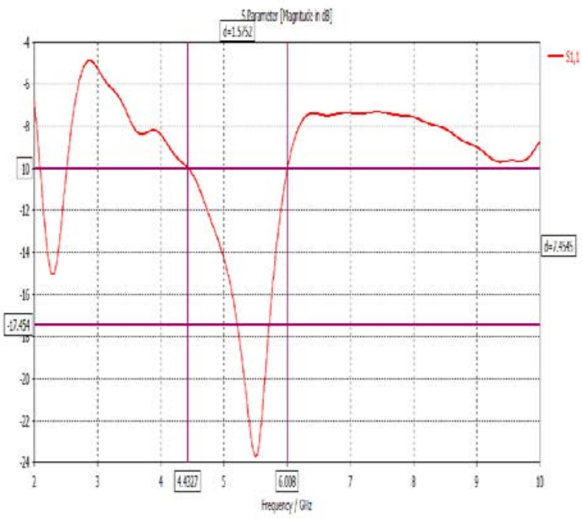


Fig. 3(a): Return loss curve for 2.45GHz

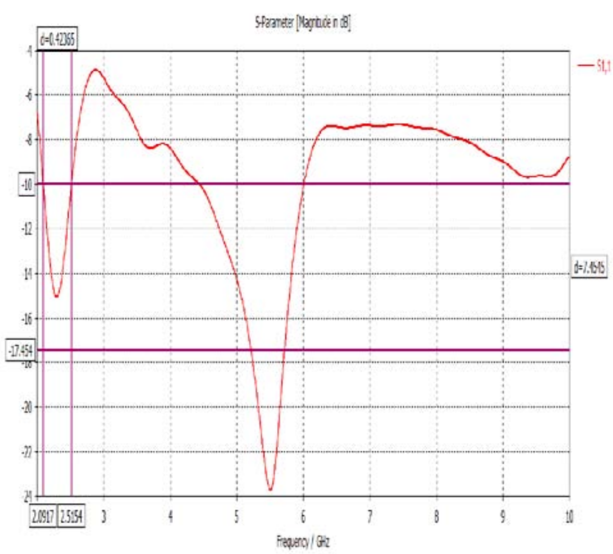


Fig. 3 (b): Return loss curve for 5.8GHz

The antenna resonates from 2.0917GHz - 2.5154GHz with center frequency 2.45GHz and 4.4327GHz -6.008GHz with center frequency 5.8 GHz as shown in Fig. 3(a) and Fig. 3(b) which is pertinent for application in ISM.

b) Directivity

Directivity measures the aggregate amount of energy which is radiated from antenna in a particular course, in fact the maximum radiated energy. Generally directivity is always greater than 1 but on account of an isotropic antenna which is having directivity equivalent to 1. An antenna which is having directivity equivalent to 1 is called directive antenna. This antenna design gives the directivity at frequency 2.45GHz as shown in Fig. 4(a) represents amount of radiation force. The design gives the directivity of 2.343 dbi at 2.45GHz as appeared in the Fig. 4(b) and 4.946 dBi at 5.8GHz as appeared in the Fig. 4(c). The simulated results of directivity are shown below.

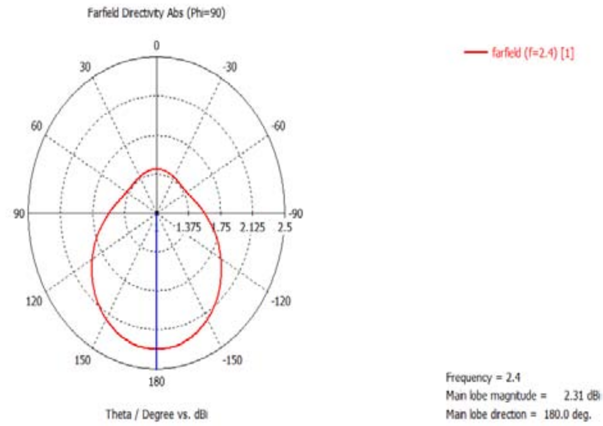


Fig. 4(a): Directivity plot at 2.45 GHz

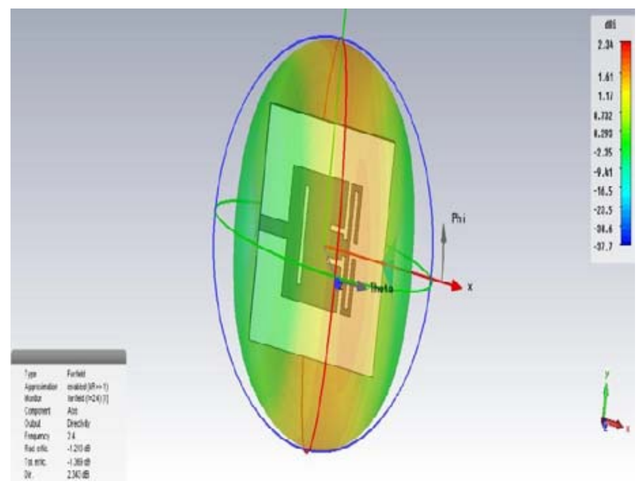


Fig. 4(b): 3D Directivity Plot at 2.45GHz

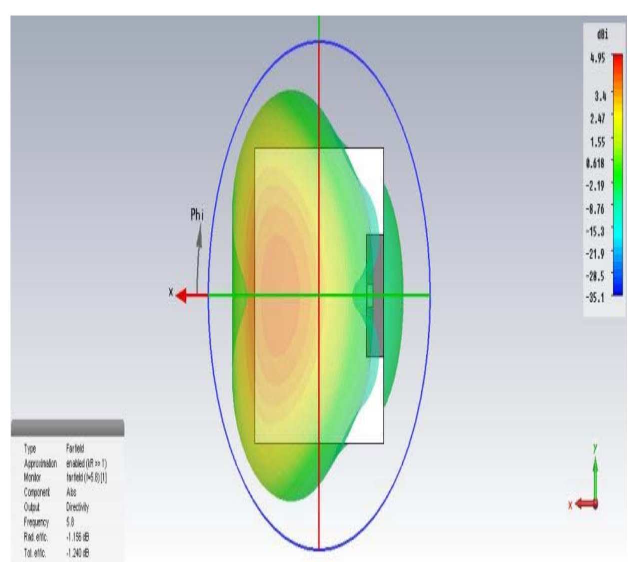


Fig. 4(c): 3D Directivity plot at 5.8 GHz

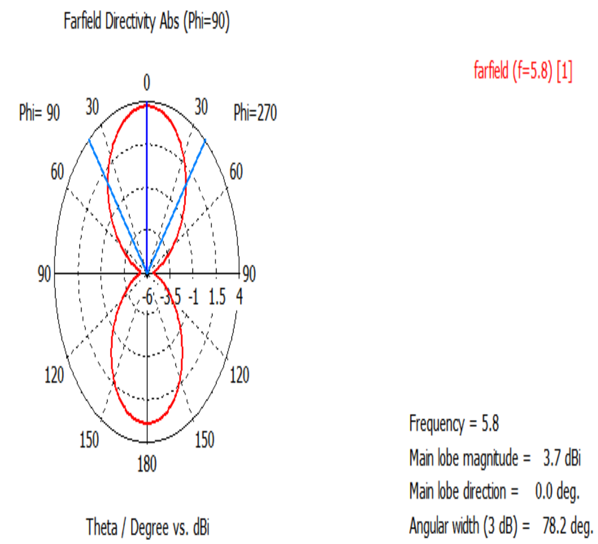


Fig. 4(d): Directivity plot at 5.8 GHz

Fig. 4(b) and Fig. 4(c) is a plot of 3D directivity of a proposed antenna. The directivity of an antenna at 5.8GHz is 4.946 dBi. The antenna radiates in specific direction as shown in the plot.

c) Gain

Ratio of intensity in a given direction to the radiation power that would be achieved from it if power is radiated by the antenna isotropically. The simulation outcomes of the gain are shown below and the gain obtained is 1.13dB at 2.45 GHz and 3.685dB at 5.8GHz.

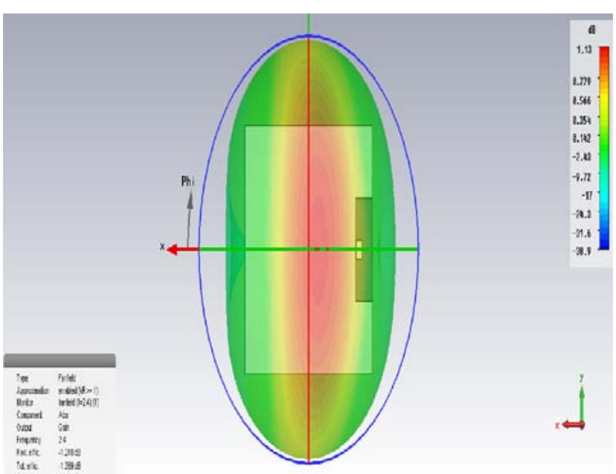


Fig. 5(a): 3D Gain at 2.45 GHz

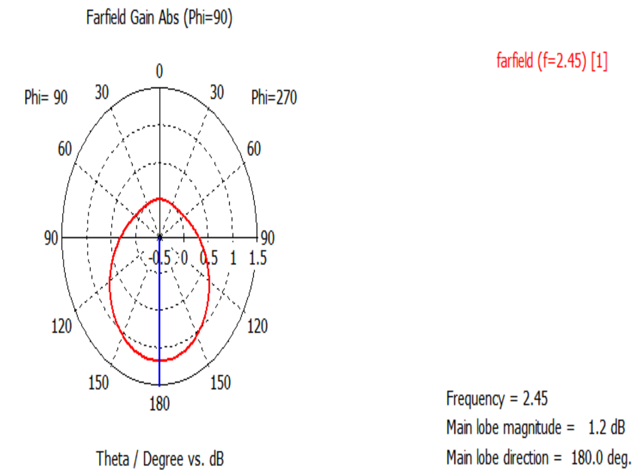


Fig. 5(b): Gain at 2.45GHz

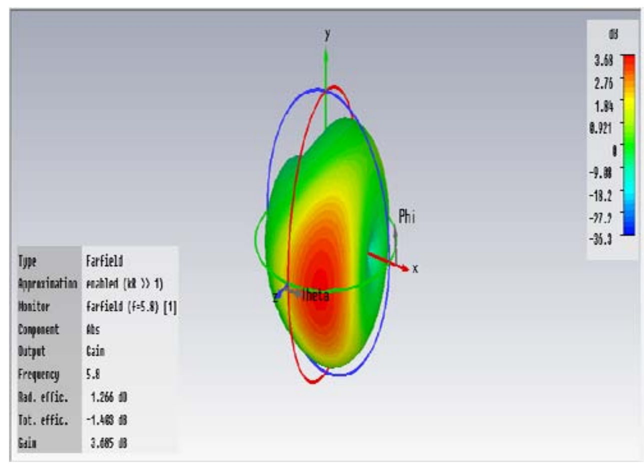


Fig. 5(c): 3D Gain at 5.8GHz

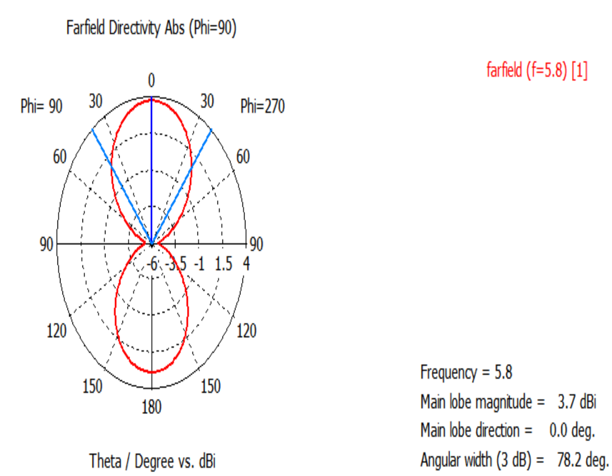


Fig. 5(d): Gain at 5.8GHz

d) Voltage standing Wave Ratio

This parameter is used for matching and tuning of the transmitting antennas. It defines how well the antenna is matched with the transmission line it is associated with. Fig. 6(a) and (b) is representing the value of VSWR lies b/w 1 & 2.

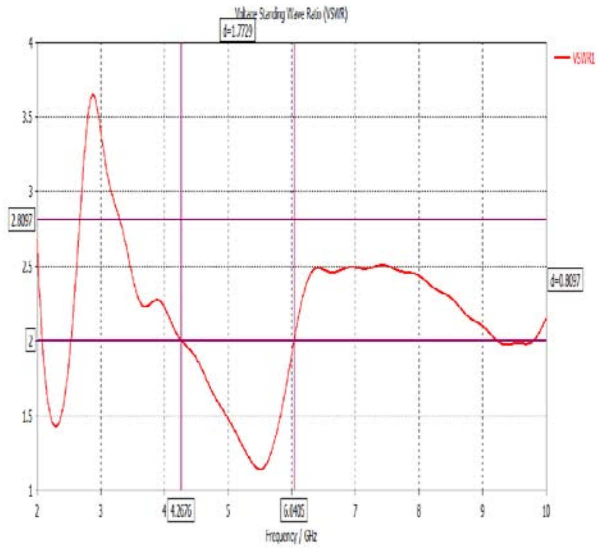


Fig. 6(a): VSWR lies between 1-2 at 2.45 GHz

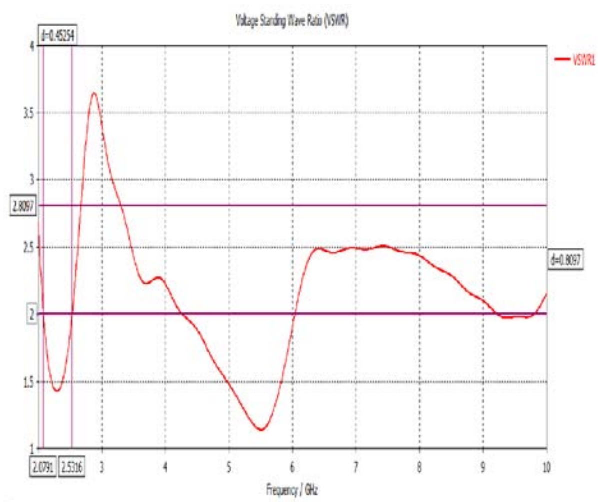
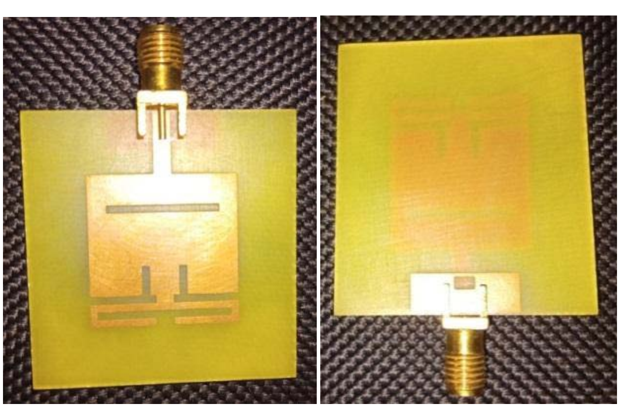


Fig. 6(b): VSWR of proposed antenna at 2.45 & 5.8GHz



(a) (b)

Fig. 7(a): Fabricated antenna front view and (b) Fabricated antenna back view

The proposed antenna resonates from 2.0917 GHz -2.5154 GHz which is covering the bandwidth range 2.4GHz-2.5GHz with center frequency 2.45 GHz and 4.4327 GHz -6.008GHz covering the bandwidth range 5.75GHz-5.875GHz with center frequency 5.8 GHz which is applicable for application in ISM as shown in the above figures. The S11 parameters of fabricated antenna are shown above which are tested in vector network analyzer at resonant frequency of 2.41 and 5.89GHz.

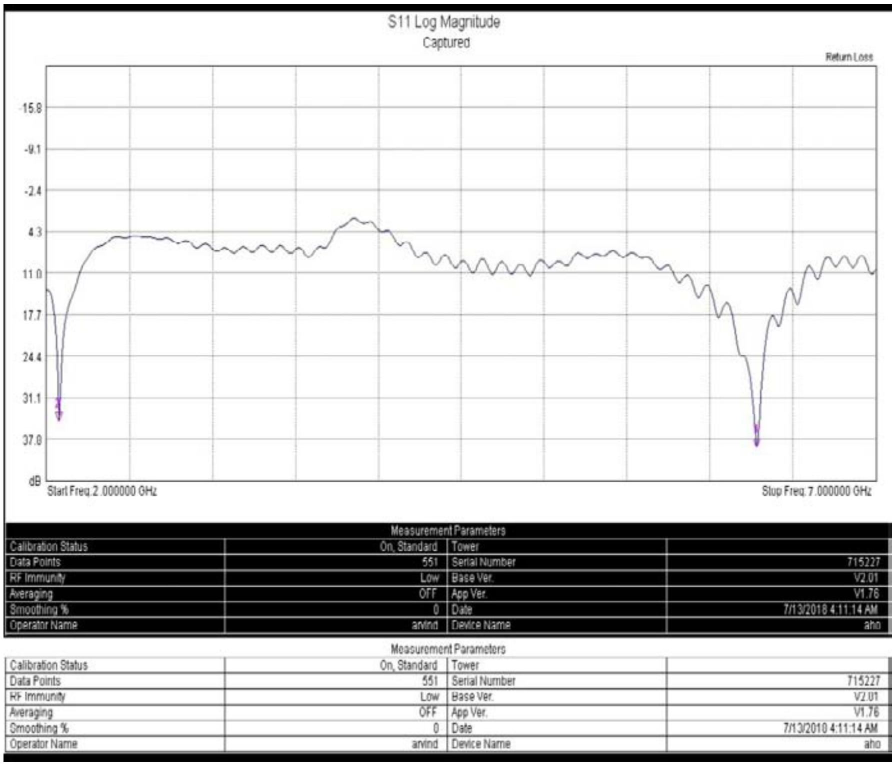


Fig. 8: S11 parameter of fabricated antenna, tested in VNA

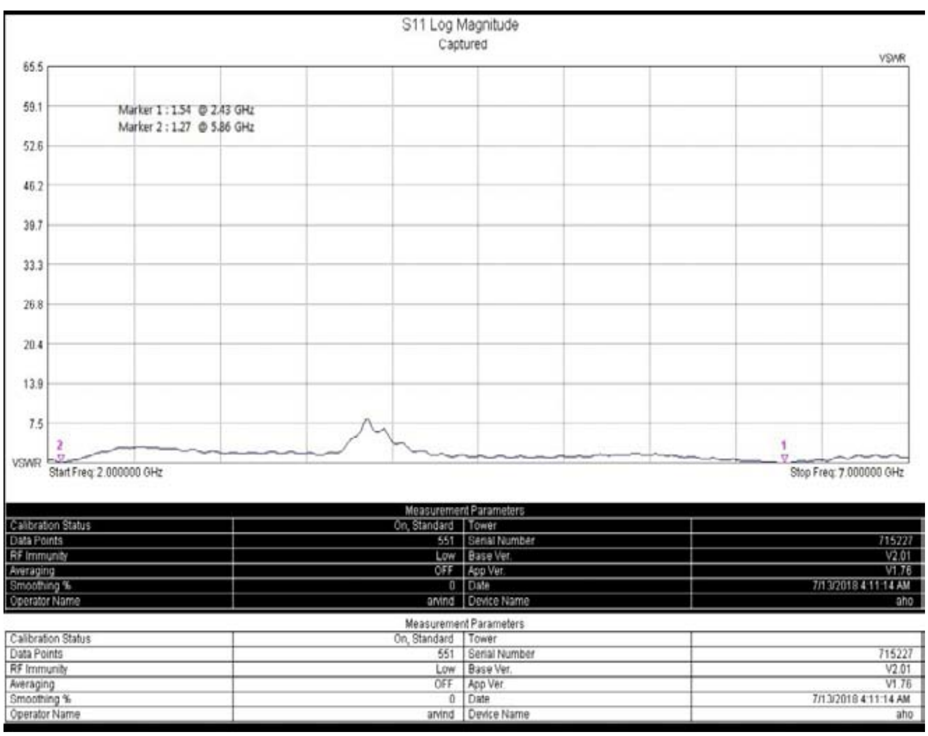
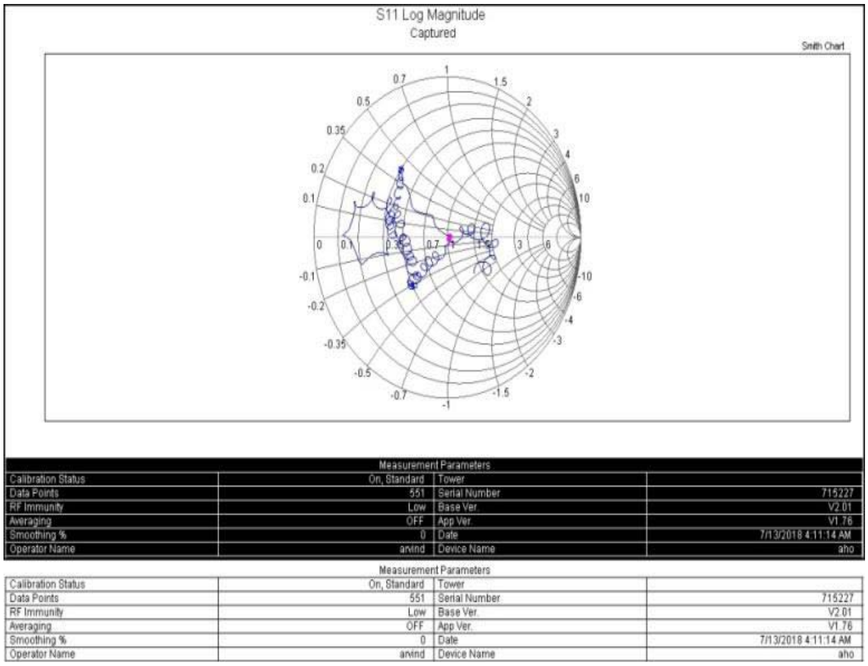


Fig. 9: VSWR of fabricated antenna

It is used for matching and tuning of the transmitting antennas. It defines how well the antenna is matched with the transmission line it is associated with. Ideally, VSWR values should recline in the range of 1 and 2 which has been achieved for 2.41GHz and 5.89GHz frequency, near the operating frequency value. The VSWR ratio of 2.41GHz and 5.89GHz frequencies is 1.54 and 1.27 respectively. Smith chart speaks that how the receiving wire impedance differs with recurrence.



III. Comparison Table

Table 2: Comparison table of Experimental and simulated results

Parameter	Simulation Results	Experimental Results
Bandwidth 1	2.03GHz-2.49GHz	2.41GHz
Bandwidth 2	4.45GHz-6GHz	5.89GHz
Voltage Standing Wave Ratio 2.4GHz	1.46	1.54
Voltage Standing Wave Ratio at 5.8GHz	1.23	1.27
Return Loss at 2.45GHz	-16.75dB	-34.6dB
Return Loss at 5.8GHz	-23.98dB	-38.1dB

The above table is about the examination of recreated result and the testing result. The deliberate and mimicked return loss qualities of the preferred antenna are appeared in Fig.4. These are -16.75dB and in case of experimental result it is -34.6dB at 2.45GHz, at 5.8GHz expected return loss is -23.98dB and in case of experimental result it is -38.1dB. The bandwidth got amid the reenactment of an antenna in CST programming first bandwidth range got is 2.03-2.49GHz and second bandwidth range got is 4.45-6GHz which is covering the frequency range of ISM. While manufactured antenna gives recurrence of 2.41GHz and 5.89GHz. Simulation process is giving VSWR range in between 1 and 2 at dual frequency and experimental result is giving VSWR of 1.54 at 2.45GHz and 1.27 at 5.8GHz. By contrasting the aftereffects of recreation process and exploratory process we can infer that exploratory outcomes are far superior to simulation result.

IV. Conclusion

In light of the conclusions, results, and limitations of the proposed work, future work can be completed are as follows: In the antenna designed with split ring and modified ground. There are various unsolved issues and to be tended later on for further improvement in this specific area. The advancement which should be possible includes minimization of unwanted leakage of radiation through the modified ground and this should be possible by adjusting the shape, structure or reconfiguring the shape of antenna. Optimization of modified ground can be done to evade clashes with radiating mode. In future diodes can also be utilized or placed in slots to perform the antenna at a particular frequency band for specific applications, just by switching on and off the diodes. By using extraordinary and unique configuration of structure, using different material of dielectric substrate the work can be expanding in this work. In future different slots on the ground and on patch can be designed for getting better and different result. Structure of patch can also be changed according to get better result. Firstly a miniaturized dual band antenna with split ring and modified ground structure has been designed for the Industrial, scientific and medical applications. The various parameters like return loss, VSWR, directivity, gain, bandwidth and operating frequency are studied for antenna designing. Initially, the work starts with the designing of simple patch antenna with a single slot in ground to obtain center frequency of 2.45GHz frequency. Modification is done in ground's dimensions that are in width and in its length. The next step is to design split ring on the patch which gives center frequency of 5.8 GHz. It is also concluded that physical parameters like resonate length and width of slot in ground effects the results of the antenna. It can be clearly seen that varying dimensions like length, width of respective substrate, patch, and ground in the right way gives optimized results for desired results.

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