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LTE Applications Based 5G Microstrip Patch Antenna Design and Analysis

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ABSTRACT: An enhancement over earlier generations, such as 4G LTE, in antenna technology is the microstrip patch antenna design. The existing antennas are operating at 4G Band frequencies (1–7) GHz resonant frequency in order to enable 4G communication. This antenna is a patch antenna that is rectangular and has a square-shaped slot. This antenna is made of Flame Retardant 4 (FR4) substrate, which has a relative permittivity of 4.4. The antenna has been simulated using the High Frequency Structure Simulator (HFSS) tool. This antenna's main drawback is its low efficiency, which is brought on by increased amounts of cross-polarization radiation, lower gain, conductor and dielectric losses, and a reduced power handling capacity. Using this method, we proposed building a microstrip patch antenna to increase gain for wireless and 5G applications. Design and simulations will be done using HFSS software. Since 5G networks are currently in demand, the most recent band to be added under WRC-23 (World Radio Communication) is 6 GHz, which is one of the spectrums.

KEYWORDS: Microstrip patch antenna, FR4, LTE applications, HFSS.

I. INTRODUCTION

Online education aims to raise the caliber of instruction by utilizing public cloud center data platforms. Furthermore, by giving engineering students practical training via online and remote labs. However, you need a high-speed data rate and large bandwidth for all of the aforementioned online education processes in order to improve the quality of online education, especially when streaming ultra-high-quality videos—which are superior to the current 4G wireless system. A rectangular microstrip patch antenna with a high bandwidth, high gain, good reflection coefficient, and exceptional antenna radiation efficiency was created in light of the aforementioned conditions. It resonantly operates at 26 GHz and utilizes 5G millimeter wave bands. In India, this offers great performance and multiple input/multiple output.

Microstrip patch antennas are crucial in the field of wireless communication. It consists of a thin metallic patch made of copper or gold, a dielectric substrate, and a ground plane. The ground plane and the patch from the dielectric substrate are separated from one another. Patch antennas come in many different shapes and sizes, such as dipole, circular, elliptical, square, rectangular, and triangle models. The most popular forms of microstrip antennas are circular and rectangular in shape. The proposed design has a four-element microstrip patch antenna array and employs the corporate feed technique applicable to the Ka-band.

The term "FR4" denotes flame retardant, and the number "4" denotes woven glass-reinforced epoxy resin, which is what we used in this design. substrate with conducting copper printed on the FR4 substrate, which serves as the radiating element and ground, and has a dielectric constant of 4.4.

II. LITERATURE REVIEW

A microstrip patch antenna's performance is influenced by a wide range of design factors, including the patch's size, shape, feed type, substrate type, and slot arrangement. The desired frequency, bandwidth, gain, radiation pattern, and impedance matching of the antenna can be obtained by optimizing these parameters. The following is a sampling of recent research on the development of microstrip patch antennas for 5G and LTE applications:

1. T.Kiran represents a microstrip patch antenna that operates at 28 GHz and 50 GHz for 5G wireless communications. The antenna has a compact structure of 11 mm x 8 mm x 0.5 mm, including the ground plane. The antenna is designed using Rogers RT/duroid 5880 substrate with a dielectric constant of 2.2 and a thickness of 0.5 mm. The antenna is simulated using HFSS software and provides a gain of 2.6dB.
2. H.V.Pallavi represents the different configurations of microstrip patch antennas for 5G millimeter-wave applications. The paper analyzes the single-element and array-element antennas in terms of return loss, bandwidth, gain, VSWR, etc. The paper also discusses the challenges and future scope of microstrip patch antennas for 5G applications.

TABLE 1. DESIGNPARAMETERS OF AN ANTENNA

Parameter Symbols	Details of Parameters	Value(mm)
w_s	Width of Substrate	6.0
L_s	Length of Substrate	6.0
w	Width of Patch	3.65
L	Length of Patch	2.0
w_f	Width of Microstrip Line Feed	1.0
L_f	Length of Microstrip Line Feed	3.5
h	Height of Substrate	1.6

The following equations for the design are used to determine the width and length of patch

$$w = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

where c is the velocity of light, f_r is the resonant frequency and ϵ_r is the dielectric constant of substrate

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

Where L_{eff} is effective length of the patch given as follows

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{eff}}} \quad (3)$$

where ϵ_{eff} is the effective dielectric constant given as follows

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + \frac{12h}{w} \right)^{-\frac{1}{2}} \quad (4)$$

ΔL is the extended incremental length given as follows

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{w}{h} + 0.8 \right)} \quad (5)$$

The Fig.1 shows the proposed microstrip patch antenna geometry with dimensions ($W_s \times L_s$). The dimensions used have shown in TABLE I.

III. DESIGN OF MICROSTRIP RECTANGULAR PATCH ANTENNA

Due to its optimal configuration among all patch geometries, the rectangular microstrip patch antenna finds widespread usage. FR4 substrate materials with a substrate height of 1.6 mm are utilized in this design in order to select the best electric substrate with a lower dielectric constant, which is important for 5G applications like e-learning. Finding the patch's length and width using equations (2) and (1), respectively, is a crucial next step. Finally, we choose 27 GHz as the best resonance frequency from the millimetre-wave band. The parameters used to design the microstrip patch antenna is shown in below TABLE I.

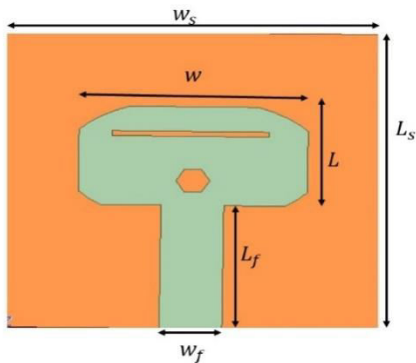


Fig.1 Geometry of proposed microstrip

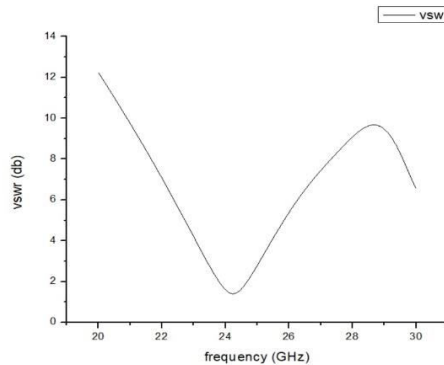


Fig. 2. Plot of Voltage standing wave ratio rectangular patch antenna

IV. SIMULATION RESULTS AND ANALYSIS

A. Reflection coefficient

Another name for the reflection coefficient, which is shown by (S11), is return loss. An antenna's performance is usually reliant on having a good reflection coefficient or a return loss of at least -10 dB or greater than -15 dB, since return loss in an antenna is a ratio of incident power to reflected power. The reflection coefficient can affect the gain, bandwidth, and radiation pattern of the microstrip patch antenna. A reflection coefficient of less than -10 dB is generally considered acceptable for optimal antenna performance.

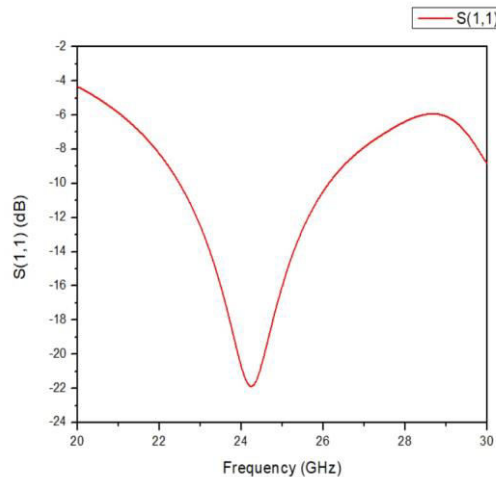


Fig 3. Plot of Return loss

B. Voltage Standing Wave Ratio

The degree to which the impedance of the microstrip patch antenna and the feed line are matched is indicated by the voltage standing wave ratio, or VSWR. Better impedance matching and reduced power loss are indicated by a lower VSWR. The microstrip patch antenna's gain, bandwidth, and radiation pattern can all be impacted by VSWR. The range of the voltage standing wave ratio (VSWR) is $[1 - \infty]$. While $VSWR=1$ denotes no reflected power from the antenna, a large VSWR value indicates greater mismatching. The standard 5G antenna has a VSWR of less than 2 only for single band.

C. Radiation Pattern

The Fig.42D radiation pattern of high gain of 10 dB respectively. The directional (angular) dependence of the radio wave strength from the antenna or other source is referred to as the radiation pattern, antenna pattern, or far-field pattern in the field of antenna design. A microstrip patch antenna's radiation pattern is one of the most important things to consider when assessing how well it works. Use the radiation pattern to gauge an antenna's energy output in any direction.

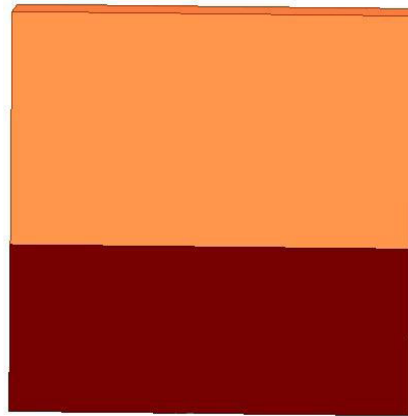
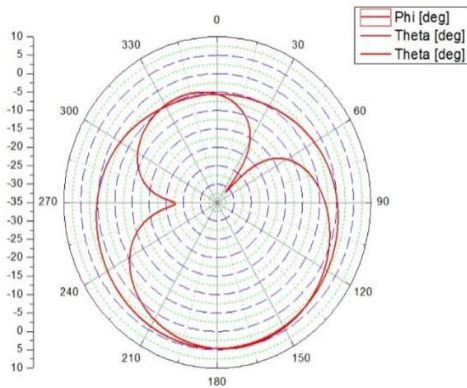


Fig 4. Plot of 2D radiation pattern with

Fig 5. Defected Ground Structure (DGS) $\phi=90^\circ$ and $\phi=0^\circ$

D. Antenna Radiation Efficiency

An additional important metric to assess an antenna's performance in transmitting and receiving radio frequency signals is its radiation efficiency, which is calculated as the ratio of the total power emitted by the antenna to the total input power received from the generator. An antenna with a high radiation efficiency efficiently radiates the input power into free space.

E. Current Density Distribution in Antenna

The electric charge movement on the patch generates current densities on the patch surface, providing the antenna with high-quality radiation. The current density distribution throughout the structure of an antenna is a significant factor that influences its radiation characteristics. In short, depending on the type of antenna and its design, the current density shows how the electric current is distributed over the surface or length of the antenna.

TABLE II. COMPARISON WITH EXISTING WORK

References	Resonant Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Bandwidth (MHz)
1	28.3	-20.8	2.6	-
4	3.5	-28.4	3.33	247.1
5	43.9	-19.2	4.64	-
3	3.46	-50.91	3.76	641.2
6	25	-25.6	5.05	23.97

TABLE III. ANTENNA RESULTS

Parameters	Results
Operating Frequency	23.5GHz
Bandwidth	1GHz
Peak Directivity	3.439
Peak Gain	5
Radiation Efficiency	88.7



Front to Back Ratio	9.951
Return Loss	-21.8

V. CONCLUSION AND FUTURE SCOPE

Using HFSS software, which is more dependable for designing and displaying high-quality results, particularly 2D radiation pattern, than other antenna design software, our suggested microstrip rectangular patch antenna is successfully constructed at the resonance frequency of 24 GHz. The above comparison table and simulation results demonstrate that the suggested design of Microstrip patch antenna has better and better return loss of -21.8 dB, voltage standing wave ratio of 1.403, higher gain of 5 dB for good signal strength, increased bandwidth of 1GHz for high quality e-learning or teaching also one can download, and finally higher antenna radiation efficiency of 88.79%. But the bandwidth and return loss of this suggested antenna are a little lower. In order to facilitate directed communication, which can boost signal strength and lower interference, more sophisticated beamforming techniques will eventually be put into use. In scenarios such as 5G, where beamforming is an essential technology, this is especially helpful.

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