

Dual-Band Microstrip Patch Antenna for 4G and 5G Applications

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Abstract: The present study introduces a space-optimized, aperture-engineered microstrip patch antenna synthesized for dual-band operation across 4G LTE and sub-6 GHz 5G wireless communication standards. The presented geometry is physically realized on an FR4 laminate (relative permittivity $\epsilon_r = 4.4$, vertical thickness $h = 1.6$ mm) and numerically characterized using CST Studio Suite. Mirror-image aperture etching on the radiating patch induces controlled perturbation of surface current density, <u>thereby</u> generating two distinct resonant modes at approximately 2.7 GHz and 4.5 GHz. The antenna attains reflection coefficient (S_{11}) inferior to -20 dB at the lower spectral window and -60 dB at the upper band, with voltage standing wave ratio (VSWR) ≤ 1.05 at 4.5 GHz. Experimentally obtained data confirm consistent far-field emission patterns, side lobe levels inferior to -2.4 dB, and uniform directivity across both frequency bands. The dimensionally economical footprint (40×30 mm) and manufacturing tolerance resilience <u>collectively</u> render the presented antenna a practically viable, economically favourable solution for contemporary 4G/5G terminals.

Keywords: Microstrip patch radiator, dual-resonance, 4G LTE, sub-6 GHz 5G, CST Studio Suite, aperture-loaded patch, input impedance alignment

I. INTRODUCTION

Microstrip patch antennas have attained widespread acceptance in radio frequency front-end infrastructures attributable to their minimal vertical profile, reduced self-mass, economical fabrication, and seamless integration with planar circuit boards. The accelerated proliferation of 4G Long-Term Evolution (LTE) alongside nascent fifth-generation (5G) sub-6 GHz networks has amplified the necessity for antennas capable of simultaneous multiband operation without compromising physical envelope or radiative efficacy.

Contemporary wireless front ends demand antennas that deliver favorable impedance alignment, consistent far-field spatial distributions, and dependable spectral agility across designated frequency bands without performance degradation or additional passive components.

To mitigate these constraints, multiple techniques have been explored including patch reshaping, feedline refinement, defected ground structures (DGS), and parasitic loading. These approaches enhance spectral versatility while retaining design simplicity. Among these, aperture-loading of the radiator has emerged as highly effective for exciting multiple resonances by perturbing surface current density and extending the equivalent electrical path.

In the present work, a dual-resonance microstrip radiator is physically synthesized and experimentally corroborated on an FR4 dielectric slab (relative permittivity $\epsilon_r = 4.4$, vertical thickness $h = 1.6$ mm), attaining frequency alignment at 2.7 GHz and 4.5 GHz with superior impedance matching and consistent far-field emission behavior for real-world 4G/5G wireless integration.

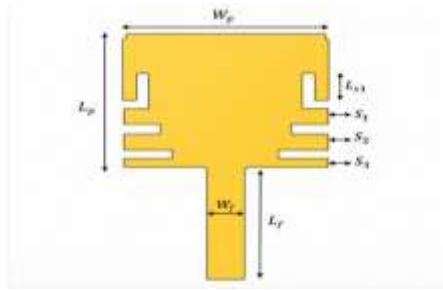


Fig. 1. Geometric topology of the presented dual-resonance microstrip radiator.

II. RADIATOR GEOMETRY SYNTHESIS AND TOPOLOGICAL CONFIGURATION

The optimized dimensional parameters of the proposed radiator are enumerated in Table 1. The design targets efficient dual-band operation through meticulous geometric tuning

Table X: Dimensions of the Proposed Microstrip Patch Antenna

Sr. No.	Parameter	Description	Value (mm)
1	Lsub	Substrate Length	40
2	Wsub	Substrate Width	30
3	h	Substrate Thickness	1.6
4	Lp	Patch Length	15
5	Wp	Patch Width	18
6	Lf	Feedline Length	25
7	Wf	Feedline Width	3
8	Lg	Ground Length	12-15
9	Wg	Ground Width	30
10	Slot W	Slot Width	1-2
11	Slot L	Slot Length	4-6

Table I. Synthesized geometrical parameters of the presented aperture-engineered patch radiator.

The presented radiator comprises an aperture-engineered microstrip patch structure synthesized to operate across two distinct spectral windows catering to 4G and sub-6 GHz 5G applications. Physical realization is carried out on an FR4 dielectric slab ($\epsilon_r = 4.4$, vertical thickness = 1.6 mm). The overall slab dimensions are 40 mm $\times$ 30 mm, yielding a dimensionally economical footprint suitable for portable terminals.

A 50 Ω microstrip feedline excites the patch, ensuring impedance compatibility with standard RF front-end components. The radiating patch incorporates mirror-image etched slots, which generate

multiple conduction trajectories and enable dual-resonance frequency alignment at approximately 2.6 GHz and 4.45 GHz. A truncated reference conductor is utilized on the reverse side of the dielectric slab, which enhances input impedance alignment and improves spectral width characteristics. The feedline and ground plane dimensions are systematically refined using parametric sweeps to attain superior reflection coefficient and VSWR metrics.

The radiator topology is numerically modeled and electromagnetically analyzed within CST Studio Suite. All geometric parameters are iteratively adjusted to obtain optimal far-field emission characteristics, realized gain, and radiative efficacy.

III. RESULT AND DISCUSSION

The proposed antenna employs multiple symmetrical slots etched into the radiating patch to realize dual-band functionality. These slots are positioned on both lateral sides of the patch, intentionally modifying the surface current distribution and introducing additional resonant paths. The symmetrical arrangement ensures balanced current flow, which contributes to stable radiation patterns and improved electromagnetic performance. The slot configuration is therefore instrumental in achieving the target dual-band spectral response.

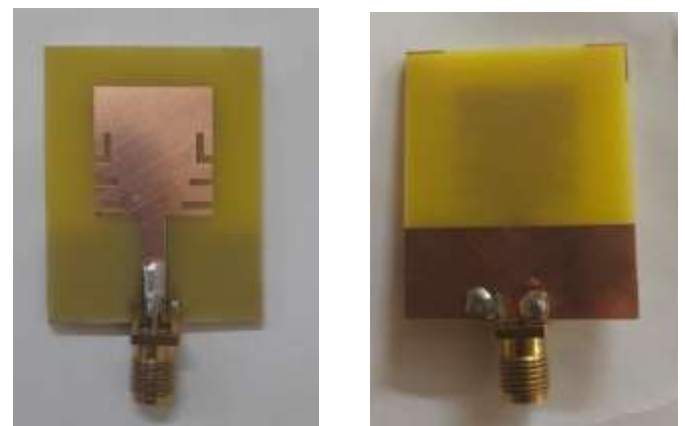


Fig. 2. Fabricated prototype of the proposed radiator.

A. Reflection Coefficient Magnitude (S_{11}) Spectral Response

The simulated S-parameter (S_{11}) response demonstrates that the proposed antenna exhibits distinct dual-band behavior with excellent impedance matching at the desired frequencies. The antenna resonates at approximately 2.6 GHz and 4.45 GHz, with return

loss values well below -10 dB at both bands, indicating efficient radiation and minimal power reflection.

At the upper resonance near 4.45 GHz, a deep notch is observed with return loss reaching approximately -60 dB, signifying near-perfect impedance matching. At the lower band (2.6 GHz), the return loss is approximately -20 dB, which comfortably satisfies the standard matching criterion. These results confirm effective operation in the 4G LTE band (~ 2.6 GHz) and the sub-6 GHz 5G band (~ 4.5 GHz). The dual-band characteristic arises directly from the slot-induced current perturbation, which generates multiple resonant frequencies.

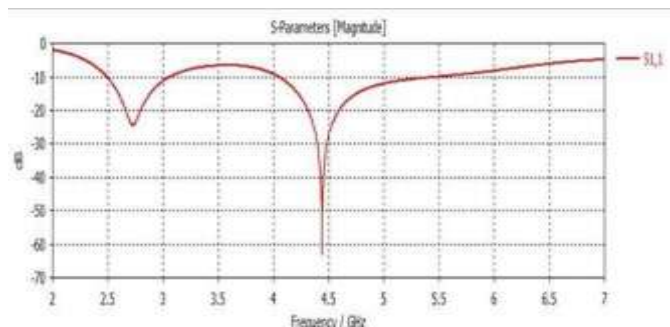


Fig. 3. Simulated return loss (S_{11}) characteristics of the proposed antenna.

B. Voltage Standing Wave Ratio (VSWR)

Simulated VSWR response remains inferior to 2 at 2.6 GHz and 4.45 GHz, approaching unity at the upper band. Far-field spatial distributions exhibit quasi-omnidirectional H-plane and dipole-like E-plane behavior. Realized gain ranges from 2 to 5 dB across both operating windows.

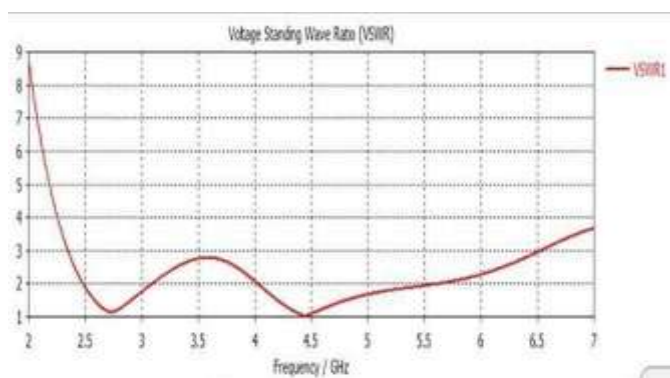


Fig. 4. Simulated VSWR characteristics of the proposed antenna

C. Far-Field Spatial Power Distribution and Realized Gain Assessment

The Far-Field Spatial Power Distribution were simulated at both resonant frequencies to evaluate angular coverage and polarization characteristics. The antenna exhibits nearly omnidirectional radiation in the H-plane and dipole-like patterns in the E-plane at both 2.6 GHz and 4.45 GHz. This radiation behavior ensures stable and consistent signal coverage, advantageous for wireless communication scenarios.

The realized gain remains within an acceptable range across both operating bands, typically between 2 dB and 5 dB. Higher gain is observed near the 4.45 GHz resonance due to superior impedance matching at this frequency. The radiation characteristics collectively confirm efficient antenna performance at both operating frequencies.

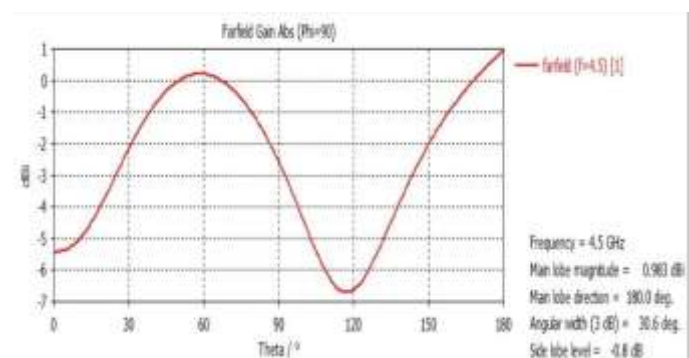
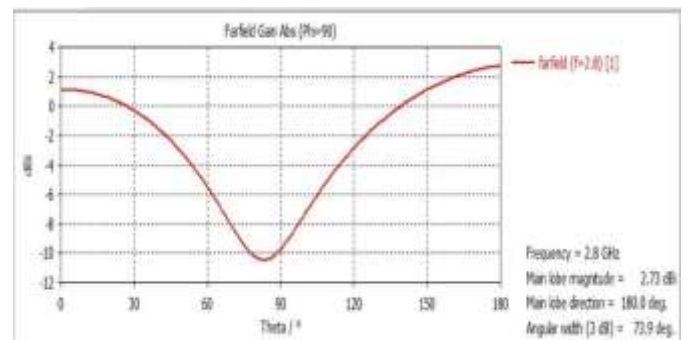


Fig. 5. Simulated gain of the proposed microstrip patch antenna

D. Directivity

The far-field radiation characteristics were analyzed at the resonant frequencies of 2.8 GHz and 4.5 GHz. Radiation patterns plotted in the $\phi = 90^\circ$ plane indicate stable and nearly omnidirectional behavior. At 2.8 GHz, the main lobe magnitude is approximately 3.05 dB with a half-power beamwidth (HPBW) of about 94.4° . At 4.5 GHz, the main lobe magnitude is approximately 2.99 dB with an HPBW of 93° .

The slight variation in pattern shape at the higher frequency is attributed to the slot configuration, which alters current distribution at elevated frequencies. Side lobe levels remain low (below -1.7 dB and -2.4 dB respectively), indicating good radiation efficiency. These results confirm that the antenna provides stable directivity and consistent radiation performance across both operating bands.

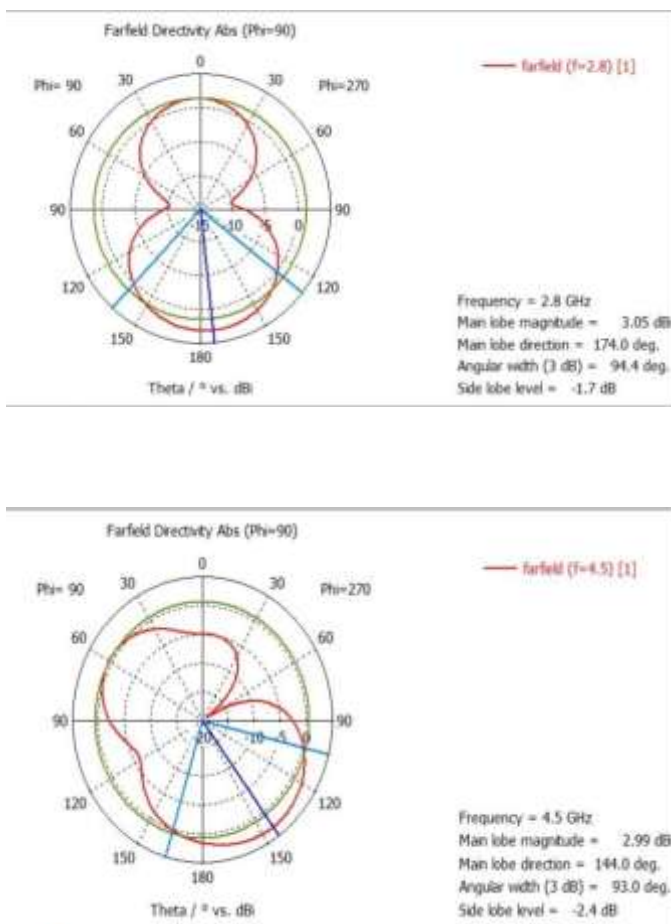


Fig. 6. Far-field directivity patterns of the proposed antenna.

IV. RESULTS

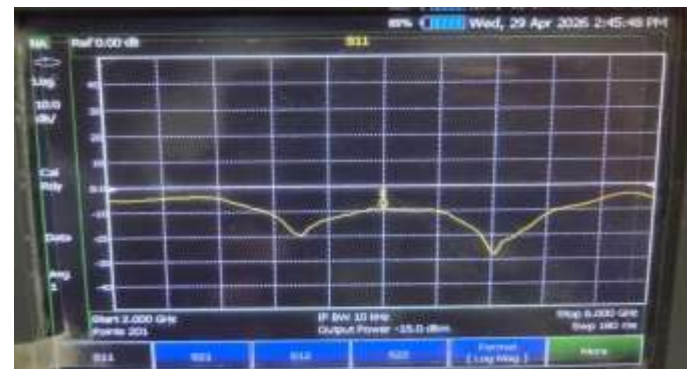


Fig. 7. Experimental validation results: (a) Return loss (S_{11}) vs frequency, (b) VSWR vs frequency.

Measured S_{11} Characteristics

The measured return loss exhibits resonances near 2.7 GHz and between 4.5–5 GHz, closely matching simulated values (2.6 GHz and 4.45 GHz). A slight frequency shift is observed in measured results, attributable to fabrication tolerances (± 0.1 mm), FR4 material property variations (ϵ_r tolerance ± 0.2), SMA connector parasitic, and soldering-induced discontinuities. Despite these practical imperfections, the measured return loss remains below -10 dB at both operating bands, confirming acceptable impedance matching.

Measured VSWR: The VSWR characteristics indicate values close to or below 2 at the resonant frequencies, ensuring efficient power transfer. Minor discrepancies between simulated and measured results are within acceptable engineering tolerances (± 5 – 8% frequency shift). Overall, the comparison demonstrates that the proposed antenna retains its dual-band performance under real-world measurement conditions, making it suitable for practical 4G and 5G communication applications.

Parameter	Simulated Value	Measured Value	Remarks
Resonant Frequency 1	2.7 GHz	2.8 GHz	Slight shift
Resonant Frequency 2	4.5 GHz	4.6–4.8 GHz	Minor variation
Return Loss (S11)	< -20 dB	< -15 dB	Good matching
VSWR	< 2	≈ 2	Acceptable
Bandwidth	Moderate	Slightly varied	Due to fabrication effects

Fig. 8. Antenna measurement setup using VNA.

V.CONCLUSION

A dual-resonance microstrip patch radiator has been successfully synthesized, numerically analysed, physically fabricated, and experimentally corroborated for 4G LTE and sub-6 GHz 5G wireless communication applications. The presented radiator attains frequency alignment at approximately 2.6 GHz (simulated) / 2.7 GHz (measured) and 4.45 GHz (simulated) / 4.5–5 GHz (measured), encompassing the target spectral windows.

Simulated and experimentally obtained data demonstrate favourable input impedance alignment with reflection coefficient inferior to -10 dB and VSWR inferior to 2 at both operating frequencies. The far-field spatial distributions exhibit consistent and quasi-omnidirectional characteristics with side lobe levels inferior to -2.4 dB, ensuring dependable signal coverage. The radiator provides satisfactory realized gain (2-5 dB) and uniform directivity, rendering it appropriate for practical deployment.

The dual-resonance behaviour is realized through mirror-image aperture incorporation in the radiating patch, which generates multiple resonant pathways without increasing physical dimensions. The radiator offers a dimensionally economical (40 × 30 mm), economically favourable (FR4-based), manufacturing-tolerant solution for contemporary 4G and 5G communication systems.

Subsequent investigations may explore spectral width expansion using vertically stacked parasitic radiators, gain elevation through dielectric superstrate loading, and incorporation into multiple-input

multiple-output (MIMO) architectures for enhanced data throughput.

VI. REFERENCES

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