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Multi Band Microstrip Patch antenna for C band, X band and 5G Cellular Systems

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***Abstract:** In this proposed work, a multiband microstrip patch antenna is designed which successfully demonstrated wideband characteristics. This design is envisaged to support 28 GHz frequency which is allocated by ITU for 5G mobile communication along with C (4-8 GHz) and X band (8-12 GHz) frequency supported applications. This design is primarily aimed to operate in 28 GHz and 38 GHz. The use of Defected Ground Structure (DGS) with two slots of dimension 1.5mm×1.5mm made this model to operate in multiband frequencies which includes 4 GHz, 9 GHz, 28 GHz and 38 GHz. The designed antenna is placed on a material called FR-4(flame retardant) whose dielectric constant (Ɛr) equals to 4.3 and the size of the substrate is 10.8 mm×12.9 mm which is known to retain its high mechanical value. The antenna is simulated and optimized with the aid of CST (Computer Simulation Technology) software a specialized tool for the 3D EM simulation of high frequency component. From the simulated results it have been shown that the proposed antenna is suitable for C band, X band and 5G wireless applications.*

***Keywords :** C Band, Microstrip patch, Wi-Fi, Wi-max, X band.*

I. INTRODUCTION

The era of mobile communication started with the growth of 1G that supported the voice call along with texting. The second generation of mobile communication 2G saw the surging of GSM technology that facilitated high voice quality with limited data services based on digital modulation techniques. The third generation that witnessed high quality voice services, graphic feature along with high video applications. Today we experience 4G LTE and Wi- Max with very high quality video applications and high speed data services that are being expedited for futuristic growth that supports autonomous vehicles, IOT based apps and much more [1].
As there is an increasing usage of wireless devices for various application the need to utilize more bandwidth corresponding to the radio frequency spectrum increases simultaneously at a rate of 25 to 50 % annually [2] which became the essence for proposal of antenna design that may cater to the above needs. There are various antenna design methodologies, but Microstrip patch antenna design has become the most opted one due to the following features such as less weight, low profile, conformal and easy fabrication technology.
Though the microstrip patch antenna suffers some severe disadvantages such as narrow bandwidth, low gain it can be overcome by other means. In this fast moving world all users of various wireless applications prefer unhindered call volumes, broadcast of multimedia data with high speed and lower latency. Some of the problems that are faced in 4G services such as spectrum insufficiency and more power consumption. There are practical difficulties in establishing 5G communication platforms which is due to the installation of large number of antennas, interference of radio frequency signals, massive radiation and cost for the proposal. Keeping aside the cons of 5G technology various aspects that facilitate the needs of digital world have inspired designers for proposing new designs. In our proposed model various parametric measurements needed to supplement the future fabrication of antenna has been studied in detail. Multiband antennas are found to be more effective in wide bandwidth characterises with MIMO (Multiple input multiple output) [3] and it can be adopted with TDMA based MAC structure to compact with 5G cellular networks [4]. A Printed Dipole Antenna Integrated with Dual-Band Balun designed for Dual-Band and Wideband Design [5] can be extended for higher frequencies. A Multiband Fractal smart antenna [6] for at least seven converged wireless network services, planar multilateral disc monopole antenna for ultra wideband (UWB) [7], rectangular tri-band patch antenna [8] with loaded elements based on genetic algorithm, Tri-band microstrip-line-fed low profile microstrip patch antenna [9] motivated to design a multiband antenna suitable for the application of C- Band, X-Band and 5G Cellular communications. The section 2 covers the design metrics of the proposed antenna. The section 3 depicts the return losses (S11), Radiation pattern, gain and efficiency. The section 4 provides the simulation results and comparison between the metrics measured and simulated.

II. PROPOSED ANTENNA DESIGN PROCEDURE

A. Calculation of Design Parameter

The antenna was designed primarily with the calculated values inferred from the design equations. For a rectangular Micro strip patch antenna, the resonance frequency for anyTM10 mode is given as:

$$f_0 = \frac{c}{2\sqrt{\epsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \quad (1)$$

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The width of the patch is

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (2)$$

The effective dielectric constant is

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}} \quad (3)$$

ε_{eff}= Effective dielectric constant.

ε_r= Dielectric constant of substrate.

h = Height of dielectric substrate.

W = Width of the patch.

The length of extension of the patch is

$$\Delta l = 0.412h\left[\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}\right] \quad (4)$$

The effective length of the patch is

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (5)$$

The finite length of the patch is

$$L = L_{eff} - 2\Delta l \quad (6)$$

The ground plane dimensions are

$$W_g = 6.223mm \quad (7)$$
$$Lg = 4.067mm \quad (8)$$

From the above formulas the calculated dimension was 4.067mm×6.223mm. The calculated dimensions showed resonating frequencies 9GHz and 28GHz. The dimension was improved in order to provide aimed multiband operation.

B. Antenna Design

The dimension of 10.8 mm×12.9 mm showed resonation at 3GHz, 9 GHZ, 14GHz and 28GHz.The further modification of the design with the inclusion of defected ground structures (DGS) structure with two square slots of dimension 1.5 mm×1.5 mm each showed the desired multiband operation at the following frequencies 9 GHz, 14 GHz, 28 GHz and 38 GHz. because it improves the return loss performance of the radiating patch element [10] for the 5G applications [11]. The simulations are performed using CST design tool for better analysis of the radiating structure. Microstrip antenna has three layers such as patch, substrate and ground.

The figure 1 shows the geometrical configuration of the proposed antenna model. This microstrip patch antenna is constructed on substrate base made of FR4 (Lossy) dielectric material since it proved the improved performance [12]. The FR4 substrate has a dielectric constant with permittivity 4.3.

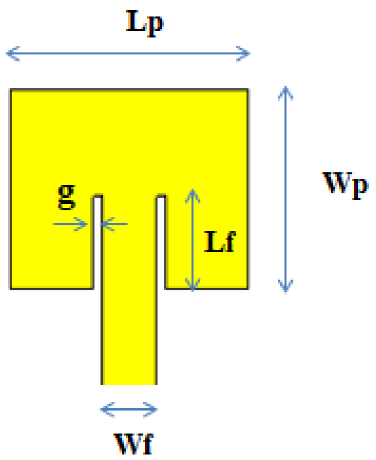

Fig. 1. a) Proposed Microstrip Patch Antenna

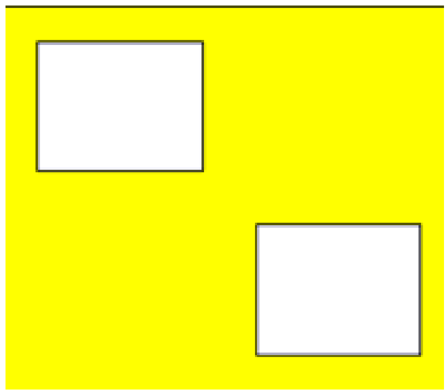

Fig. 1. b) Defective Ground structure with two slots

The antenna design starts with the computation of resonant frequency measurement, as we are proposing this model to work on the 28GHz, C and X band applications in wireless communication.

The dimensions of the microstrip patch antenna, thus the length and width measurements are obtained. The dimensions of the proposed antenna are given below. In the first phase the Microstrip Patch Antenna is designed using CST software without the DGS structure and the results are recorded.

In the second phase the DGS structure with two slots included is designed and the results show the Tetra-Band frequency operations of the design parameters are verified. The best result obtained from the second phase by incorporating the DGS structure with two slots in the ground plane. The final phase involved studying the characteristics of various parameters on comparison with existing system.

Table- I: Dimensions of the proposed antenna

Antenna Parameter	*Dimension(in mm)*
Length of substrate (Ls)	10.8
Width of substrate (Ws)	12.9
Length of ground (Lg)	10.8
Width of ground (Wg)	12.9
Length of patch (Lp)	5.4
Width of patch (Wp)	6.45

The simulation part begins with the construction of ground plane with the dimensions obtained above. Similarly the FR4 substrate is constructed above the ground plane. The next step in design is to construct the patch over the substrate whose dimensions are proposed below. This model utilizes the thick microstrip feed line whose width is 2.932 that offers 50 ohm impedance approximately. In this model, the use of the defective ground structure (DGS) helps to avoid the bands interfering with our proposed bands of operation.

III. RESULTS AND DISCUSSION

For the Design of multiband microstrip patch antenna resonating at 9 GHZ, 14GHz and 28GHz and 38 GHz we obtain the following parameters by simulation using CST Microwave suite.

A. Return Loss

The return loss is defined as the quantity that measures the amount of signal that is returned to the source from the load. The above design is simulated and their return loss characteristic is shown in Fig 2 and it shows the good return loss which are analyzed in Table 2.

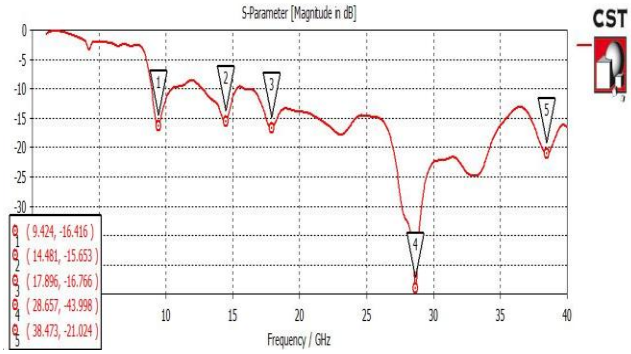

Fig. 2. Return loss plot of the proposed antenna

The return loss values obtained at different resonant frequencies are given in below table.

Table- II: Return loss values for the resonant frequencies

Frequency (GHz)	*Return Loss (dB)*
9.424	-16.416
14.481	-15.653
17.896	-16.766
28.657	-43.998
38.473	-21.024

B. Total Efficiency

The total efficiency of an antenna is defined as the product of the radiation efficiency and impedance mismatch loss of the antenna, when connected to a transmission line or receiver.

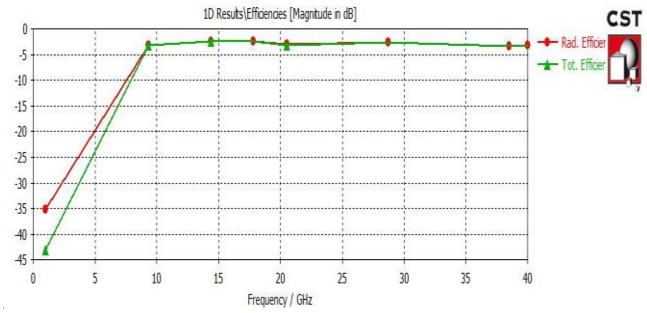

Fig 3-Total efficiency and Radiation efficiency of the proposed antenna

C. Equations

The characteristic impedance of an infinite transmission line at a given angular frequency is the ratio of the voltage and current of a pure sinusoidal wave of the same frequency travelling along the line. The proposed system is matched with the characteristic impedance of approximately 51Ohms.

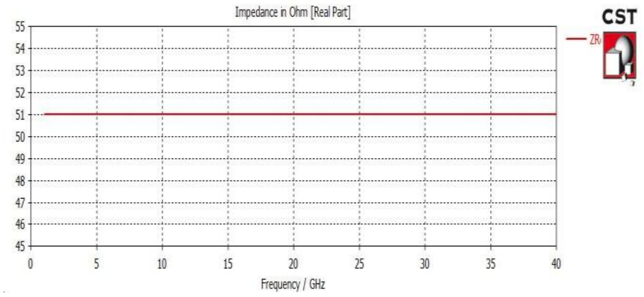

Fig 4- Characteristic Impedance (Z0) of the proposed antenna

D. Voltage Standing Wave Ratio (VSWR)

VSWR stands for Voltage Standing Wave Ratio, and is also denoted to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. For the operating frequency the VSWR must be approximately 1. And the proposed antenna achieves the value as described in following figure.

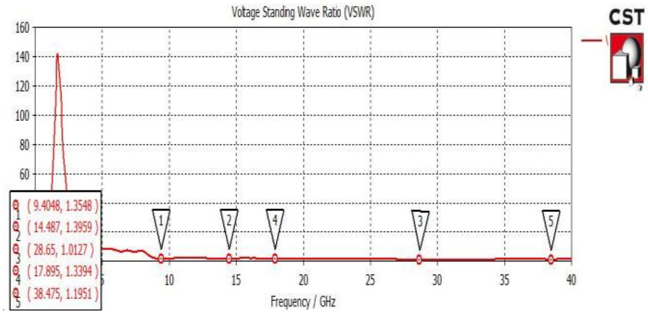

Fig 5. Voltage Standing Wave Ratio (VSWR) of the proposed antenna

E. *Radiation Pattern*

In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source.

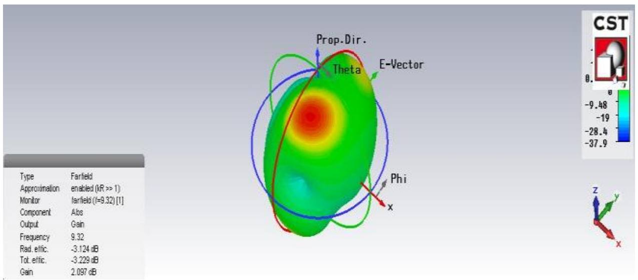

Fig 6. Far field pattern Parameters at F=9 GHz

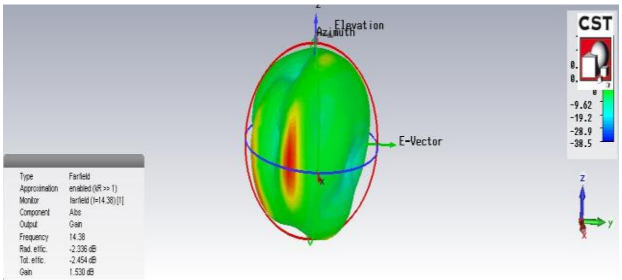

Fig 7. Far field pattern Parameters at F=14 GHz

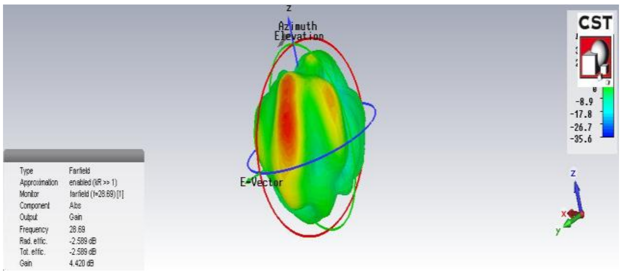

Fig 8. Far field pattern Parameters at F=28 GHz

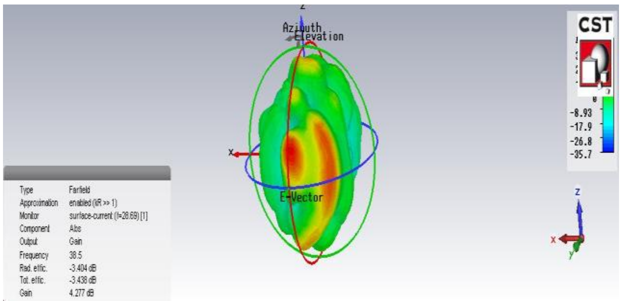

Fig 9. Far field pattern Parameters at F=38 GHz

The radiation pattern of the antenna at multiple resonant frequencies such as 9 GHz, 14 GHz, 28GHz and 38 GHz are shown above in Fig 6, 7, 8 and 9 respectively.

Table- II: Parameters of the proposed antenna

Frequency (GHz)	*Return Loss (dB)*	*Gain(dB)*	*Total Efficiency*	*VSWR*
9.424	-16.416	2.034	-3.667	1.35
14.481	-15.653	1.824	-2.506	1.39
28.657	-43.998	4.849	-2.581	1.01
38.473	-21.024	5.800	-3.453	1.19

IV. CONCLUSION

The Multiband Microstrip Patch antenna is simulated using CST MICROWAVE STUDIO. Designs are made using FR4 substrate having dielectric constant value of 4.3 which is a low cost material and easily available. Microstrip feed line of approximately 50ohms is used. The design resonates at the multi-band frequency range of 9.424, 14.481, 28.657, 38.473 GHz. From the simulated results it is seen that, it supports future 5G technology alongside C and X band frequency applications.

V. FUTURE WORK

The simulated antenna will be fabricated and will be tested to verify the deviation in results to optimize the design as compatible for the practical usage.

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