

Analysis and Performance Improvement of Hexagonal Microstrip Patch Antenna

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ABSTRACT

The increasing demand for high-frequency wireless communication systems has driven the need for compact and efficient antenna designs. This paper presents the design and analysis of a hexagonal microstrip patch antenna operating at 15 GHz for advanced communication applications. The proposed antenna is modeled and simulated using High Frequency Structure Simulator (HFSS) software, considering suitable substrate material and optimized geometrical parameters. The hexagonal patch structure is chosen to enhance radiation characteristics and improve overall antenna performance compared to conventional shapes. The antenna exhibits desirable performance metrics, including low return loss (S11), acceptable Voltage Standing Wave Ratio (VSWR), improved gain, and stable radiation patterns in both 2D and 3D views. The achieved bandwidth and efficiency make the antenna suitable for high-frequency applications such as 5G communication, satellite systems, and radar technologies. The results demonstrate that the proposed design offers a compact structure with reliable performance, making it a promising candidate for modern wireless communication systems.

Key Words-Microstrip antenna, VSWR, High Gain Antenna, HFSS Simulation, Impedance Matching

INTRODUCTION

The rapid advancement of wireless communication technologies has created a growing demand for high-performance antennas capable of operating at higher frequencies. Microstrip patch antennas have gained significant attention due to their advantages such as low profile, light weight, ease of fabrication, and compatibility with integrated circuits. These features make them suitable for modern applications including 5G communication, satellite systems, and radar technologies.

However, conventional microstrip patch antennas suffer from certain limitations, including narrow bandwidth, low gain, and reduced efficiency at higher frequencies. To overcome these drawbacks, various techniques such as shape modification, substrate selection, and structural optimization have been explored in recent research. Among these approaches, the geometry of the patch plays a crucial role in determining the overall antenna performance.

Different patch shapes such as rectangular, circular, and triangular have been widely studied, each offering specific advantages and limitations. Recently, hexagonal patch structures have attracted attention due to their ability to provide improved

radiation characteristics, better impedance matching, and enhanced gain compared to conventional geometries. The unique shape helps in distributing surface currents more effectively, leading to improved antenna performance.

In this work, a hexagonal microstrip patch antenna operating at 15 GHz is designed and analyzed using High Frequency Structure Simulator (HFSS). The proposed design focuses on achieving improved gain, bandwidth, and radiation characteristics while maintaining a compact structure. The antenna performance is evaluated in terms of return loss (S11), Voltage Standing Wave Ratio (VSWR), gain, and radiation patterns.

LITERATURE SURVEY

Recent research in Several hexagonal microstrip antennas have been designed for ultra-wideband (UWB) applications due to their compact size and capability for multi-band operation. However, these antennas often suffer from limitations such as low gain, poor impedance matching, and reduced radiation efficiency at higher frequencies. Additionally, most existing designs operate below

10.6 GHz and require further optimization to improve overall performance.

[1] Jagdish M. Rathod studied a microstrip patch antenna for wireless communication applications. In this work, different feeding techniques were analyzed and simulated using IE3D software. The antenna operates at approximately 5.35 GHz. Simulation results show a return loss (S11) of about -14 dB, a gain of around 6.8 dB, and a bandwidth of nearly 51 MHz. The antenna uses a dielectric substrate with a relative permittivity of 2.2, and the VSWR is less than 2, indicating good impedance matching. The study highlights the influence of feeding techniques on antenna performance.

[2] S. A. Ali designed and analyzed a microstrip patch antenna for wireless communication operating at 2.4 GHz. The antenna is fabricated on an FR-4 epoxy substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. The results show a return loss (S11) of approximately -23 dB, a gain of about 7 dB, and a VSWR of 1.15, indicating efficient radiation and good impedance matching. This design is suitable for 2.4 GHz wireless communication systems.

[3] Xun Gong et al. (2016) proposed a microstrip-fed hexagonal ultra-wideband antenna with triple notched bands. The antenna operates from 2.93 GHz to 10.04 GHz with a return loss below -10 dB and VSWR less than 2. The measured gain ranges from 1.3 dB to 7.4 dB. It is fabricated on a Rogers 4350B substrate ($\epsilon_r = 3.66$, thickness = 0.51 mm), providing stable radiation characteristics suitable for UWB applications.

[4] Prem P. Singh and Sudhir K. Sharma designed a triple-band microstrip patch antenna for WLAN, satellite TV broadcasting, and radar applications. The antenna uses an FR-4 substrate ($\epsilon_r = 4.4$, thickness = 1.6 mm) and operates at 5.38 GHz, 6.76 GHz, and 8.82 GHz. The simulated return loss values are -30.88 dB, -45.32 dB, and -47.93 dB, respectively, indicating excellent impedance

matching. The gains achieved are 2.42 dBi, 2.46 dBi, and 4.28 dBi, with VSWR less than 2.

[5] N. Kusuma Kumari and R. Kumar proposed a rectangular microstrip patch antenna for wireless communication. The antenna operates at 2.45 GHz using an FR-4 substrate ($\epsilon_r = 4.4$, thickness = 1.6 mm). The results show a return loss (S11) of approximately -32 dB, a gain of about 6.9 dBi, and a VSWR of around 1.05, demonstrating excellent impedance matching and radiation performance.

[6] Bhanumathi and Swathi (2019) proposed a bandwidth-enhanced microstrip patch antenna using an inverted L-shaped patch with a U-slot. The antenna operates at 5.2 GHz and 7.4 GHz on an FR-4 substrate ($\epsilon_r = 4.4$, thickness = 1.6 mm). The design achieves a return loss of -24.7 dB, VSWR less than 2, and a bandwidth of 28%, making it suitable for UWB, WLAN, and satellite applications.

EXISTING METHOD

Conventional microstrip patch antennas with standard geometries such as rectangular, circular, and triangular shapes are widely used in wireless communication systems due to their simple structure, low profile, and ease of fabrication. These antennas consist of a metallic radiating patch printed on a dielectric substrate with a ground plane on the opposite side, forming a compact and efficient radiating element.

Various feeding techniques, including microstrip line feed, coaxial probe feed, aperture coupling, and proximity coupling, are commonly used to excite the antenna and achieve proper impedance matching. The performance of these antennas depends on factors such as substrate material, dielectric constant, patch dimensions, and operating frequency.

In general, conventional microstrip patch antennas provide moderate gain in the range of 5–7 dB and a narrow bandwidth of about 2–5%. The return loss (S11) is typically maintained below -10 dB, and the Voltage Standing Wave Ratio (VSWR) is kept below

2 for acceptable operation. However, at higher frequencies, these antennas suffer from increased losses, reduced efficiency, and limited radiation performance.

Although standard geometries offer simplicity in design, they do not effectively support enhanced current distribution, which restricts improvements in gain and bandwidth. As a result, there is a need for advanced geometrical modifications to improve antenna performance for high-frequency applications.

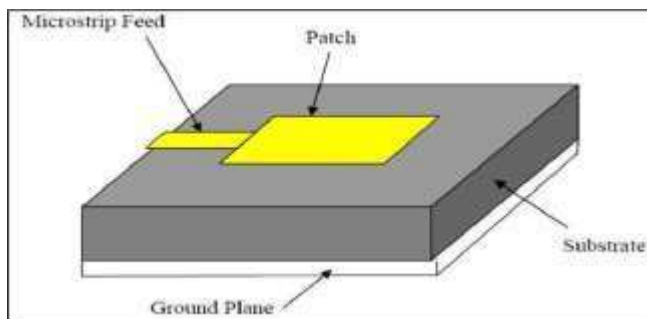


Fig 1: Structure of Conventional Microstrip Patch Antenna

MICROSTRIP PATCH ANTENNA

To address the limitations of conventional microstrip patch antennas, a hexagonal microstrip patch antenna is proposed for operation at 15 GHz. The selection of a hexagonal geometry is intended to improve surface current distribution, which in turn enhances radiation characteristics, gain, and impedance matching compared to traditional patch shapes.

The proposed antenna structure consists of a hexagonal radiating patch printed on a dielectric substrate with a ground plane on the opposite side. A suitable substrate material is chosen to support high-frequency operation, and the antenna dimensions are carefully designed to achieve resonance at the desired frequency. A microstrip line feeding technique is employed due to its simplicity and ease of integration with planar circuits.

The antenna is designed and analyzed using High Frequency Structure Simulator (HFSS). Key design parameters, including patch dimensions, substrate properties, and feed position, are optimized to obtain improved performance. The simulation results indicate that the proposed antenna achieves better return loss (S11), acceptable VSWR, enhanced gain, and stable radiation patterns.

Thus, the proposed hexagonal microstrip patch antenna offers improved performance and compact size, making it suitable for advanced high-frequency applications such as 5G communication, satellite systems, and radar technologies.

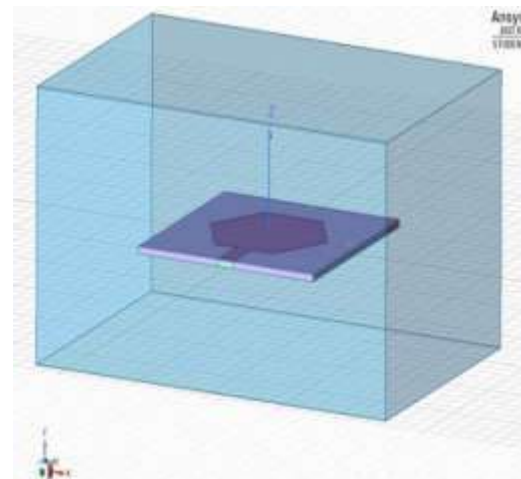


Fig 2: 3D View of Proposed Hexagonal Microstrip Patch Antenna

DESIGN EQUATIONS AND CALCULATIONS

Here, MSA is configured using hexagonal shaped radiating patch. The structure is designed to operate in the ultra-wideband frequency range of 3.1 to 10.6 GHz. The radius of Hexagonal Patch (a_h) is given by,

$$a_h = \frac{F}{\left\{ \sqrt{1 + \frac{2h}{\pi \epsilon_r F}} \left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726 \right] \right\}}$$

Where,

$$F = \frac{8.791 \times 10^9}{f_0 \sqrt{\epsilon_r}}$$

The side length of hexagonal patch (l) is given by,

$$\pi a_h^2 = l^2 \frac{3\sqrt{3}}{2}$$

The height of hexagonal patch (L) is given by,

$$L = \sqrt{[3]}a_h$$

The dimensions of the proposed hexagonal microstrip patch antenna are calculated using standard design equations. The parameter F is first determined from the operating frequency and substrate dielectric constant, which is then used to find the patch radius (a_h). The side length (l) is obtained by equating the area of a circular patch to the hexagonal patch, and the height (L) is calculated using geometric relations. These dimensions ensure resonance at 15 GHz and are simulated using ANSYS HFSS to evaluate performance.

RESULTS AND DISCUSSION

The performance of the proposed hexagonal shaped microstrip patch antenna has been investigated using HFSS software. The antenna structure provides a return loss less than -10 dB and a VSWR less than 2 at the operating frequency of 15 GHz. The design also exhibits improved gain and stable radiation characteristics, making it suitable for high-frequency applications such as 5G, satellite, and radar systems.

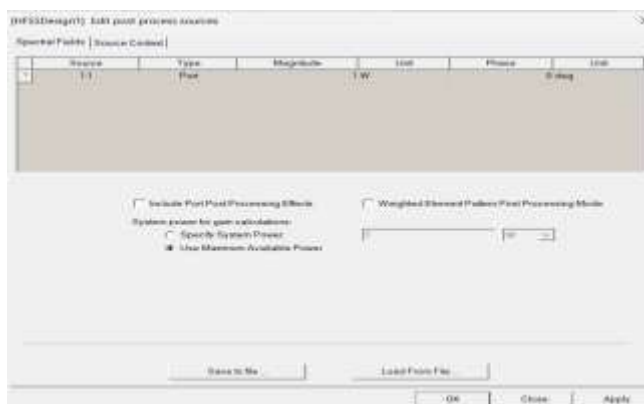


Fig 3: Input Port and Power Configuration in HFSS

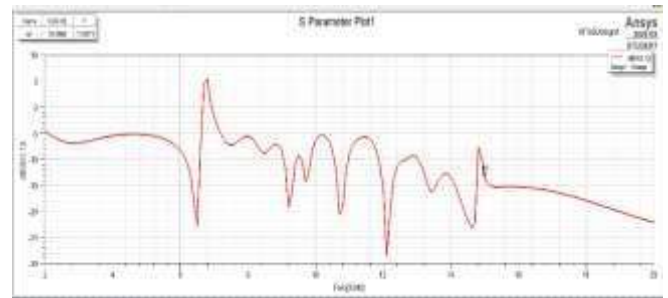


Fig 4: Return loss(s11) Analysis

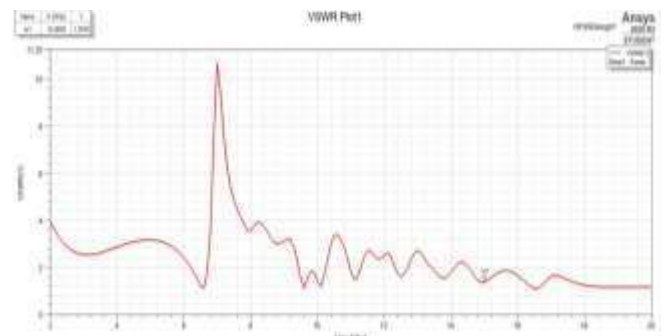


Fig 5: VSWR (VOLTAGE STANDING WAVE RADIO)

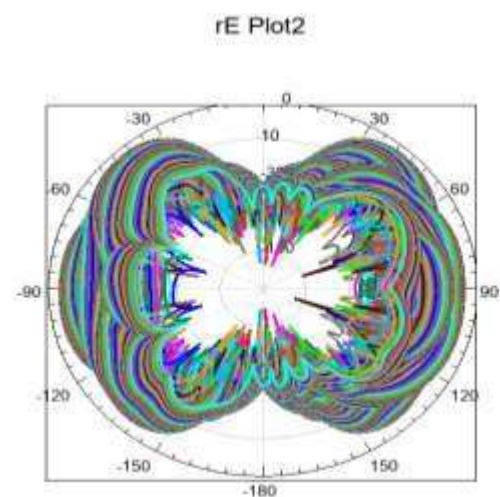


Fig 6: Radiation pattern in 3D

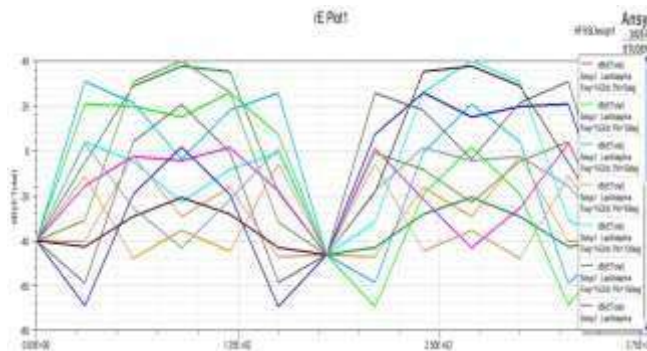


Fig 7: Radiation pattern in 2D

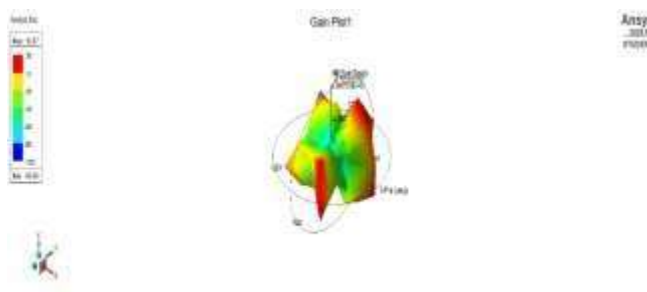


Fig 8: Gain

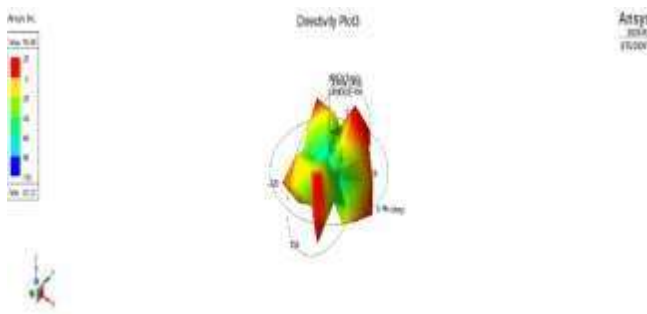


Fig 9: Directivity

Table 1: Results summary

Parameters	Target	Obtained
Resonant Frequency	15 GHz	~15GHz
Return Loss (S11)	< -10 dB	-15.6dB

VSWR	< 2	1.3
Gain	> 5 dB	13.6dB
Directivity	> 7 dB	16.9dB

CONCLUSION

In this work, a hexagonal shaped microstrip patch antenna operating at 15 GHz has been designed and analyzed using HFSS software. The proposed antenna demonstrates improved performance compared to conventional microstrip patch antennas in terms of gain, bandwidth, and radiation characteristics. The antenna achieves a return loss less than -10 dB and a VSWR less than 2, indicating good impedance matching at the desired frequency. The radiation patterns obtained are stable in both 2D and 3D views, confirming effective radiation behavior. The compact size and enhanced performance make the proposed antenna suitable for high-frequency applications such as 5G communication, satellite systems, and radar technologies.

REFERENCES:

- [1] J. M. Rathod, Comparative study of microstrip patch antenna for wireless communication application, IJIMT, 1 (2010).
- [2] A. S. Ali and D. Mathur, A novel UWB modified hexagonal microstrip antenna with improved gain, IJCE, 3 (2015).
- [3] X. Gong, L. Tong, Y. Tian and B. Gao, Design of a microstrip-fed hexagonal shape UWB antenna with triple notched bands, Electromagnetics, 62, 77-87 (2016).
- [4] P. P. Singh and S. K. Sharma, Design and fabrication of a triple band microstrip antenna for WLAN, satellite tv and radar applications, Electromagnetics, 117, 277-289 (2021).
- [5] N. Kushwaha and R. Kumar, Design of slotted ground hexagonal microstrip patch antenna and gain improvement with FSS screen, Electromagnetics, 51, 177-199 (2013).

[6] V. Bhanumathi and S. Swathi, bandwidth enhanced microstrip antenna for UWB application, microelectronics, (2019).