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REGULAR ARTICLE

Compact Flower-Shaped Dual-Band Patch Antenna with Rectangular DGS for WLAN/WiMAX Applications

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This paper presents a compact dual-band microstrip patch antenna with a flower-shaped radiator and rectangular defected ground structure (DGS) for enhanced gain and bandwidth in wireless applications. Resonating at 2.46 GHz and 3.04 GHz, it targets WLAN (2.4-2.48 GHz), WiMAX (2.95-3.10 GHz), Sub-6 GHz, and IoT systems. The DGS beneath the feedline suppresses surface waves, improves current distribution, and boosts measured gains to 4 dBi and 5 dBi, respectively. Fabricated on FR-4 (ε_r = 4.4, h = 1.6 mm), it achieves return losses of – 45.16 dB and – 15.08 dB with stable radiation patterns. Compared to prior DGS and slotted designs, this single-layer structure offers superior gain, miniaturization, and fabrication simplicity for portable devices.

Keywords: Microstrip patch antenna, Dual-band, Defected ground structure (DGS), WLAN, WiMAX, Gain enhancement.

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1. INTRODUCTION

The rapid evolution of wireless communication systems has intensified the need for compact, low-cost, and multi-band antennas that support WLAN, WiMAX, IoT, and emerging sub-6 GHz applications. Microstrip patch antennas remain popular due to their planar profile, ease of fabrication, and compatibility with integrated circuits. However, conventional patch antennas commonly suffer from limited bandwidth and reduced gain due to surface-wave losses, dielectric loading, and constrained current distribution [1, 2]. These limitations motivate the exploration of improved design techniques such as Defected Ground Structures (DGS), fractal geometries, slotted patches, and hybrid miniaturization strategies.

Recent research has demonstrated that DGS is an effective solution for enhancing gain, radiation efficiency, and impedance matching. Soni et al. proposed a flexible DGS-integrated antenna for wearable applications, achieving improved surface-wave suppression and compactness [1]. Attioui introduced a circular flower-shaped fractal antenna that achieved natural multi-band behavior through recursive geometry manipulation [2]. Nahas reported a high-gain dual-band slotted antenna optimized for wireless modules, emphasizing enhanced radiation through slot-based perturbation [3]. Similarly, El-Hakim designed a 5G-supported multiband microstrip antenna using structural synthesis techniques to improve coverage in future networks [4]. A WLAN-focused dual-band antenna was investigated by M. B. H. et al., showing reasonably low return loss and stable radiation suitable for 2.4 GHz devices [5]. Studies in [6-12] further confirm that DGS is widely adopted for performance improvement, including bandwidth enhancement, shifting resonant frequency, and facilitating compact multi-band operation. Recent works also explore hybrid methods such as slotted patches [9], wearable-optimized antennas [14], and low-SAR designs for WBAN [15].

Although these works achieved notable improvements, most existing designs either require complex fractal geometries, involve larger antenna footprints, or produce moderate gain (< 4 dBi) in compact configurations. Very few works achieve dual-band operation simultaneously with gain enhancement using a single-layer FR-4 structure with simple fabrication steps. Additionally, flower-shaped patch antennas with DGS enhancement remain sparsely explored in the literature. To address these gaps, this paper proposes a compact DGS-loaded flower-shaped dual-band microstrip patch antenna resonating at 2.46 GHz and 3.04 GHz, achieving measured gains of 4 dBi and 5 dBi, respectively. The inclusion of a rectangular DGS beneath the feed significantly improves radiation efficiency, return loss, and gain without increasing antenna size. Experimental validation using a VNA shows return losses of – 45.16 dB and – 15.08 dB at the respective bands, making the design suitable for WLAN (2.4 GHz), WiMAX (3 GHz), IoT devices, and portable wireless nodes.

2. METHODOLOGY AND ANTENNA DESIGN

2.1 Geometric Configuration

The proposed antenna is fabricated on an FR-4 epoxy substrate with a thickness of 1.6 mm and a dielectric constant (ε_r) of 4.4. The design features a flower-shaped

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radiating patch fed by a microstrip line, with a rectangular DGS etched into the ground plane directly beneath the feedline. The specific geometric parameters were optimized to achieve the target resonant frequencies. To achieve optimal dual-band performance, the design methodology involved a systematic evolution of the patch geometry and ground structure.

Fig. 1 – Proposed antenna: (a) front (flower patch) (b) back (rectangular DGS)

The optimized design values antenna geometriesaregiven in Table 1.

Table 1 – Antenna dimensions

Parameters	Dimensions (mm)
L_s	20
W_s	18
W_g	18
L_g	8
W_f	3.25
L_f	9.75
R_s	1.54
r_0	7
R_i	5
r_1	2.6
r_2	1
W	2

Step 1: Patch Shape Optimization The impact of the radiating element's shape was analyzed by comparing three configurations: a circular patch, a flower-shaped patch, and a symmetrical flower-shaped patch.

Circular Patch: Simulations revealed a weak lower-band resonance at 3.18 GHz ($S_{11} \approx -4.6$ dB), failing to meet the − 10 dB impedance bandwidth requirement. This behavior is mainly due to the limited effective current path length and uniform surface current distribution of the circular geometry.

Flower-Shaped Patch: Modifying the patch into a flower shape introduced a dominant resonance at 3.02 GHz with good impedance matching ($S_{11} \approx -18.2$ dB). This frequency shift is attributed to the increased effective current path length and enhanced capacitive coupling introduced by the petal structure, which enables stronger electromagnetic coupling.

Symmetrical Flower Patch: The symmetrical design provided the best trade-off by ensuring balanced current distribution along multiple axes. This symmetry improves impedance matching and supports stable multi-band operation without increasing antenna size.

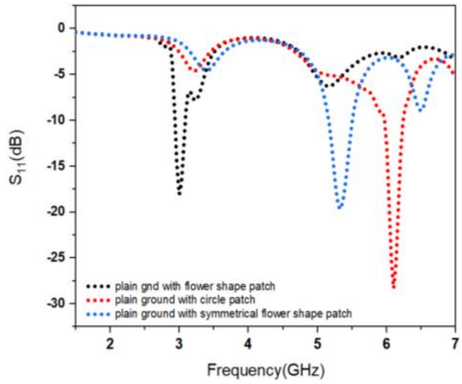


Fig. 2 – S_{11} response of variation of patch shape

Step 2: Defected Ground Structure (DGS) Integration To further enhance performance, a rectangular defected ground structure (DGS) was introduced beneath the feedline. The DGS functions as a band-stop filter element that perturbs the ground-plane current distribution and suppresses surface-wave propagation. This suppression improves the quality factor (Q) of the antenna and enhances impedance matching compared to a solid ground plane. By reducing surface-wave losses and improving radiation efficiency, the DGS contributes significantly to gain enhancement, resulting in a measured gain of 2.8-3.5 dB without increasing antenna size.

3. RESULTS AND DISCUSSION

The fabricated antenna was evaluated using a calibrated vector network analyzer. The measured S_{11} response confirms dual-band operation with resonances at 2.46 GHz and 3.04 GHz.

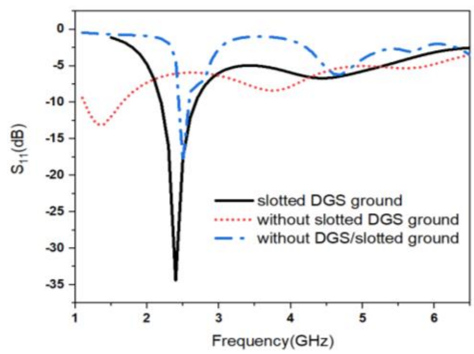


Fig. 3 – S_{11} response of variation of ground structure

Figure 2 illustrates the simulated reflection coefficient (S_{11}) of three antenna configurations: (i) plain ground with flower-shaped patch, (ii) plain ground with circular patch, and (iii) plain ground with symmetrical flower-shaped patch.

The flower-shaped patch with plain ground exhibits a dominant resonance at 3.02 GHz with a minimum S_{11} of approximately − 18.2 dB, indicating strong impedance matching at the lower band. A secondary resonance near 5.15 GHz with $S_{11} \approx -6.1$ dB corresponds to a higher-order mode.

The circular patch antenna shows a weaker lower-band resonance around 3.18 GHz ($S_{11} \approx -4.6$ dB), which does not satisfy the − 10 dB criterion. However, a strong higher-frequency resonance at 6.02 GHz ($S_{11} \approx -28.5$ dB) confirms efficient excitation of the dominant TM_{11} mode.

The symmetrical flower-shaped geometry achieves improved impedance matching and bandwidth enhancement due to increased effective current path length and capacitive coupling introduced by the petal structure, making it suitable for compact dual-band applications.

3.1 Radiation Characteristics

The normalized *E*- and *H*-plane radiation patterns of the proposed antenna are illustrated in Fig. 4. In the *E*-plane, the antenna exhibits bi-directional broadside radiation with nulls near ±90°, while the *H*-plane shows quasi-omnidirectional behavior. The symmetry of the patterns confirms stable radiation characteristics.

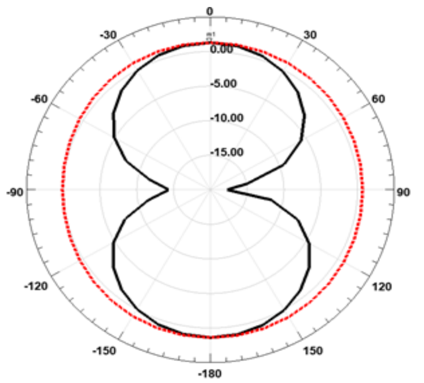
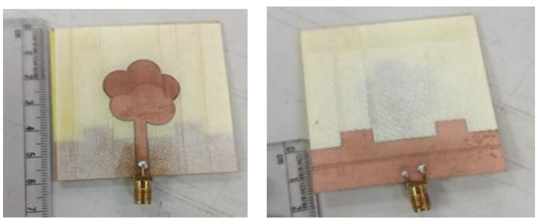


Fig. 4 – *E* and *H* fieldradiation pattern

3.2 Measured Results

The fabricated antenna was experimentally evaluated, and the measured S_{11} response clearly demonstrates dual-band operation.



(a) Front side of antenna (b) Back side of antenna

Fig. 5 – Fabricated proposed antenna design

Two resonances occur at 2.46 GHz and 3.04 GHz with return losses of − 45.16 dB and − 15.08 dB, respectively. The deep lower-band resonance indicates excellent impedance matching, while the upper band satisfies operational requirements. The bandwidths fully cover WLAN and WiMAX bands, confirming suitability for multi-standard wireless systems.

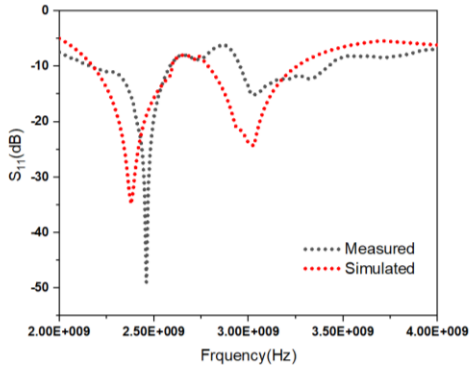


Fig. 6 – Simulated vs measured S_{11} response of proposed antenna design

Table 2 – Comparison with existing works

Ref	Antenna Type / Technique	Operating Bands	Gain (dBi)	Size	Application	Limitation
[1] Soni (2024)	Flexible DGS	Sub-6 GHz	3.2	Large flexible surface	Wearable	Moderate gain
[2] Attioui (2024)	Flower-shaped fractal	Multi-band	2.8	Medium	IoT/WiFi	Complex geometry
[3] Nahas (2024)	Slotted patch	Dual-band	3.5	Larger	Wireless devices	Lower return loss than proposed
[5] M.B.H. (2023)	Dual-band patch	2.4/5 GHz	3.0	Medium	WLAN	No gain enhancement method
[9] IndJST (2024)	Slot-loaded	Dual-band	3.2	Compact	5G/WiMAX	Difficult slot optimization
Proposed Work	Flower-shaped + DGS	2.46 / 3.04 GHz	2.8/ 3.5	Compact	WLAN/WiMAX/IoT	(Improved gain & S11)

The comparison of proposed antenna with recent works shows that most reported dual- and multiband microstrip antennas achieve gains in the range of 2.8-3.5 dBi and often require complex fractal or slot-loaded geometries or larger antenna footprints. Flexible DGS-based designs improve bandwidth but suffer from moderate gain, while conventional dual-band patch antennas lack effective gain-enhancement mechanisms. In contrast, the proposed flower-shaped patch with defected ground structure achieves a measured gain of 4-5 dBi at 2.46 GHz and 3.04 GHz, representing an improvement of approximately 1-2 dB over comparable designs, while maintaining a compact planar structure. The antenna also exhibits superior impedance matching at both operating bands, confirming the effectiveness of combining geometry-induced multi-resonance with DGS-based surface-wave suppression for WLAN, WiMAX, and IoT applications.

4. CONCLUSION

A compact DGS-loaded dual-band microstrip patch antenna supporting WLAN and WiMAX applications has been successfully designed and validated. The flower-shaped patch and DGS combination effectively enhances gain and return-loss characteristics while maintaining simple fabrication and low-cost implementation.

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Компактна дводіапазонна патч-антена у формі квітки з прямокутним DGS для застосувань WLAN/WiMAX

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У цій статті представлено компактну дводіапазонну мікросмужкову патч-антену з квіткоподібним випромінювачем та прямокутною дефектною заземлювальною структурою (DGS) для покращеного коефіцієнта посилення та пропускної здатності в бездротових системах. Вона резонує на частотах 2,46 ГГц та 3,04 ГГц і призначена для систем WLAN (2,4-2,48 ГГц), WiMAX (2,95-3,10 ГГц), Sub-6 ГГц та Інтернету речей. DGS під живильною лінією пригнічує поверхневі хвилі, покращує розподіл струму та підвищує виміряні коефіцієнти посилення до 4 дБі та 5 дБі відповідно. Виготовлена на FR-4 (ε_r = 4,4, h = 1,6 мм), вона досягає втрат на відбиття – 45,16 дБ та – 15,08 дБ зі стабільними діаграмами спрямованості. Порівняно з попередніми DGS та щілинними конструкціями, ця одношарова структура пропонує чудове посилення, мініатюризацію та простоту виготовлення для портативних пристроїв.

Ключові слова: Мікросмужкова патч-антена, Дводіапазонна, З дефектною заземлювальною структурою (DGS), WLAN, WiMAX, З підсиленням коефіцієнта посилення.