ADVANCEMENT IN 5G TECHNOLOGY: A 70GHZ MICROSTRIP PATCH ANTENNA

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ABSTRACT:
The evolution of communication systems towards the fifth generation (5G) has been propelled by the need for compact, high-speed, and wide bandwidth solutions. The compact dimensions of the antenna are 2.514 mm x 2.893 mm x 0.2 mm. It operates at the 69.79 GHz frequency, loses the yield of -40.694 DB, the bandwidth of 847 MHz, 6.63 DB gain, and 70.18 % efficiency. The insertion transmission line was used to secure the optimal comparison between the radiant patch and the 50 -ohm micropolist supply line. This design uses a Roger RT DUROID 5880 substrate, which is characterized by a loss of 2.2, 0.0009, and a thickness of 0.2 mm. The antenna geometry was carefully calculated and the simulation results were analyzed using Microwave Studio's computer simulation technology.
Key-words: 70 GHz, millimeter wave, Microstrip patch antenna, 5G, Return Loss.

INTRODUCTION:
The fifth-generation network is anticipated to significantly improve communication capacity by leveraging the extensive spectrum available in the millimeter wave range. It is projected to deliver and support data rates that are up to 100 times greater than those of the fourth generation [1], [2]. This advancement introduces new and challenging requirements for network infrastructure and antenna design in 5G communication systems to accommodate the expected data rates and capacity. The remarkable surge in mobile data associated with 5G will notably enhance various sectors, including realistic Ultra High Definition, Artificial Intelligence, Blockchain, and Internet of Things applications such as Smart Cities, Smart Transportation, and Smart Grids. As the mobile industry moves towards the utilization of the millimeter-wave spectrum, telecommunications providers are likely to adopt the 28, 38, and 73 GHz frequency bands that will be accessible for future technologies [3]. In light of the demands of 5G, antennas that are lightweight, low-profile (compact), cost-effective for mass production, easy to install, adaptable to both planar and non-planar surfaces, mechanically robust when mounted on rigid surfaces, and compatible with monolithic microwave integrated circuits are essential [4]. Despite its limited bandwidth, the microstrip patch antenna emerges as an ideal candidate to fulfill these requirements. This research proposes a single microstrip patch antenna designed for 5G communication, resonating at 70 GHz, featuring a low-profile structure with dimensions of 2.514 mm × 2.893 mm × 0.2 mm.

MATERIALS AND METHODS:
For performance prediction and simplified analysis, a rectangular microstrip patch antenna operating at 70 GHz is proposed for 5G applications as shown in the figure below.

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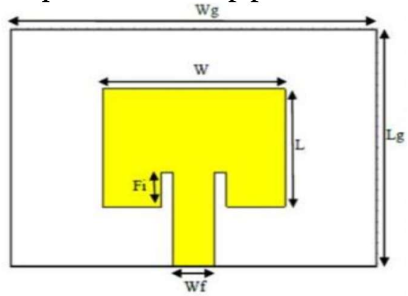
Figure. 1: Proposed microstrip patch antenna geometry



After selecting the operating frequency (70 GHz) and the dielectric constant of the substrate (RT Duroid 5880), the main parameters are the length L, width W, and thickness h of the substrate as shown in the figure. 1. The dimensions of the microstrip patch antenna were calculated using the following approximate formulas [5], [6], [7]: patch width, W.

$$W = \frac{c0}{(2fr\sqrt{\varepsilon r+1\ 2})} \qquad (1)$$

Where co is the speed of an electromagnetic wave in free space, fr is the operating frequency, εr is the dielectric constant of the substrate.

Effective permittivity, ε_{reff}.

$$\varepsilon_{Reff} = \frac{(R+1)}{2} + \frac{(R-1)}{2}\left(1+12\frac{h}{W}\right)^{-0.5} \qquad (2)$$

Here, H is the thickness of the MM substrate, and W is the width of the MM spot.

Effective long, reflex. $L_{eff} = \frac{co}{(2fr\sqrt{Reff})}$ (3)

Antenna patches are electrically longer than physical dimensions for fringe coefficient. This coefficient is deducted from the effective length and gives the actual length of the patch given:

$$\Delta L = 0.412\,\frac{(W/H+0.264)\,(\varepsilon Reff+0.3)}{(\varepsilon Reff-0.258)\,(W/H+0.813)} \qquad (4)$$

$$L = LEFF - 2\delta L \qquad (5)$$

Here, ΔL is an extension of length, and L is the actual length of the antenna. The proposed antenna was connected to a 50 Ω recessed-fed transmission feedline. This technique was used because it does not require any additional matching elements. The length and width of the transparent power line are calculated using the equation. In order to match the input impedance, the power position is 0.576 mm from the end, and the space between the points and the power line is 0.048 mm.

$$F_i = 10-4\ \{0.001699\varepsilon_r^7 + 0.13761\varepsilon_r^6 - 6.1783\varepsilon_r^5 + 93.187\varepsilon_r^4 - 682.69\varepsilon_r^3 + 2561.9\varepsilon_r^2 - 4043\varepsilon_r + 6697\}\ L/2 \qquad (6)$$

$$Wf = \frac{(7.48\times h)}{e^{\left(\frac{z0\,(\sqrt{\varepsilon r+1.41})}{87}\right)^{1}}} \qquad (7)$$

Where $z0$ is the input resistance and t is the thickness of the earth in mm.

Ground plane dimensions

$$Sg = 6h + W \qquad (8)$$

$$Lg = 6h + L \qquad (9)$$

Where W_g is the width of the ground plane in mm and L_g is the length of the ground plane in mm. Figures 1 and 2 show the geometry and simulation environment of a rectangular patch antenna, respectively. The overall size of the antenna is 2.514 mm and 2.893 mm with the length and width of the base, respectively. The dimension of physical parameters has been optimized as tabule in Table 1

Table 1. Optimised Dimension of the Proposed Antenna

Parameter	Dimension (mm)
Ground Plane Length, L_g.	2.514
Ground Plane width, W_g..	2.893
Length of patch, L.	1.36

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Length of width, W.	1.64
Height of substrate, h.	0.2
Width of feedline, W_f.	0.5
Feedline insertion, F_i.	0.5

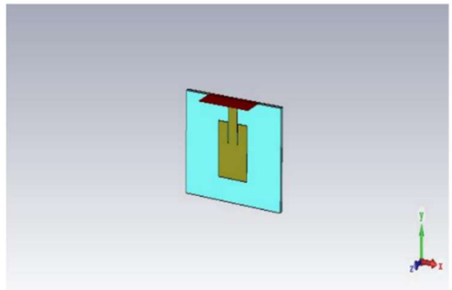


Fig.2: simulation environment of the proposed rectangular microstrip patch antenna

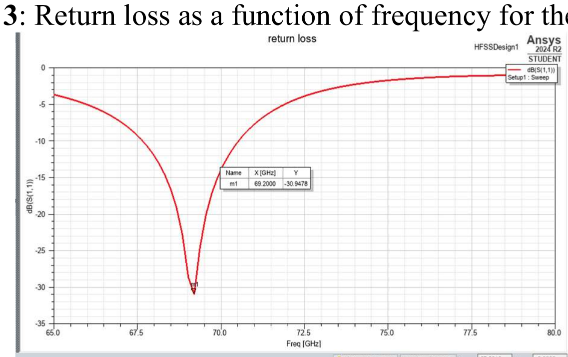
SIMULATED RESULTS AND DISCUSSION:

The design, modeling and simulation of the antenna was performed using the student version of ANSYS HFSS software.

RETURN LOSS:

A return loss value of -10 dB is considered as a reference point indicating that 10% of the incident power is reflected and 90% is absorbed by the antenna. This is considered to be excellent performance for mobile communication systems. The patch antenna resonates at 69.200GHz with a return loss of -30.94dB, as shown in Figure 3 below. The S11 parameters were extracted using a waveguide port configuration. The impedance bandwidth of the antenna is 2.89 GHz.

Figure 3: Return loss as a function of frequency for the proposed antenna



VSWR

For a patch antenna, the voltage standing wave ratio (VSWR) should ideally be 1 and should not exceed 2 or fall below 1 over the entire useful bandwidth. Figure 4 shows the ROS as a function of frequency. As shown in Figure 4, the ROS value at the resonant frequency of 69.200GHz is 1.0584. This indicates that the antenna operates efficiently and has an acceptable level of impedance matching over the required frequency range.

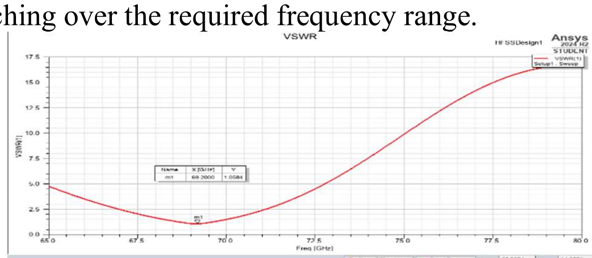


Figure.4: VSWR of the proposed antenna

Gain

The antenna has a relatively high gain of 7.85 dB which is considered very good for a compact microstrip antenna, with a half-power beamwidth of 70.39° and a sidelobe level of -15 .3 dB as shown in Figure 5.

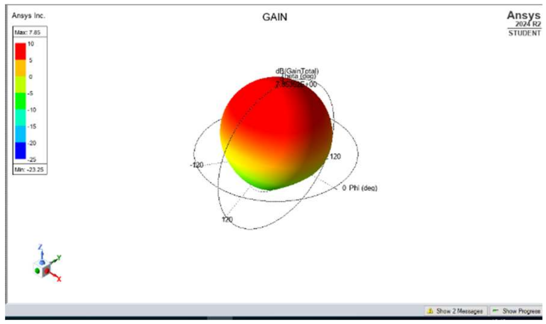


Figure.5: 3D graph of gain of the proposed antenna

RADIATION PATTERN:

The radiation pattern of the 70 GHz antenna shows that the signal is concentrated in a specific direction with a maximum gain of about 7.85 dB. The diagram is plotted for different angles (Φ) from -180° to -164°. The narrow beam of the antenna demonstrates its ability to focus signals in one direction, which is useful for 5G applications such as beamforming and high-speed communications. The model checks the efficiency of the antenna and its suitability for mmWave systems

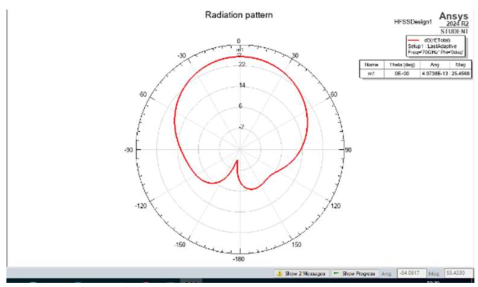


Figure.6: 2-D polar plot of the radiation pattern of the proposed antenna at phi=0

SURFACE CURRENT:

Surface current in a microstrip patch antenna represents the distribution of electric current across the antenna's metallic surfaces. For this 70 GHz millimeter wave antenna, the surface current would indicate how electromagnetic energy flows across the patch and ground plane at the resonant frequency (69.79 GHz). While the document includes a section for surface current, it lacks specific details about the current distribution pattern. Such current flow is critical in understanding the antenna's radiation mechanism, impedance matching, and overall electromagnetic performance

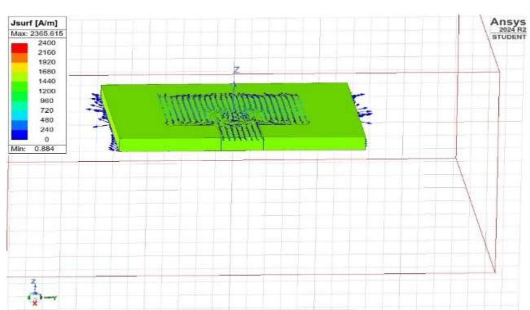


Figure.7: Surface current distribution of the proposed antenna

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SMITH CHART

The Smith chart shows the impedance characteristics of the proposed 70 GHz millimeter-wave patch antenna. It indicates that the antenna is well-matched to the 50 ohm system impedance at the 69.200GHz operating frequency, which is important for efficient power transfer.

Figure.8: Smith Chart of the proposed antenna

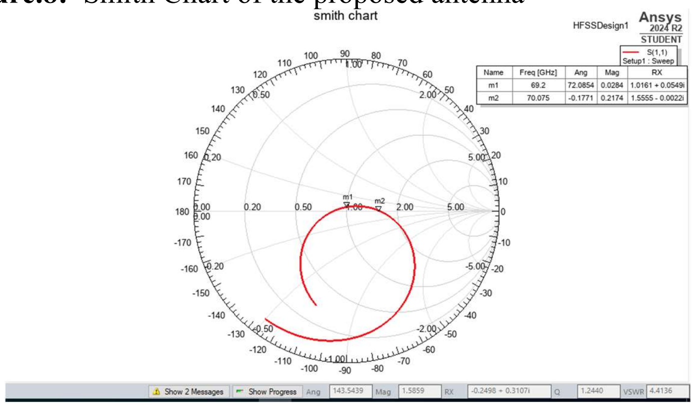

Table-2 Summary of Simulated Results

Antenna Parameter	Values
S11	-30.9478 dB
Bandwidth	2.89 GHz
Gain	7.85 dB
VSWR	1.0584
Efficiency	85.18%

CONCLUSION

Upon observing the increased demand for mobile data and portable devices, a patch antenna with a rectangular Microruban design has been developed for applications in the 5G realm. This antenna resonates at 69.79 GHz with a return loss of -40.69 dB, demonstrating a radiation efficiency of 70.18% and a gain of 7.85 dB. Notably, the antenna presents a bandwidth of 2.89 GHz, showcasing a significant advancement compared to prior studies. For instance, previous works [8] and [9] reported bandwidths of 847 MHz and 582 MHz, respectively. The expanded bandwidth of this antenna positions it as a promising candidate for 5G mobile communications, especially in scenarios where high bandwidth is crucial. Furthermore, its compact size renders it suitable for devices where spatial constraints play a vital role.

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