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Design and Performance Analysis of a Dual Band F-Shaped Microstrip Antenna Using Defected Ground Structure

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Abstract: This paper presents the design, optimization, and analysis of a dual-band F-shaped microstrip antenna incorporating a Defected Ground Structure (DGS) for improved bandwidth and gain. The proposed antenna operates efficiently at 2.375 GHz and 5.325 GHz, offering reflection coefficients of −30.6 dB and −41.85 dB, respectively. The integration of a partial ground and optimized stubs enhances impedance bandwidth and return loss characteristics. Simulation results show impedance bandwidths of 270 MHz and 1.12 GHz, with respective gains of 2.3 dBi and 3.5 dBi, indicating suitability for WLAN and Wi-Fi applications.

Keywords: Microstrip patch, DGS, WLAN and Wi-Fi.

1. Introduction

Wireless communication systems require compact, multi-band, and high-performance antennas to support modern standards such as WLAN, Wi-Fi, and Bluetooth. Microstrip patch antennas (MPAs) are widely preferred for these applications due to their low profile, lightweight design, and ease of fabrication. However, conventional MPAs suffer from narrow bandwidth and limited gain. To overcome these challenges, techniques such as Defected Ground Structure (DGS), slot modification, and stub tuning are employed to improve antenna performance. This paper focuses on the design and development of a dual-band F-shaped microstrip antenna with DGS, optimized for enhanced impedance bandwidth and gain performance.

2. Literature Survey

The evolution of dual-band microstrip antennas [1-2] has been extensively explored to meet modern wireless communication requirements. Pochaiya et al. [4] presented a dual-band bi-directional microstrip antenna employing a complementary split-ring resonator (CSRR) and defected patch structure (DPS) for bandwidth enhancement at 3 GHz and 5 GHz. Abdelaziz [5] achieved significant bandwidth improvement by coupling dual radiating elements through a matched section, realizing up to 12% enhancement via parasitic elements. The concept of Defected Ground Structure (DGS) has been comprehensively discussed by Weng et al. [6], who demonstrated its capability to modify effective inductance and capacitance, thereby improving impedance bandwidth and reducing harmonics. Further developments were reported by Acıkaya and Yıldırım [7], who proposed a dual-band 2.45/5 GHz WLAN antenna featuring harmonics suppression using asymmetrical edge cuts and matching networks on an FR4 substrate.Ramineni [8] introduced a dual-band microstrip antenna for Sub-6 GHz applications, optimized using HFSS, achieving improved reflection coefficient, gain, and radiation efficiency. A recent review by Sunil et al. [9] highlighted the historical development and effectiveness of DGS in enhancing antenna performance through techniques like harmonic suppression, cross-polarization reduction, and size miniaturization. Finally, Wang et al. [10] discussed data center communication demands and the need for compact, wideband antennas in dense network environments—further motivating antenna miniaturization and multi-band operation. Collectively, these studies underline that ground-plane defect engineering and geometry optimization (like F-shaped designs) offer a reliable means to achieve compact, high-gain, dual-band antennas suitable for WLAN and Wi-Fi applications.

3. Implementation of Proposed Method

The design evolution of the proposed antenna involves several stages of modification and optimization. Initially, a standard rectangular microstrip patch was designed to operate at the target frequencies. Subsequent stages introduced an F-shaped patch geometry and a Defected

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Ground Structure (DGS) to enhance impedance bandwidth and return loss. Parametric studies were performed on both the upper and lower stubs of the F-shape to achieve optimal resonance characteristics.

The proposed dual-band F-shaped microstrip antenna was developed through a systematic series of modifications aimed at improving impedance bandwidth and gain. The design process was divided into five distinct phases, as described below.

***Phase 1**: Conventional Patch Antenna*

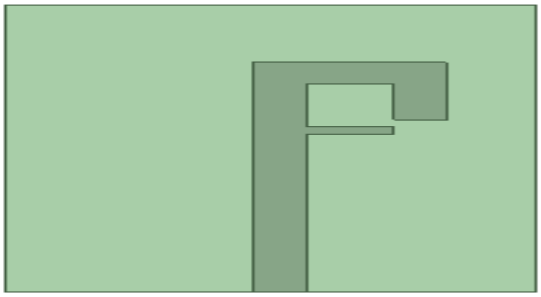


Fig.1 F Shape patch antenna

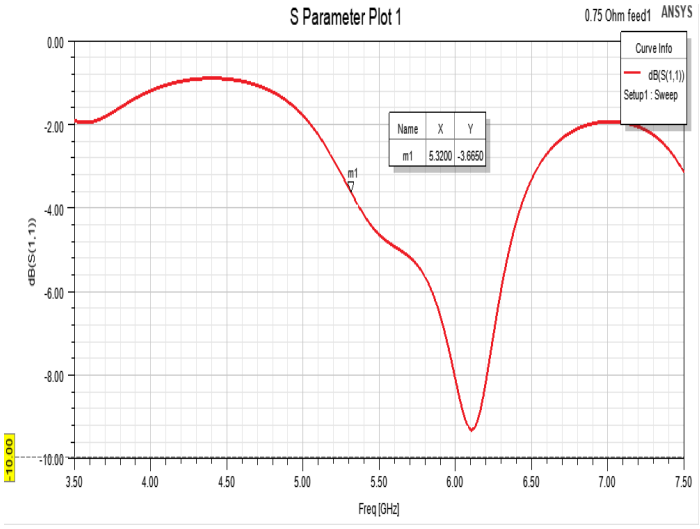


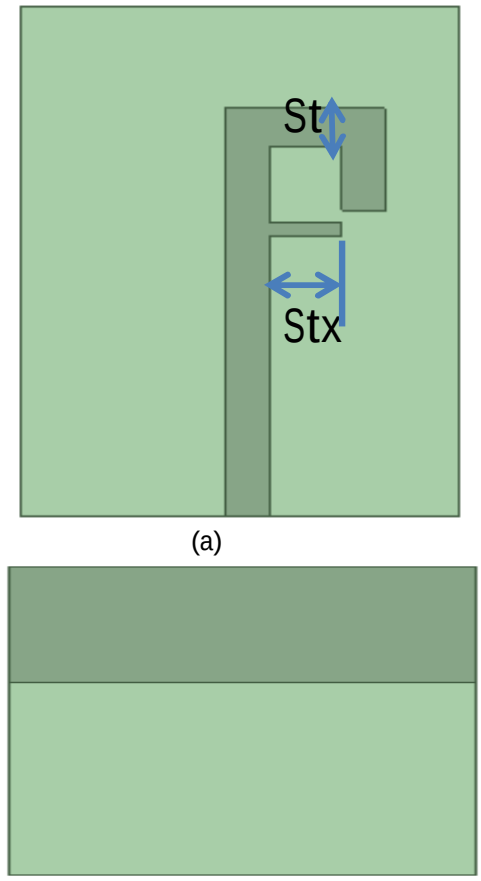
Fig.2 S11 Parameter of F shape antenna

The initial configuration consisted of a standard rectangular microstrip patch designed to resonate at 2.375 GHz and 5.325 GHz as shown in Fig.1.

At this stage, the antenna exhibited a poor return loss of 0 dB as shown in Fig.2, indicating inefficient impedance matching and negligible radiation efficiency.

The bandwidth was nearly zero, confirming the need for structural modification to achieve acceptable dual-band characteristics.

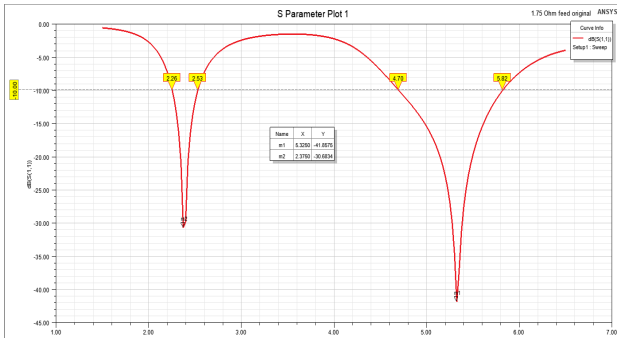
***Phase 2:** Partial Ground Plane Implementation*



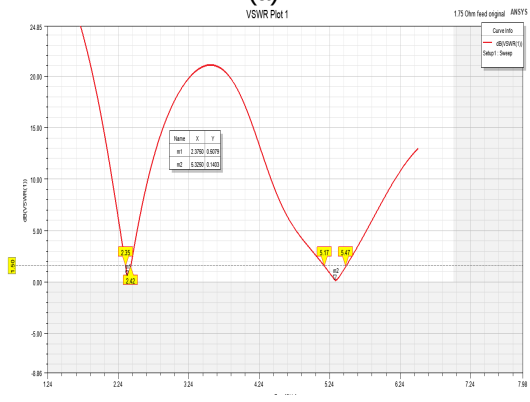
(a)

(b)

Fig.3 Front and back views of the proposed dual-band F-shaped microstrip antenna.



(a)



(b)

Fig.4 S11 Parameter of proposed dual-band F-shaped microstrip antenna

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In the second phase, the ground plane was partially removed to form a slot beneath the radiating patch as shown in Fig. 3(b). This modification altered the surface current distribution and introduced capacitive coupling between the patch and the ground plane. As a result, significant improvement in impedance matching was observed, with return loss values of −30.6 dB and −41.85 dB at 2.375 GHz and 5.325 GHz, respectively as shown in Fig.4(a). The impedance bandwidths extended to 270 MHz and 1.12 GHz, and the antenna gain improved to 2.3 dBi and 3.5 dBi, respectively.

Phase 3: *Defected Ground Structure (DGS) Optimization*

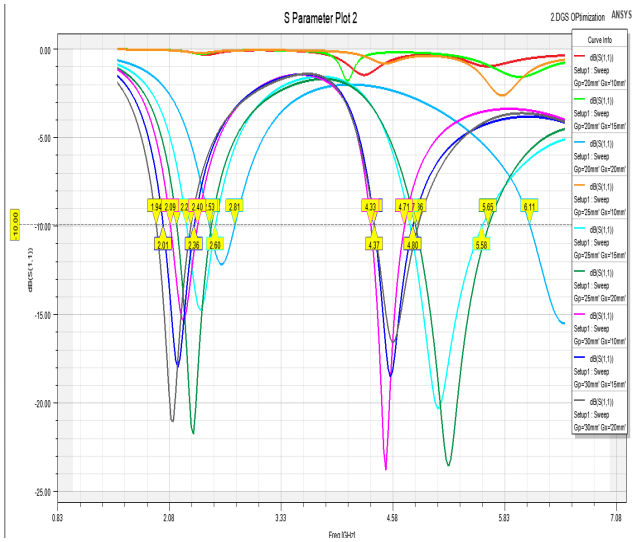


Fig.5 S11 parameter of Optimization of DGS

To further enhance bandwidth and suppress unwanted surface currents, a Defected Ground Structure (DGS) was introduced on the ground plane. The DGS acted as a resonant slot that disrupted current flow, effectively lowering the Q-factor and widening the impedance bandwidth. This modification also contributed to better return loss and stable VSWR across the dual-band region.

Phase 4: *Parametric Study on Upper Stub of F-Shape*

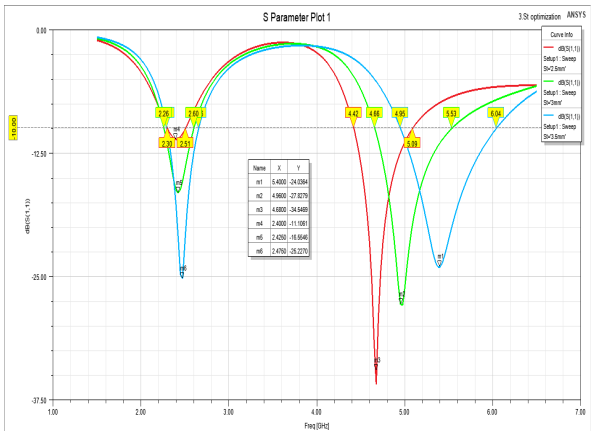


Fig.6 reflection coefficient (S_{11}) for Upper stub of F Shape

In this phase, a detailed parametric analysis was conducted on the upper stub of the F-shaped radiating element. By adjusting the length and width of the upper stub, fine-tuning of the lower-band resonance was achieved. The modification optimized the coupling between the radiating arms, improving impedance matching at 2.375 GHz as shown in Fig.6.

Phase 5: *Parametric Study on Lower Stub of F-Shape*

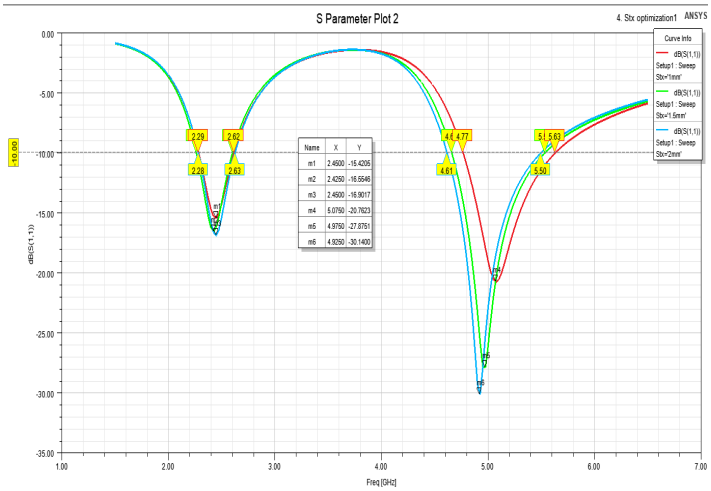
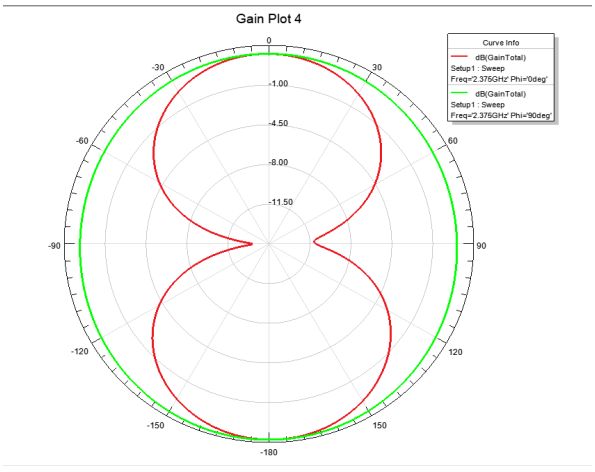


Fig.7 Reflection coefficient (S_{11}) for Lower stub of F Shape

Finally, the lower stub was optimized to influence the higher-frequency resonance at 5.325 GHz as shown in Fig.7. This modification allowed better current distribution and improved the overall gain. The optimized design demonstrated excellent dual-band performance with compact geometry, making it ideal for WLAN and Wi-Fi applications.

4. Results and Discussion

The simulated performance of the proposed antenna was analyzed in terms of reflection coefficient (S_{11}), Voltage Standing Wave Ratio (VSWR), impedance bandwidth, and gain.



(a)

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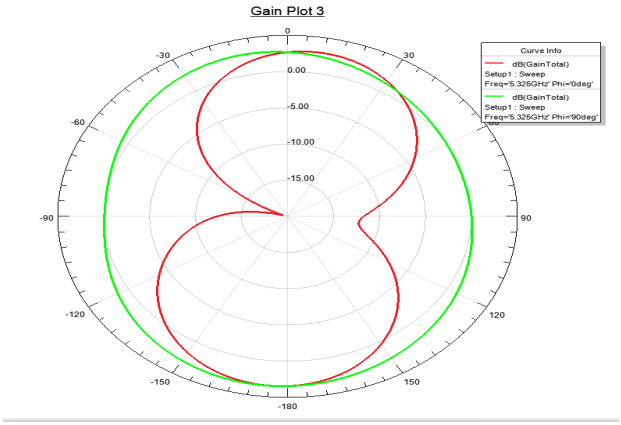

(b)

Fig.8 E-Plane (red) and H-Plane (Green) plots at (a) 2.37 GHz and (b) 5.32 GHz

The VSWR remains below 2 across both operating bands, confirming good impedance matching as shown in Fig.4(b). The gain plot (Fig.8) indicates improved radiation efficiency, achieving 2.3 dBi at the lower band and 3.5 dBi at the higher band. The incorporation of DGS effectively enhances bandwidth by suppressing surface currents and improving impedance matching. Table 1 summarizes the key performance parameters obtained from simulation.

Table 1. Summary of the antenna performance parameters.

Parameter	2.375 GHz	5.325 GHz	Remarks
Return Loss (dB)	−30.6	−41.85	Excellent impedance matching
Impedance Bandwidth (MHz)	270	1120	Enhanced by DGS
VSWR	< 2	< 2	Stable performance
Gain (dBi)	2.3	3.5	Improved with stub optimization

5. Conclusion

A compact dual-band F-shaped microstrip antenna with Defected Ground Structure (DGS) has been successfully designed and analyzed. The antenna achieves resonances at 2.375 GHz and 5.325 GHz with improved impedance bandwidths of 270 MHz and 1.12 GHz, respectively. The incorporation of DGS and optimized stubs enhances return loss and gain characteristics, making the design suitable for WLAN and Wi-Fi applications. Future work may involve experimental validation and fabrication to verify simulated results and explore further miniaturization techniques.

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