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OPTIMIZATION OF MICROSTRIP PATCH ANTENNA FOR 5G APPLICATIONS AT 27GHz

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Abstract:
Communication systems are constantly evolving and the cellular communication technology is now in it's fifth generation (5G). It requires systems that are compact, high-speed, and can operate in wide-bandwidth. In this study, we are focusing on designing and simulating a microstrip patch antenna operating at 27 GHz. The dimensions of the antenna are 23.20 mm × 14 mm × 0.254 mm, ensuring a compact structure. It resonates at 26.77 GHz with a return loss of -32.766 dB, offering a gain of 11.96 dBi, a bandwidth of 831 MHz, and directivity of 12.51 dBi. The design utilizes a Roger RT 5880 substrate. Antenna geometry is thoroughly analyzed, and simulation results are investigated using Computer Simulation Technology Studio.

Keywords:
Microstrip, Patch Antenna, 5G, Communication, VSWR, Gain, Directivity, Bluetooth, Frequency

1. INTRODUCTION:
Microstrip antennas, renowned for their adaptability and compactness, are extensively utilized across various domains. It is an antenna type that operates within the microwave frequency range. Applications of microstrip antennas span diverse sectors including Satellite Communication, RFID, Radar Systems, Wireless Communication Systems, and automotive systems.
In wireless communication systems, Microstrip antennas feature prominently in mobile phones, Wi-Fi routers, WiMAX technology, and Bluetooth devices. Notably, microstrip antennas play an essential role in advancing 5G technology, facilitating the development of compact and high-performance communication systems. The new age 5G mmWave technology works in the range of 24 GHz and above, and hence this system requires components and devices that are compatible in this frequency range. The suitability of Microstrip antennas for millimetre-wave communication is attributed to their compact dimensions and capacity to establish directional radiation patterns, thereby effectively addressing propagation losses and interference.

2. ANTENNA DESIGN:
The process of antenna design involves several stages, such as geometry optimization, simulation, and performance analysis. By employing established microstrip patch design methodologies, the antenna is tailored to resonate at a frequency of 26.77 GHz. The antenna's dimensions are based on the target resonance frequency and other specified performance criteria. Subsequent modifications to the antenna's geometry involve having an array of patches, with the dimensions of these patches fine-tuned to attain the desired resonance frequency. The Figure 1 displays the design of the Microstrip Patch Antenna being proposed. The dimensions of the proposed antenna are as follows:

S. No.	Parameters	Value
1.	Length of Ground	23.20 mm
2.	Width of Ground	14 mm
3.	Height of Ground	0.025 mm
4.	Length of Substrate	23.20 mm
5.	Width of Substrate	14 mm
6.	Substrate Height	0.175 mm

7.	Length of Patch	5.70 mm
8.	Width of Patch	3.95 mm
9.	Length of Feed Line	6.85 mm
10.	Width of Feed Line	0.80 mm
11.	P1	2.30 mm
12.	P2	1.10 mm
13.	P3	0.80 mm
14.	T1	1.70 mm
15.	T2	1.70 mm
16.	T3	0.42 mm
17.	T4	0.70 mm
18.	T5	3.85 mm
19.	T6	0.30 mm

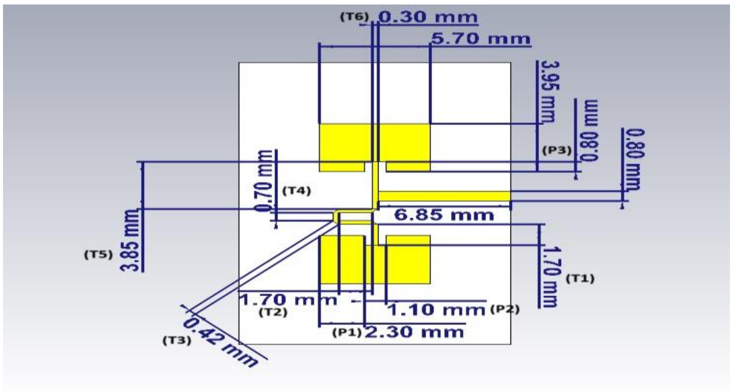

Figure 1: Proposed Microstrip Patch Antenna Design

The Figure 2 shows an example of conventional design of a Microstrip Patch Antenna without cuts.

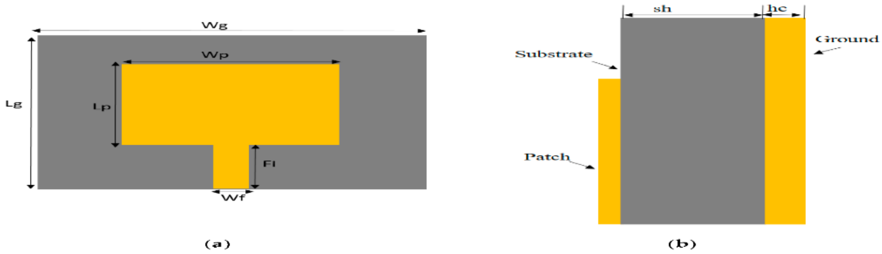

Figure 2: Conventional Microstrip Patch Antenna Design

The Figure 3 demonstrates the S-parameter of a conventional Microstrip patch antenna without cuts.

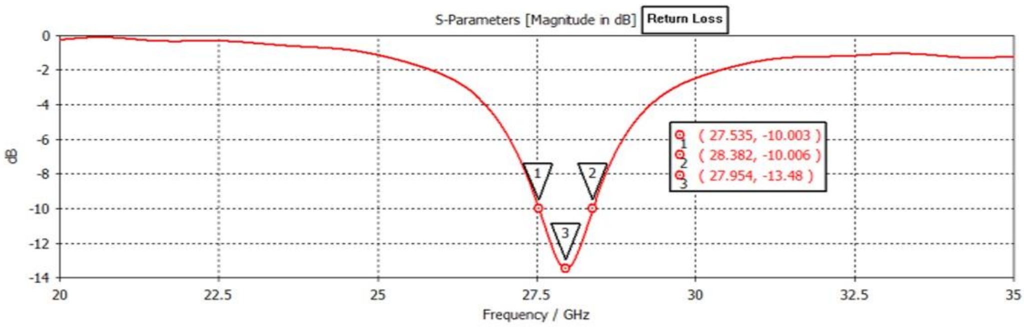

Figure 3: S-Parameter of a Conventional Microstrip Patch Antenna

3. Microstrip Patch Antenna Design with modifications:

Microstrip patch antennas are integrated into wireless communication systems owing to their distinctive advantages, including their adaptability to custom dimensions and performance requirements. By implementing targeted design modifications, such as incorporating cuts into the antenna design and also forming an array of patches, we can directly impact the antenna's performance, enabling its versatility for a wide array of applications.

Improving the performance:

By having an array of patches in the antenna design, we can expect to improve the performance of the antenna in terms of crucial parameters like Gain, Directivity, Return Loss and VSWR.

Radiation Pattern Improvement:

The Radiation Pattern of the antenna can also be improved by designing the dimensions and shape of the patches. This improvement can further help in improving other coverage characteristics. Also, it can be helpful if there are specific-application requirements.

Adjustment of Frequency Band:

Fine tuning of the Frequency band can be achieved by an antenna by having an array of two patches. When we place the patches calculatedly, we can adjust the projected direction of frequency. This helps to increase its flexibility and versatility in communication systems.

4. Simulation Results:

CST (Computer Simulation Technology) is capable of simulating a microstrip patch antenna, providing a platform to derive a range of valuable outcomes including Directivity, Gain, VSWR (Voltage Standing Wave Ratio), Bandwidth, Return Loss and other essential performance metrics.

Simulating the proposed antenna on CST provides following results:

A) RETURN LOSS:

In an antenna, Return Loss measures the proportion of power reflected back towards the source due to mismatches in the impedance between the antenna and the transmission line or surrounding environment. It's quantified in decibels (dB). If the Return Loss is high, it implies better matching of impedance, and also we can infer that less power is being reflected back towards the source, which is crucial for efficient signal transmission.

In simpler terms, return loss indicates the portion of the signal that "bounces back" to the transmitter instead of being transmitted outward by the antenna. This parameter significantly influences the efficiency and performance of signal transmission, making it essential in antenna design and evaluation.

Figure 4 shows us the Return Loss by the antenna design being proposed. Return Loss of -32.766 indicates good impedance matching.

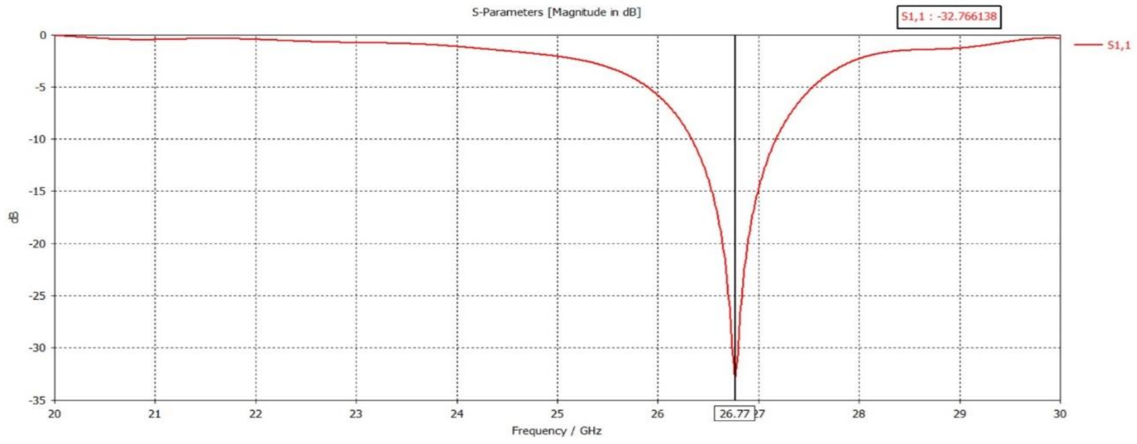

Figure 4: Return Loss of the Proposed Microstrip Patch Antenna

B) BANDWIDTH:

The antenna's bandwidth encompasses the frequencies over which it functions effectively. It can be defined as the frequency span between points where the antenna's performance aligns with specified criteria, such as predetermined levels of return loss, gain, or efficiency.

In simple words, bandwidth denotes the frequency range where the antenna can efficiently transmit or receive signals without notable performance decline. A broader bandwidth enables the antenna to operate across a wider spectrum of frequencies, enhancing its adaptability and suitability for various communication needs.

From Figure 5, we can infer that the Bandwidth of the microstrip antenna being proposed is 831 MHz.

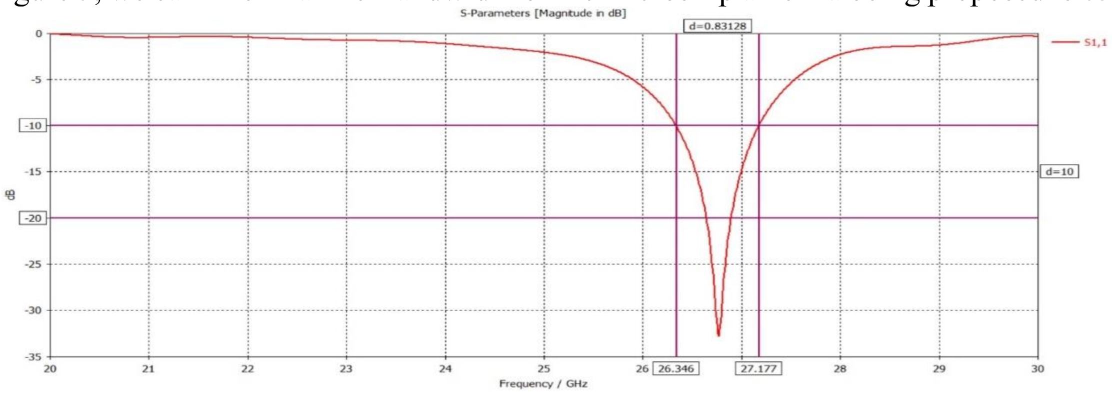

Figure 5: Bandwidth of Proposed Microstrip Patch Antenna

C) GAIN:

The antenna's gain indicates its ability to concentrate radio waves in a specific direction during transmission or to capture signals effectively from a particular direction during reception.

Greater gain values signify enhanced transmission or reception capability in the intended direction. Nevertheless, it's essential to understand that gain is always measured relative to a reference, like an isotropic radiator or a dipole antenna, and does not necessarily mean amplification of signal power.

From Figure 6, we can observe that the Gain of the proposed microstrip antenna is 11.9686 dBi, that is, decibels relative to an isotropic radiator.

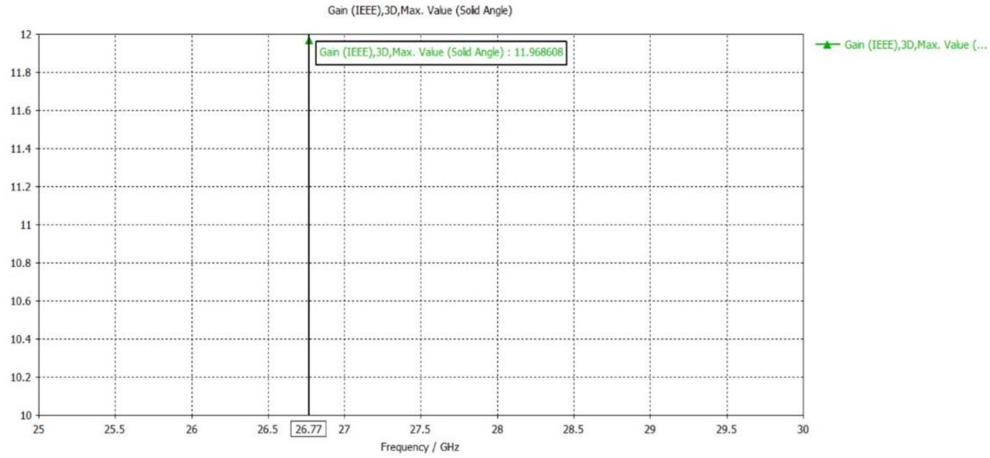

Figure 6: Gain of the Proposed Microstrip Antenna

D) DIRECTIVITY:

In an antenna, directivity pertains to the capacity of an antenna to concentrate RF (Radio Frequency) energy in a specific direction during transmission or to receive signals more efficiently from a particular direction during reception.

Antennas with high directivity channel their energy into a narrower beam, facilitating extended-range communication in a particular direction.

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From Figure 7, we can infer that the Directivity of the proposed Microstrip Patch Antenna is 12.51 dBi, that is, decibels relative to an isotropic radiator.

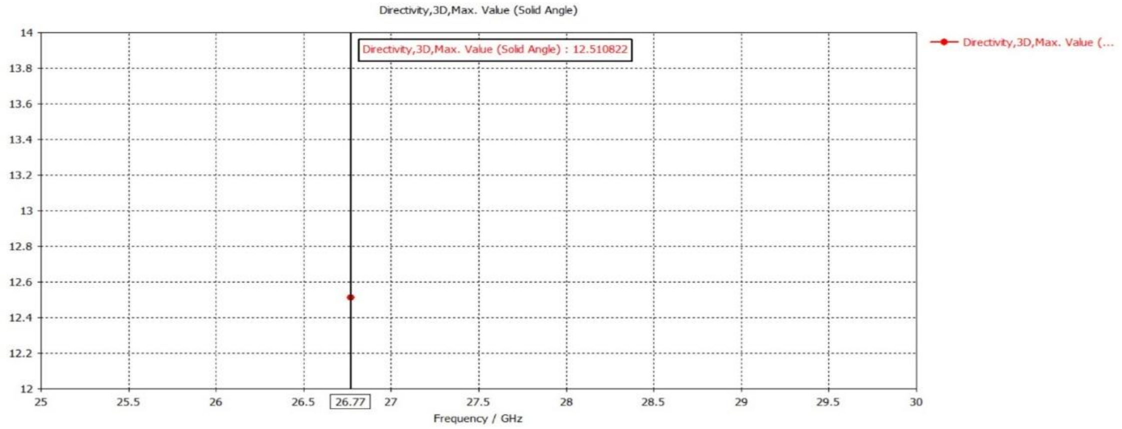

Figure 7: Directivity of the Microstrip Patch Antenna being proposed

E) EFFICIENCY:

In an antenna, Efficiency denotes its capability to effectively transform input power into radiated electromagnetic energy. This metric measures the antenna's proficiency in transmitting or receiving signals while minimizing power dissipation as heat or losses within the system.

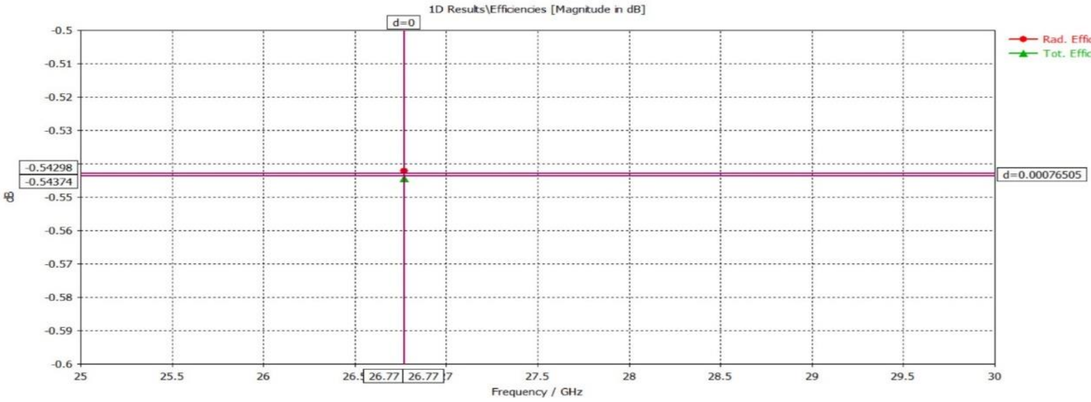

Figure 8: Efficiency Graph of the Proposed Microstrip Antenna

F) VSWR:

VSWR, or Voltage Standing Wave Ratio, assesses how well an antenna aligns with the transmission line or the connected system. When there's a mismatch in impedance between the antenna and the transmission line or system, some of the energy sent along the line reflects back.

VSWR measures the extent of signal reflection due to this mismatch. A VSWR value of 1 signifies optimal conditions where all the energy passes through the line without reflection. On the other hand, as the VSWR value rises, more energy is reflected back, indicating poorer alignment between the antenna and the system.

Practically lower VSWR values are preferred as they denote better impedance matching, resulting in more effective signal transmission and reception. VSWR serves as an important parameter in antenna design and system performance assessment.

Figure 9 shows us the VSWR offered by the proposed Microstrip Antenna. We can expect good performance from the proposed antenna as its VSWR value is 1.04.

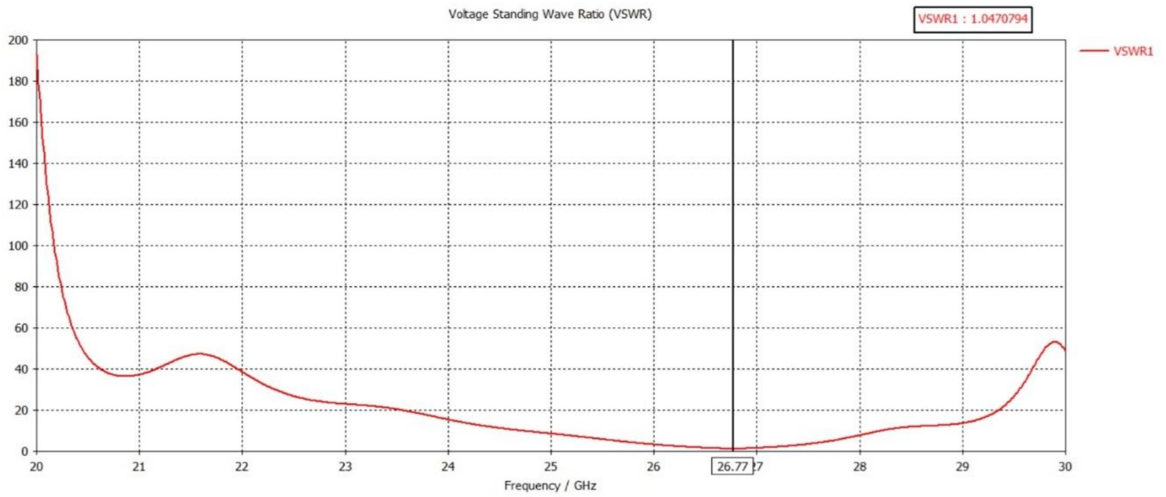

Figure 9: VSWR offered by the proposed Microstrip Patch Antenna

G)RADIATION PATTERNS:

The radiation pattern of an antenna depicts how the electromagnetic energy is emitted or received in three-dimensional space. It showcases the antenna's emission or reception characteristics across various directions.

The Understanding of an antenna's radiation pattern is crucial for designing and refining wireless communication systems, as it directly influences the efficiency of signal transmission and reception across different directions.

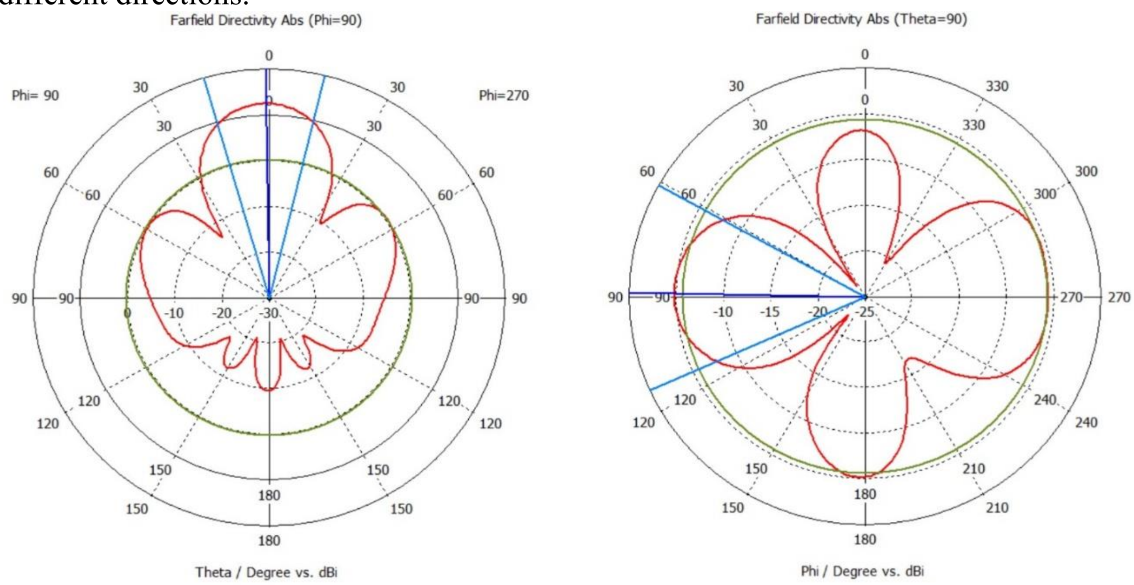

Figure 10: Radiation Pattern of the Proposed Microstrip Patch Antenna

5. Conclusion:

In this research, we present a Microstrip Patch Antenna design aimed at achieving our desired performance outcomes. The antenna is crafted to be compatible with 5G applications by resonating at the frequency of 26.77 GHz, falling within the 5G mmWave specification.

Utilizing computer simulation technology and theoretical analysis, we observe that the proposed antenna exhibits outstanding performance across crucial antenna parameters such as Gain, Directivity, Bandwidth and VSWR.

6. Applications and Uses:

i) **Cellular Networks:**

The new age 5G mmWave technology that offers high speed wireless internet and services, works in the frequency range of 24GHz and above. The antenna that is being proposed has a resonance frequency of 26.77 GHz; therefore, it can operate at the desired frequency range.

ii) **Radar Networks:**

Radar Waves of K band falls in the range of 18 to 27 GHz. So, for radar applications like defence, surveillance and aerospace, the proposed antenna can be very useful.

iii)**Radio Telescope:**

Radio Telescope is an astronomical device used for detection of radio waves from astronomical radio sources. It comprises of an antenna system which is used to detect radio frequency range between 30 MHz to 300 GHz.

iv)**Possible future application in 6G Technology:**

6G (Sixth generation) is the upcoming wireless communication network technology, and as per the initial phase of research, it will use frequency bands similar to that of the existing 5G technology, so the proposed antenna may be used in the future for 6G applications also.

7. Acknowledgement:

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