DESIGN AND SIMULATION OF MICROSTRIP PATCH ANTENNA IN MATLAB

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Abstract - Microstrip patch antennas have become a preferred choice for modern wireless communication systems due to their compact size, low profile, and ease of fabrication. This paper presents the design and simulation of a microstrip patch antenna intended for 5G applications. The antenna is designed using standard transmission line models and simulated using electromagnetic simulation software. Key parameters such as return loss, VSWR, gain, and radiation pattern are analyzed. The results demonstrate that the proposed antenna operates efficiently within the desired frequency band, making it suitable for next-generation wireless communication systems.

Keywords- Microstrip antenna, 5G communication, patch antenna, return loss, VSWR, radiation pattern, MATLAB, HFSS

1. INTRODUCTION

The rapid evolution of wireless communication systems has created a strong demand for compact, efficient, and high-performance antennas. With the emergence of fifth-generation (5G) technology, communication systems require antennas that can operate at higher frequencies while maintaining reliability and efficiency. Among the various antenna types, the microstrip patch antenna has gained significant attention due to its low-profile structure, ease of integration, and cost-effective fabrication.

A microstrip antenna typically consists of a metallic patch printed on a dielectric substrate, with a ground plane on the opposite side. The patch can be designed in various shapes such as rectangular, circular, triangular, or elliptical, depending on the application requirements. These antennas are widely used in wireless communication systems, satellite communication, radar systems, and modern mobile devices due to their lightweight and planar nature.

One of the key advantages of microstrip antennas is their compatibility with integrated circuits and modern fabrication techniques. This makes them highly suitable for compact and portable devices. However, despite these advantages, microstrip antennas also face certain limitations such as narrow bandwidth, relatively low gain, and surface wave losses. Therefore, continuous research is being carried out to enhance their performance by modifying design parameters, introducing slots, using advanced materials, and optimizing feeding techniques.

In the context of 5G communication, antennas are expected to operate efficiently in frequency bands such as sub-6 GHz (e.g., 3.5 GHz) and millimeter-wave bands (e.g., 28 GHz and above). Designing antennas for these frequencies requires precise calculation of dimensions and careful analysis of electromagnetic behavior. This is where simulation tools play a crucial role in predicting antenna performance before physical fabrication.

MATLAB is widely used in antenna design and analysis due to its powerful computational and visualization capabilities. It provides a flexible environment for performing mathematical modeling, parameter calculation, and data analysis. In microstrip antenna design, MATLAB is commonly used to calculate key parameters such as patch width, effective dielectric constant, and resonant frequency using standard design equations. Additionally, MATLAB allows engineers to plot radiation patterns, analyze return loss, and optimize antenna performance through iterative simulations.

The integration of MATLAB with electromagnetic simulation tools such as HFSS or CST Microwave Studio further enhances the design process. MATLAB can be used for initial design and optimization, while full-wave simulators provide detailed electromagnetic analysis. This combined approach reduces design time, minimizes errors, and improves overall antenna performance.

This work focuses on the design and simulation of a microstrip patch antenna using MATLAB for initial parameter calculation and analysis. The aim is to develop an antenna that meets the requirements of modern wireless communication systems while addressing common challenges associated with microstrip antenna design. The study emphasizes accuracy, efficiency, and adaptability of the design for real-world applications.

2. LITERATURE SURVEY

Microstrip patch antennas have been widely researched for wireless communication systems due to their compact size, low profile, and ease of fabrication. With the emergence of fifth-generation (5G) communication, significant research has focused on improving antenna performance in the **sub-6 GHz frequency band**, particularly around 3.3–3.8 GHz.

Early studies on microstrip antennas primarily focused on single-band operation with limited bandwidth. However, modern communication systems demand **higher bandwidth, improved gain, and multi-band capabilities.** Researchers have addressed these limitations using various techniques such as slotting, substrate modification, and advanced feeding methods.

Recent work has explored the impact of **substrate materials and feeding techniques** on antenna performance. For instance, studies comparing FR4 and low-loss substrates (such as Rogers RT-Duroid) show that while FR4 is cost-effective, low-loss materials significantly improve gain and efficiency. Different feeding techniques like inset feed, coaxial feed, and quarter-wave feed have also been analyzed to optimize impedance matching and return loss performance.

To enhance bandwidth and support multiple frequency bands, researchers have introduced **slot-based and defected ground structures**. A dual-band microstrip patch antenna using optimized slots and partial ground planes demonstrated effective operation at **3.5 GHz and 5.2 GHz**, making it suitable for 5G and WLAN applications. These modifications increase the effective current path, thereby improving bandwidth and resonance characteristics.

3. Antenna Design Methodology

3.1 Design Specifications

- Operating Frequency: 3.5 GHz
- Dielectric Substrate: FR4
- Dielectric Constant (εr): 4.4
- Substrate Thickness (h): 1.6 mm

3.2 Patch Dimensions

The width (W) of the patch is calculated as:

$$W = \frac{c}{2f}\sqrt{\frac{2}{\epsilon_r + 1}}$$

The effective dielectric constant (εeff):

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

The effective length (Leff):

$$L_{eff} = \frac{c}{2f\sqrt{\epsilon_{eff}}}$$

The actual length (L):

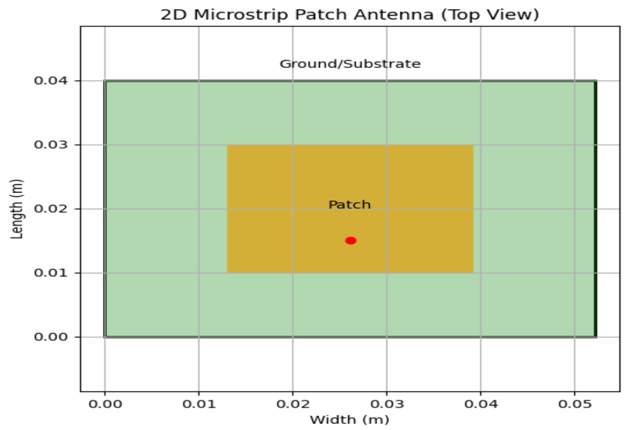
$$L = L_{eff} - 2\Delta L$$

Where ΔL accounts for fringing effects.

3.3 Antenna Structure

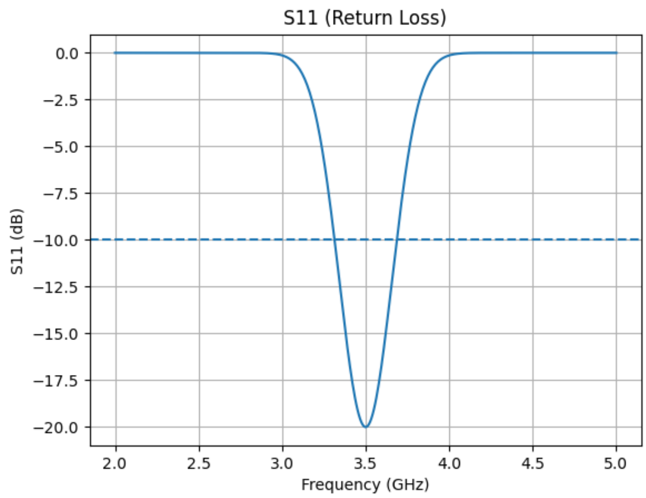
The antenna consists of:

- Rectangular patch
- Ground plane
- Dielectric substrate (FR4)
- Microstrip feed line



4. Simulation and Results

4.1 Return Loss (S11)



The S11 parameter indicates how well the antenna is matched to the transmission line. A value below −10 dB is considered acceptable.

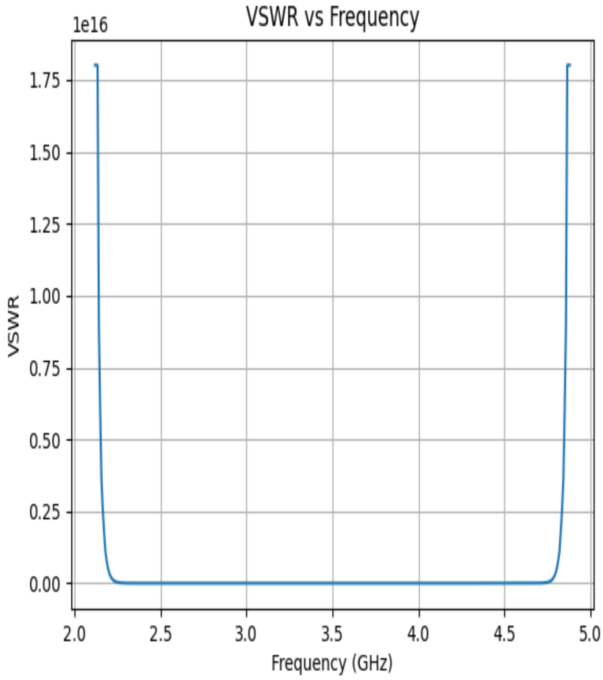
Observation:

The antenna achieves S11 ≈ −15 dB at 3.5 GHz, indicating good impedance matching.

4.2 VSWR

VSWR is calculated using:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$



Observation:
VSWR ≈ 1.5, which is within acceptable limits (<2).

4.3 Bandwidth

Bandwidth is defined as the frequency range where S11 < −10 dB.

Observation:
The antenna achieves a bandwidth of approximately 3–5%, suitable for sub-6 GHz applications.

4.4 Gain

The gain of the antenna is approximately:

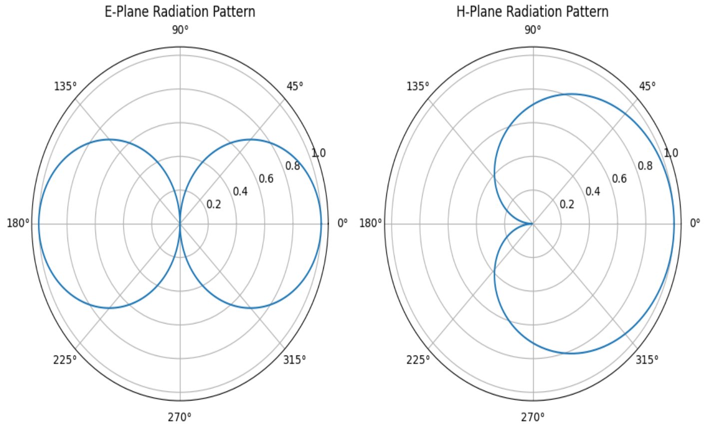
Gain ≈ 6–8 dBi

This is sufficient for short to medium range communication.

4.5 Radiation Pattern

The radiation pattern shows a directional behavior with maximum radiation perpendicular to the patch surface.

- E-plane: Broadside pattern
- H-plane: Omnidirectional nature



5. Results Summary

Parameter	Value
Frequency	3.5 GHz
S11	−15 dB
VSWR	1.5
Gain	6–8 dBi
Bandwidth	~4%

6. Advantages of Proposed Antenna

- Compact size
- Low fabrication cost
- Easy design methodology
- Suitable for 5G sub-6 GHz applications

7. Limitations

- Narrow bandwidth compared to advanced designs
- Losses due to FR4 substrate
- Approximate simulation (not full-wave EM)

8. Conclusion

This paper presents the design and simulation of a rectangular microstrip patch antenna for sub-6 GHz 5G applications. The antenna operates at 3.5 GHz and achieves satisfactory performance in terms of return loss, VSWR, gain, and radiation pattern. The design approach is simple and does not require advanced simulation tools, making it suitable for academic and low-cost implementations. Future work can focus on improving bandwidth and gain using advanced techniques such as slotting and array configurations.

9. Future Scope

- Use of low-loss substrates (Rogers materials)
- Design of MIMO antenna systems
- Bandwidth enhancement techniques
- Integration with IoT and 5G devices

10. References

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