DESIGN OF MULTIBAND MICROSTRIP PATCH ANTENNA USING E-SHAPED STRUCTURE FOR WIRELESS APPLICATIONS

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***Abstract*—Antennas are essential components in wireless communication systems, enabling the transmission and reception of electromagnetic signals. With the rising demand for compact devices operating across multiple wireless standards, multiband antennas have become a critical requirement. Microstrip patch antennas (MPAs) are widely favored due to their low profile, lightweight nature, planar configuration, and ease of integration with circuit boards. This paper presents the design and analysis of a multiband microstrip patch antenna using an E-shaped structure, aimed at wireless applications. The proposed antenna is designed to resonate at four distinct frequencies: 4.18 GHz, 5.32 GHz, 5.57 GHz, and 6.66 GHz—making it suitable for various sub-6 GHz wireless systems including WiFi and other high-speed communication protocols. The antenna is fabricated on an FR4 substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm. Multiband performance is achieved by introducing strategically placed slots within the E-shaped patch. The design is simulated using Keysight Advanced Design System (ADS) software. Key antenna parameters such as return loss, gain, directivity, and radiation efficiency are evaluated, and the results demonstrate that the proposed design provides efficient multiband operation with compact size and desirable radiation characteristics.**

***Index Terms*—Microstrip Patch Antenna, Wi-Fi 6E, 6 GHz Band, Antenna Design, ADS Simulation, High-Frequency Antennas.**

I. INTRODUCTION

With the rapid advancement of wireless communication technologies [16], there is an increasing demand for compact, efficient, and multiband antennas capable of supporting various wireless standards such as WLAN [14], WiMAX, and emerging 5G networks [12]. Microstrip patch antennas (MPAs) have become popular [7] in such applications due to their low profile, lightweight, ease of integration, and cost-effective fabrication. However, conventional MPAs are limited by their narrow bandwidth [9] and single-frequency operation, which restricts their use in modern multiband systems.

To address these challenges, geometrically modified patch structures, such as the E-shaped design, have been explored for their ability to support multiple resonant frequencies within a single compact antenna [6]. The E-shaped patch introduces slots that enable the excitation of multiple modes, thus achieving multiband operation while maintaining desirable radiation characteristics and impedance matching [10].

This research paper presents the design, simulation, and analysis of a multiband E-shaped microstrip patch antenna using Keysight Advanced Design System (ADS) software [3]. Keysight ADS offers a comprehensive environment for high-frequency and RF circuit design, enabling accurate simulation of antenna performance. The proposed antenna is analyzed for key parameters such as return loss, VSWR, gain, and radiation pattern. The results confirm the effectiveness of the E-shaped structure in achieving efficient multiband performance for wireless applications.

II. ANTENNA DESIGN

A. Choice of Substrate

The selection of an appropriate substrate material is as critical [1] as the patch design itself in determining the overall performance of a microstrip patch antenna. The substrate directly influences the radiative properties, efficiency, and bandwidth of the antenna. Key parameters that guide substrate selection include dielectric constant (ε_r), thickness (h), and loss tangent [2].

To initiate effective radiation, a low dielectric constant is generally preferred, as it allows for larger fringing fields and better radiation efficiency. However, increasing substrate thickness can enhance impedance bandwidth. Despite this, thicker substrates may introduce surface wave losses and degrade radiation patterns. Conversely, thin substrates improve accuracy but may restrict bandwidth and reduce radiation efficiency, especially at higher frequencies. Therefore, substrates exhibiting high dielectric losses at elevated frequencies should be avoided in practical fabrication [13].

Typically, the substrate thickness is chosen within the range:

$$0.003\lambda_0 \leq h \leq 0.05\lambda_0$$

where λ_0 is the free-space wavelength at the operating frequency. The dielectric constant ε_r usually falls in the range:

$$2.2 \leq \varepsilon_r \leq 12$$

In the proposed antenna design, FR4 (Flame Retardant 4) is used as the substrate [13] due to its wide availability and adequate performance in microwave applications. FR4 has a dielectric constant $\varepsilon_r = 4.4$ and a substrate thickness of $h =$

1.6 mm. The ground plane dimensions are selected as 41.99 mm × 26.70 mm, which are equal to the dimensions of the FR4 substrate.

The Antenna is designed and simulated using Advance designing system software. Figure shows the layout of the proposed antenna structure.

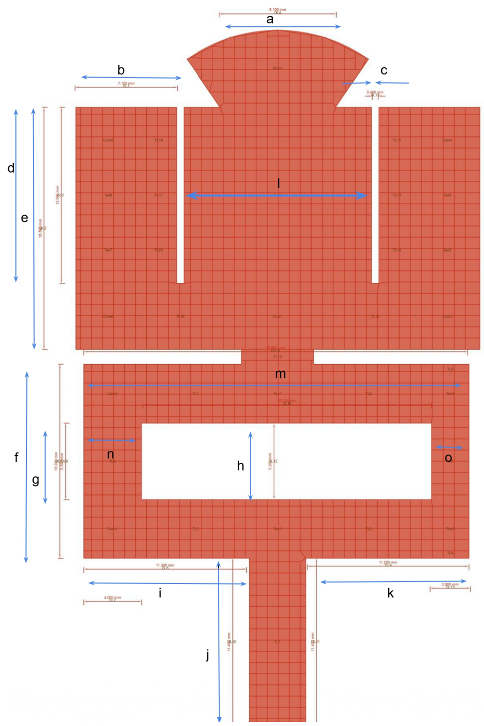


Fig. 1: Structure of proposed layout

Parameters	a	b	c	d	e
Values	8.000	7.000	0.400	12.000	16.500

f	g	h	i	j	k
13.200	5.200	5.200	11.500	11.400	11.300

l	m	n	o
13.000	26.800	4.00	2.600

TABLE I: Values of different parameters

B. Radiation Fields

The theoretical radiation characteristics of the antenna can be described using the electric field in the E-plane and magnetic field in the H-plane, given by the following equations [1]:

For E-plane ($\phi = 90°$):

$$E(\theta) = \frac{I_0}{2j\lambda} \cdot \sin(\theta) \cdot \left[\frac{\sin(kL\cos\theta/2)}{\cos(\theta/2)}\right]$$

For H-plane ($\theta = 90°$):

$$H(\phi) = \frac{I_0}{2j\lambda} \cdot \sin(\theta) \cdot \left[\frac{\sin(kL\sin\phi/2)}{\sin(\phi/2)}\right]$$

Where:

- $E(\theta)$: Electric field in the E-plane
- $H(\phi)$: Magnetic field in the H-plane
- θ: Polar angle in the E-plane
- ϕ: Azimuthal angle in the H-plane
- k: Free-space wave number
- λ: Wavelength
- L: Effective length of the patch
- I_0: Input current at the feed

These expressions help predict the shape and intensity of the radiation patterns, and are critical in analyzing the directional characteristics of the antenna.

III. Simulation Result

By simulating the proposed E-shaped antenna design [8], four distinct resonant frequencies were observed, as illustrated in Fig.2 These resonant frequencies occur at 4.18 GHz, 5.32 GHz, 5.57 GHz, and 6.66 GHz, demonstrating the multiband behavior of the antenna suitable for various wireless applications [11].

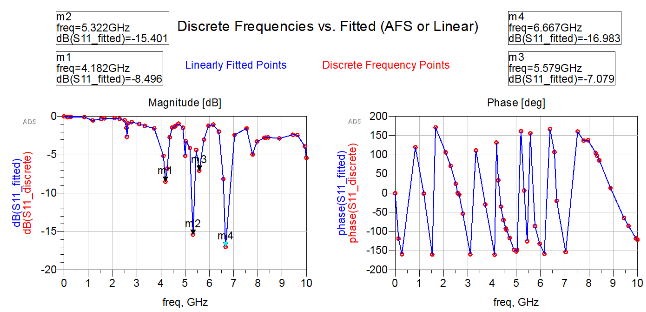


Fig. 2: Simulated return loss (S_{11}) vs frequency

The performance of the proposed E-shaped microstrip patch antenna was evaluated using Keysight Advanced Design System (ADS) simulation software [3]. The antenna was analyzed in terms of its return loss, directivity, gain, and radiation efficiency across the frequency range of interest.

A. Return Loss

Return loss (S_{11}) indicates how well the antenna is matched to the feed line [2]. A return loss of less than -10 dB is generally considered acceptable, as it implies that over 90% of the power is radiated and less than 10% is reflected back. The simulated antenna exhibits four resonant frequencies:

- 4.18 GHz with a return loss of -8.49 dB
- 5.32 GHz with a return loss of -15.40 dB
- 5.57 GHz with a return loss of -7.07 dB
- 6.66 GHz with a return loss of -16.98 dB

These values confirm that the antenna operates effectively across multiple frequency bands. Fig. 2 shows the return loss plot of the antenna, highlighting the resonant dips at the specified frequencies.

B. Directivity

The directivity of the antenna describes its ability to focus energy in a specific direction [1]. From the simulation, the antenna demonstrates satisfactory directivity performance across the resonant bands, as shown in Fig. 3. The gain, which accounts for both the directivity and efficiency, is also found to be satisfactory for practical wireless applications.

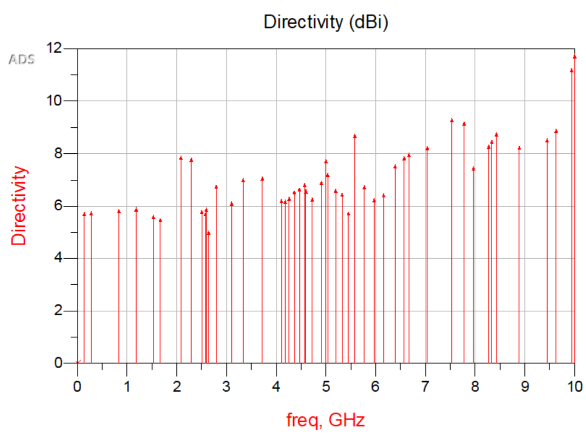


Fig. 3: Graph obtained for directivity

C. Radiation Efficiency

Radiation efficiency is defined as the ratio of radiated power to the accepted power by the antenna [1]. The proposed design achieves high radiation efficiency across the operating bands, as illustrated in Fig. 4. The efficiency values indicate minimal losses and effective radiation performance.

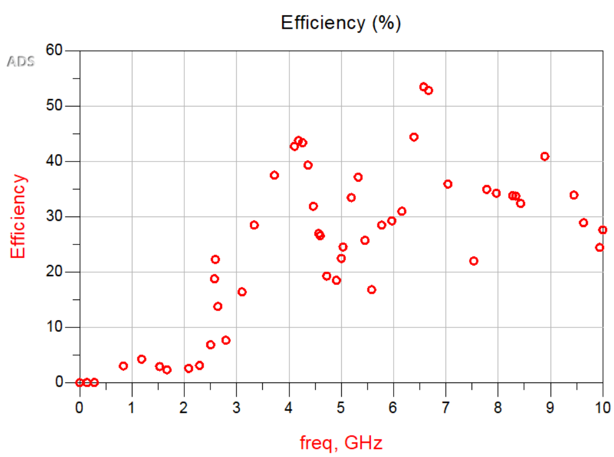


Fig. 4: Efficiency Pattern

D. Radiation Patterns

The radiation patterns were evaluated at each of the resonant frequencies [1]. The antenna exhibits nearly omnidirectional behavior in the E-plane and directional characteristics in the H-plane, which is suitable for most wireless communication scenarios. Fig. 8 illustrates the 2D radiation patterns at the resonant frequencies.

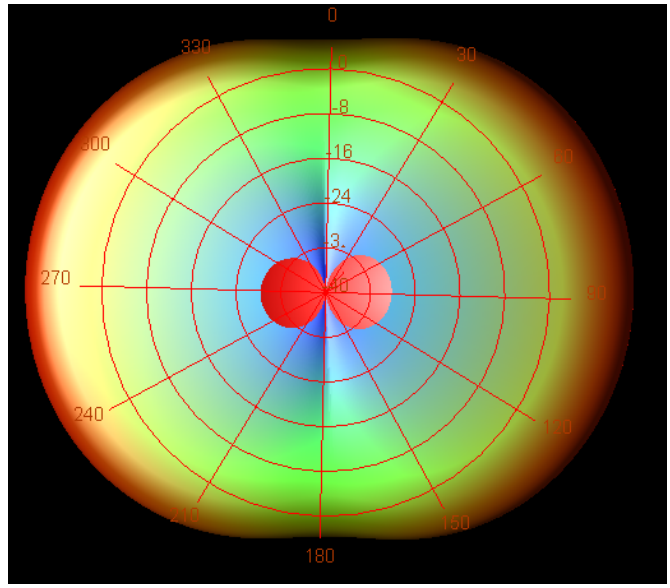


Fig. 5: Simulated 2D radiation pattern at 4.18 GHz

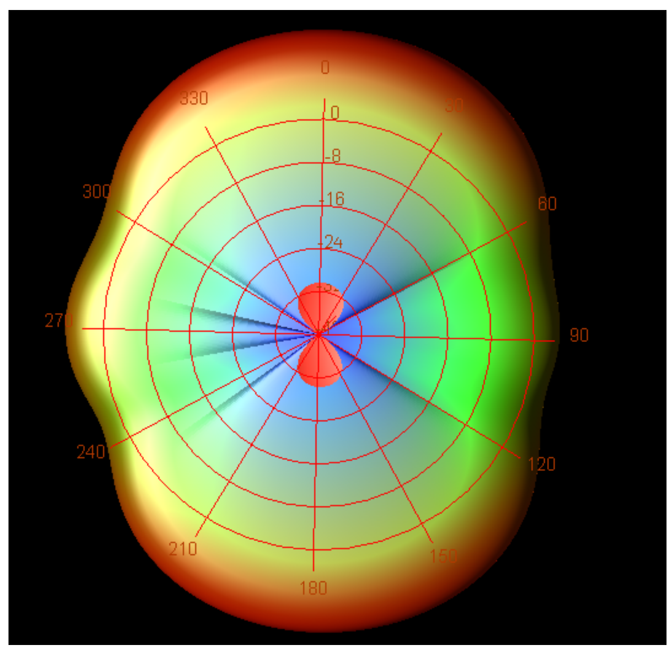


Fig. 6: Simulated 2D radiation pattern at 5.32 GHz

IV. Conclusion

In this work, a compact E-shaped microstrip patch antenna was designed and analyzed for multiband wireless applications using Keysight ADS simulation software [3]. The proposed antenna structure, fabricated on an FR4 substrate with a

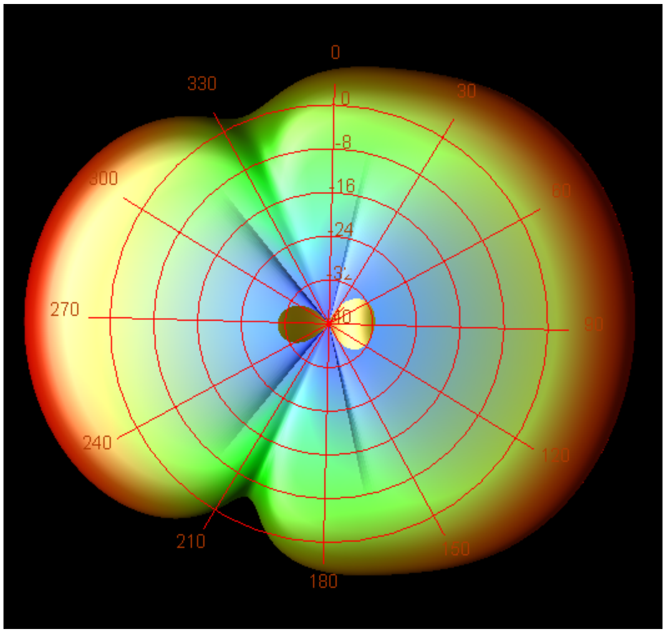


Fig. 7: Simulated 2D radiation pattern at 5.57 GHz

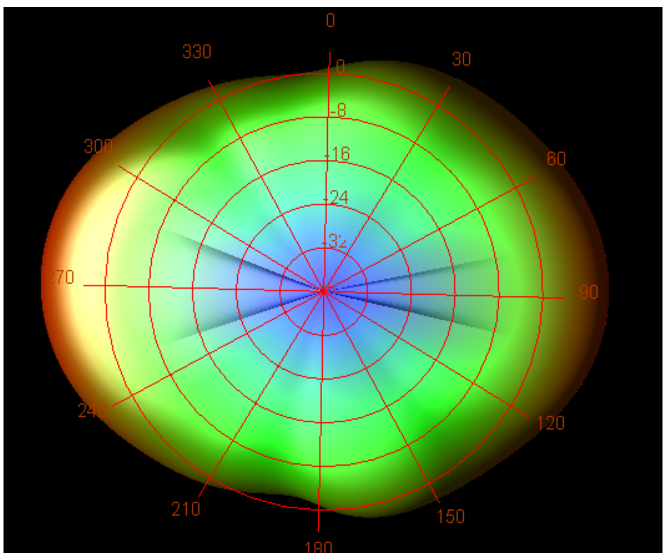
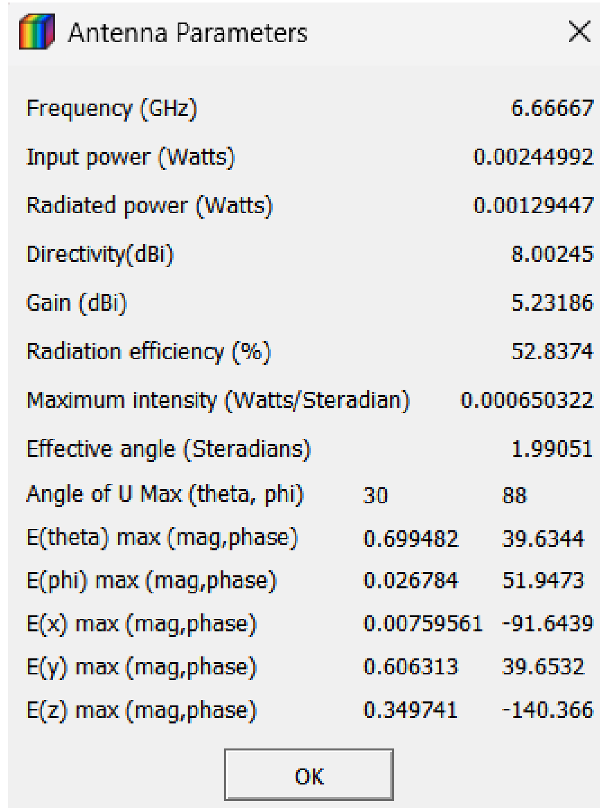


Fig. 8: Simulated 2D radiation pattern at 6.66 GHz

dielectric constant of 4.4 and thickness of 1.6 mm, successfully demonstrated four resonant frequencies at 4.18 GHz, 5.32 GHz, 5.57 GHz, and 6.66 GHz. These frequencies make the antenna suitable for a variety of sub-6 GHz applications such as WLAN [14], Wi-Fi [11], and other high-speed wireless communication systems.

The simulation results validated the antenna's multiband behavior, with particularly strong return loss performance observed at 5.32 GHz and 6.66 GHz (15.40 dB and 16.98 dB respectively). These values indicate efficient impedance matching at those frequencies. The return loss at 4.18 GHz and 5.57 GHz, although slightly above the 10 dB threshold, still supports operation with moderate performance and can be further optimized in future work.



Antenna Parameters

Frequency (GHz)		6.66667
Input power (Watts)		0.00244992
Radiated power (Watts)		0.00129447
Directivity(dBi)		8.00245
Gain (dBi)		5.23186
Radiation efficiency (%)		52.8374
Maximum intensity (Watts/Steradian)		0.000650322
Effective angle (Steradians)		1.99051
Angle of U Max (theta, phi)	30	88
E(theta) max (mag,phase)	0.699482	39.6344
E(phi) max (mag,phase)	0.026784	51.9473
E(x) max (mag,phase)	0.00759561	-91.6439
E(y) max (mag,phase)	0.606313	39.6532
E(z) max (mag,phase)	0.349741	-140.366

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Fig. 9: Antenna Parameters

Additionally, the antenna exhibited stable and directional radiation patterns, acceptable gain, and high radiation efficiency across its operating bands, confirming its effectiveness in radiating and receiving electromagnetic energy. The E-shaped geometry with properly optimized slots contributed to both bandwidth enhancement and frequency tunability without significantly increasing the overall size of the antenna [8].

The compact size, simple structure, and satisfactory performance metrics make this antenna a promising candidate for integration into compact and portable wireless devices. The use of a single-layer FR4 substrate and standard microstrip feeding mechanism ensures ease of fabrication and cost-effectiveness.

Future Work

To further enhance performance, future investigations may consider:

- Incorporating advanced techniques such as Defected Ground Structures (DGS) [15] or Electromagnetic Bandgap (EBG) structures to improve impedance bandwidth and gain.
- Exploring reconfigurable geometries or introducing active components for frequency agility.
- Fabricating and experimentally testing the antenna prototype to validate simulated results.

Overall, the proposed E-shaped microstrip patch antenna demonstrates great potential as a multiband radiator for modern wireless communication systems.

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