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IMPLEMENTATION OF MULTI-BAND SLOTTED ANTENNA FOR WIRELESS APPLICATIONS

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Abstract— A compact multi-band slotted patch antenna with an octagonal design, measuring 27.5 mm × 22 mm × 1.6 mm, is designed and analysed for its efficiency across multiple resonating characteristics. This antenna is optimized for four operating modes, supporting tetra wireless standards. Proposed design achieved S-band WLAN (2.4 GHz – IEEE 802.16b), C-band WLAN (5.0 GHz – IEEE 802.11j, 5.8 GHz – IEEE 802.11a), 5G NR bands (n40: 2.3–2.4 GHz, n46: 5.15–5.925 GHz, n47: 5.855–5.925 GHz, n96: 5.925–7.125 GHz, n102: 5.925–6.425 GHz, n104: 6.425–7.125 GHz), X-band (8–12 GHz for radar, space communication, and broadband), lower Ku-band (13.64–15.72 GHz for satellite communication), and upper Ku-band (16.32–17.24 GHz for molecular rotational spectroscopy) wireless communication applications. Simulated results confirm its performance, showcasing favourable return loss and gain across the targeted bands, with stable operation across the antenna's resonating modes.

Keywords*— Octagonal shape slotted patch,quad-band, WLAN, X band.*

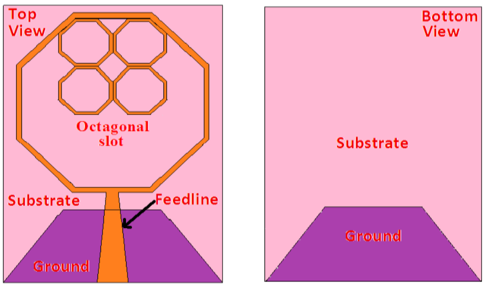
I. INTRODUCTION

Modern wireless networks demand compact antenna design capable of functioning across multiple communication modes to support various wireless standards. To address this need, several antenna structures have been designed. One such innovation is a triple-band antenna using a CPW-fed configuration, optimized for WLAN and WiMAX applications [1]. The split-ring resonators and slot formation on radiating section approach have been proposed to achieve multiband functionality within a single antenna. The octagonal slotted configuration on radiating patch area, in particular, stands out for its compact size, low power consumption, and multiple resonant characteristics. Continuing advancements in the field include the development of a slotted ACS-fed monopole antenna, demonstrating triple-band performance for wireless applications [2]. The published works [3-7] has recommended multiple operating band antenna designs implementing methods such as slot etching, miniaturization, and split-ring resonators (SRR), catering to a variety of wireless communication applications. The etching slots technique inclusion in antenna designs allows for size reduction and multiband operation by leveraging current perturbation. Furthermore, the integration of metamaterial elements, such as SRR/CSRR (which exhibit negative permeability and permittivity), enhances the multiband capabilities. Recent studies have documented several multiband antennas incorporating metamaterial loading [15-21].

Proposed antenna design presents an octagonal-shaped slotted patch section with a trapezoidal-shaped partial ground, to achieve a wide range of wireless communication modes, including S-band, C-band, 5G NR bands, X-band, and lower/upper Ku-band. The antenna structure incorporates a double duplication of octagonal slotted geometries within the radiating patch. Additionally, a trapezoidal-shaped defected ground structure is implemented on the back of the antenna to enable operation across WLAN (2.4 GHz), WLAN (5.0/5.8 GHz), 5G NR bands (n40, n46, n47, n96, n102, n104), X-band (8-12 GHz), and lower/upper Ku-band wireless applications.

II. ANTENNADESIGN

Figure 1 illustrates the front and back sectional view of the proposed structure, showing the slotted radiating patch and ground area. The upper part of antenna represents the radiating patch features a slotted octagonal shape attached with a 50-ohm trapezoidal feedline, while the lower part ground plane adopts a trapezoidal slotted design with defected ground properties. The proposed antenna is designed on FR4 substrate material with a thickness of 1.6 mm (εr = 4.4 and $\tan\delta$ = 0.02) [5], resulting in a compact size of 27.5 × 22 × 1.6 mm³. The design incorporates an octagonal shaped double duplicated sections within radiating patch and a trapezoidal slotted partial ground, enabling quad-band operation across WLAN (2.4/5.0/5.8 GHz), the full X-band (8-12 GHz), and the lower/upper Ku-band for wireless standards. Detailed antenna parameteric dimensions are mentioned in Table 1.



(a) **(b)**

Figure 1Antenna configurations: (a) Top view and (b) bottom view.

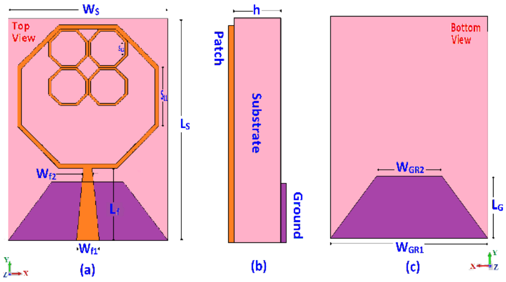


Figure 2 Antenna geometry with dimensions.

Table 1 Dimensions of the projected slotted multiband antenna.

Parameter	L_S	W_S	h	L_F	W_{f1}	W_{f2}	L_G	W_{GR1}	W_{GR2}	S_{L1}	S_{L2}
Dimension (mm)	27.5	22	1.6	9.5	3.16	1.2	8	22	10	8	2

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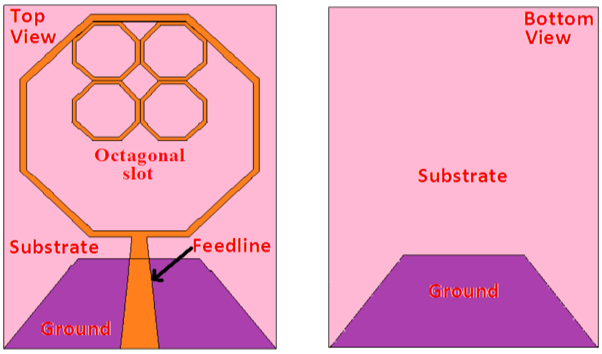

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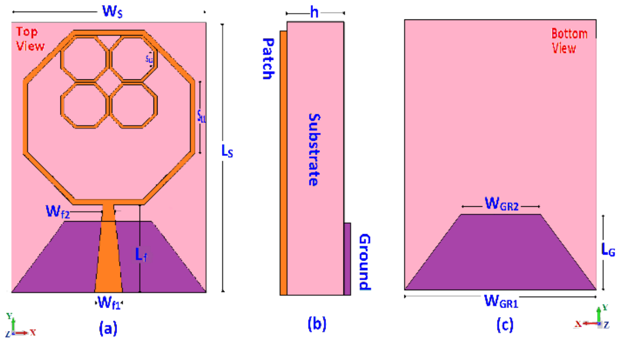

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III. RESULTS AND DISCUSSION

The simulation of the proposed antenna design is carried out using CST software [8] to evaluate its reflection coefficient (S_{11}), peak gain, radiation efficiency, and radiation patterns. The simulations are conducted across the microwave frequency range to analyse the radiation characteristics at the targeted resonating modes relevant to various wireless communication standards [9].

A. Simulated S Parameters (S_{11})

Figure 3 presents the simulated S-parameters, specifically the reflection coefficient (S_{11}). The proposed double duplicated octagonal slotted antenna design successfully achieves fouroperatingmodes, supporting a variety of wireless communication applications. Detailed information on the resonating bands, including their bandwidths and corresponding applications, is outlined in Table 2.

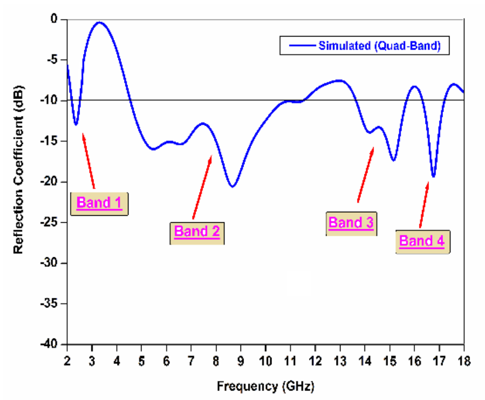

Figure 3. Simulated $S_{11}$of the proposed design.

Table 2: Operating band analysis of proposed antenna design.

Sr. No.	Resonating Band	Impedance Bandwidth (Simulated)	Achieved wireless communication applications
1	Band-1	2.16–2.52 GHz	• S band WLAN (2.4 GHz – IEEE 802.16b)
2	Band-2	4.55–11.53 GHz	• C band WLAN (5.0 GHz – IEEE 802.11j, 5.8 GHz – IEEE 802.11a) • 5G NR bands (n40 – 2.3 to 2.4 GHz, n46 – 5.15 to 5.925 GHz, n47 – 5.855 to 5.925 GHz, n96 – 5.925 to 7.125 GHz, n102 – 5.925 to 6.425 GHz, n104 – 6.425 to 7.125 GHz) • X band (8 to 12 GHz – Radar, space communication, terrestrial broadband, amateur radio applications)
3	Band-3	13.64-15.72 GHz	• Lower K_U band (13.64-15.72 GHz – satellite communication)
4	Band-4	16.32-17.24 GHz	• Upper K_U band (16.32-17.24 GHz – molecular rotational spectroscopy)

B SIMULATED PEAK GAIN

Figure 4 shows the simulated peak gain observation for the proposed antenna structure across various operating frequencies. It is noticed that the peak gain is lower at frequencies below 10 GHz compared to the higher frequencies above 12 GHz. A notable result from the simulations is the high average antenna gain of 4.54 dBi at 16.89 GHz, making it particularly suitable for upper K_U-band molecular rotational spectroscopy applications [9, 10].

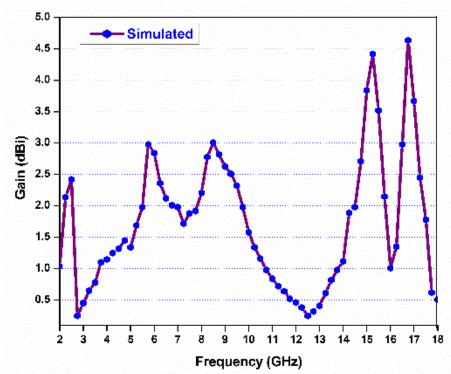

Fig. 4 Simulated peak gain observation.

IV. CONCLUSION

This paper introduces a multi-resonant antenna design that accommodates various wireless standards, characterized by an octagonal slotted structure with double duplication and a trapezoidal-shaped feedline. The proposed design is compact, measuring 27.5 × 22 × 1.6 mm³, and is fed by a microstrip line coupled with a trapezoidal-shaped defected ground structure. The antenna demonstrates quad-band characteristics, covering frequency ranges of 2.16–2.52 GHz, 4.55–11.53 GHz, 13.64–15.72 GHz, and 16.32–17.24 GHz. These frequency bands support various wireless communication standards, including WLAN (2.4/5.0/5.8 GHz), the entire X-band (8-12 GHz), and lower/upper Ku-band applications.

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