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Research Article

Microstrip Patch Antenna Reconfiguration Ability

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ABSTRACT

The Dual-band microstrip patch antenna exhibits bandwidth and frequency reconfiguration capabilities, as evidenced by the agreement between simulated and measured radiations. The antenna's ability for frequency reconfigurability stems from its patch design flexibility, featuring two cuts at its edges. Table 3 tabulates the measured and simulated antenna gain, along with other enhancements. Notably, the antenna demonstrates radiation pattern reconfigurability at lower frequencies (2.4 GHz, 2.45 GHz, 2.5 GHz) and higher frequencies (5 GHz, 5.2 GHz, 5.4 GHz, and 5.6 GHz). This reconfigurability is consistent across various lower-order and higher-order frequencies, highlighting the robust agreement between the measured and simulated radiation patterns. This work applies to present-day IoT devices.

Keywords: 5G, microstrip patch antenna, frequency reconfigurability.

INTRODUCTION

The onset of the third decade in the 21st century marks the emergence of the Internet of Things (IoT), with 5G technology at the forefront, utilizing millimeter wave (mm Wave) frequency signals to facilitate the ever-increasing demands of our essential wireless devices. These capabilities are instrumental in powering our daily connectivity needs, seamlessly spanning across our residences, workplaces, and public spaces. Enabling the connection of billions of wireless devices demands a substantial IoT infrastructure to accommodate this extensive demand. The pivotal factor in achieving this is the ability to achieve higher data transmission rates within the constraints of limited bandwidth, which is the cornerstone of a 5G network. This capability is what makes highly interconnected and widely distributed IoT systems possible. Establishing connections for billions of wireless devices within networks also necessitates a significant amount of power, a challenge that can be addressed by optimizing the microstrip patch antennas used for wireless device connectivity. The key lies in developing low-profile antennas that offer both high gain and exceptional efficiency. These microstrip patch antennas serve as vital and fundamental components of wireless devices and the networks that support them. The freedom to utilize diverse patch antenna substrates grants device engineers significant flexibility, offering options for reconfiguration and bandwidth enhancement [2]. For instance, a dual-band wide-bandwidth microstrip patch antenna (MPA) capable of extending bandwidth up to 2.45/5GHz finds valuable application in Wireless Local Area Networks (WLAN) [3]. A dual-band microstrip patch antenna offers the capability for bandwidth and frequency reconfiguration due to the flexibility in patch design, involving two cuts at its edges. In a recent publication, an MPA antenna tailored for 5G applications, featuring multiple inputs and multiple outputs (MIMO), demonstrates remarkable reconfigurability within the 32-46 GHz range. This results in enhanced data transmission rates and higher gain [4]. The frequency reconfigurability of the microstrip patch antenna (MPA) [5] can be achieved by adjusting the lumped parameter of the patch, enabling

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reconfiguration up to 60GHz. This flexibility in patch design is demonstrated by the frequency reconfigurability of MPAs [4], which offers various reconfiguration options through techniques such as modifying the lumped parameters of the patch antenna [5]. Both of these reconfigurability methods successfully enhance the operating frequency of MPAs, along with increasing their gain.

In the context of 5G applications, particularly targeted at 28GHz for Internet of Things (IoTs), a reconfigurable microstrip patch antenna (MPA) is detailed in a specific study [6]. This work explicitly delves into the application of the finite integration technique and finite element method for simulation and analysis. Similarly, another investigation focuses on a multiple-cut patch antenna MPA designed for the broader range of 5G applications, spanning from 26.5 to 40 GHz. This antenna incorporates a metamaterial substrate, yielding notable results in terms of frequency reconfigurability, as highlighted in a separate study [7]. The wideband frequency reconfigurability of microstrip patch antennas (MPA) designed for 5G applications within the 24 to 29.5 GHz range is specifically highlighted in a study [8]. This research explicitly demonstrates reconfigurability by systematically varying the shape of the patches, exploring a total of eleven different shapes. The investigation underscores the importance of shape variation as a mechanism for achieving versatile and effective frequency reconfigurability in the specified frequency range. In addition to frequency reconfigurability, patch antennas offer the potential for other forms of reconfigurability. This includes radiation reconfigurability, polarization reconfigurability, and hybrid reconfigurability. Specifically, polarization reconfigurability can be achieved through the use of a graphene substrate, as discussed in references [11-13]. These additional dimensions of reconfigurability enhance the versatility and adaptability of patch antennas, making them capable of meeting diverse requirements in different communication scenarios. The primary focus of this work centres exclusively on frequency reconfigurability, and it is organized into five distinct sections: I. Introduction II. Patch Antenna Structure III. Antenna Parameters IV. Results V. ConclusionEach section plays a specific role in presenting and analyzing the frequency reconfigurability of the patch antenna. The systematic organization of these sections provides a clear and structured exploration of the work's objectives and outcomes related to frequency reconfigurability.

II. PATCH ANTENNA STRUCTURES AND VARIATIONS

(a) (b)

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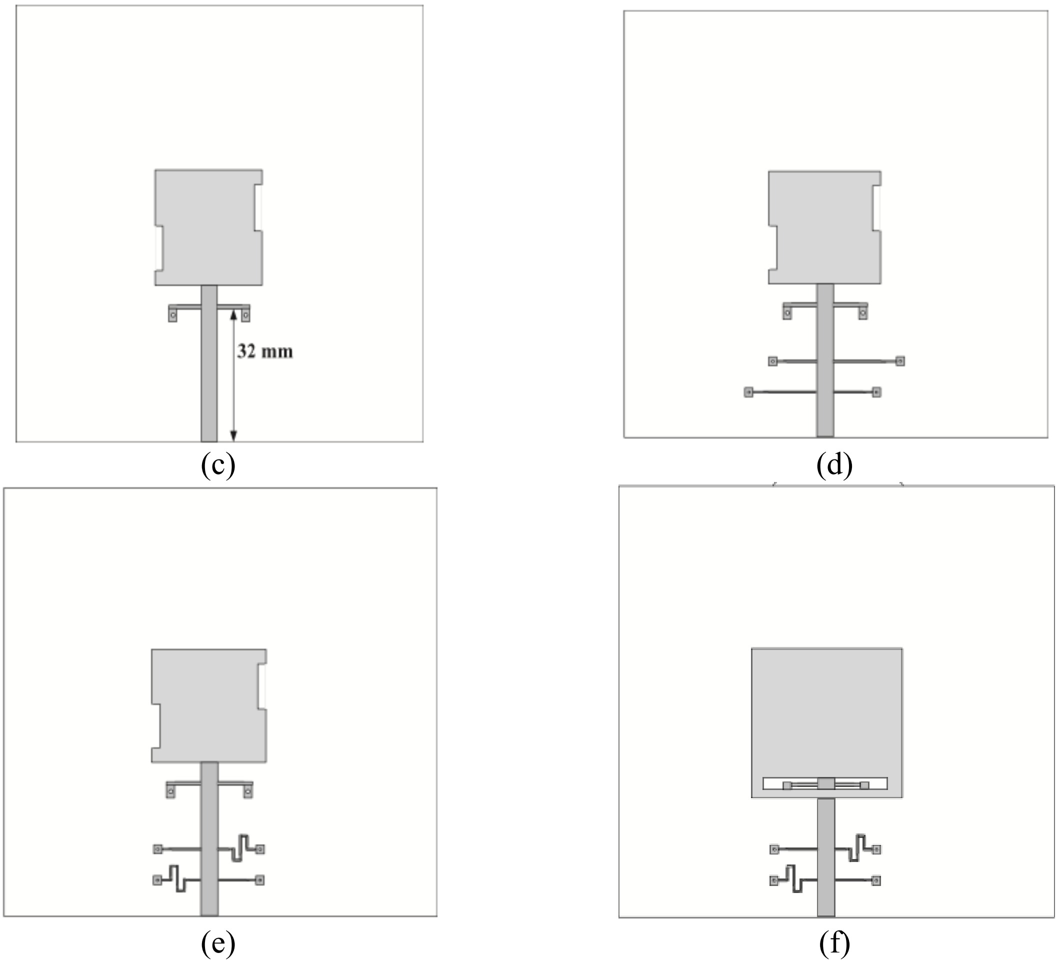

Fig. 1 (a) Basic patch antenna with dimensions (L = W = 28mm, l_t = 36mm and w_t= 2.8mm), (b) Improved patch antenna with an asymmetrical cut at left and right edges, (c) Improved patch antenna with shunt inductor at 32mm above from feed point, (d) Improved patch antenna with microstrip resonators, (e) Improved patch antenna with microstrip symmetrical resonators, and (f) Improved patch antenna with parasitic patch and slot[14,15].

III. PROPOSED PARAMETERS AND MEASUREMENT

Table 1. Depicts the comparison between measured and simulated antenna parameters of the proposed antenna

Frequency (GHz)	Measured Gain (dBi)	Simulated Gain (dBi)	Measured S_{11}(dB)	Simulated S_{11}(dB)
2.4	1.72	1.05	-3.69	-3.29
2.45	3.49	2.88	-7.01	-5.59
2.5	4.5	4.58	-.89	-14.19
5.0	-9.85	-1.08	-2.34	-2.30
5.2	-5.147	1.6	-5.82	-8.77
5.4	1.8	3.83	-15.49	-15.33
5.6	3.24	4.5	-21.87	-24.24
5.8	5.03	5.12	-18.8	-15.7

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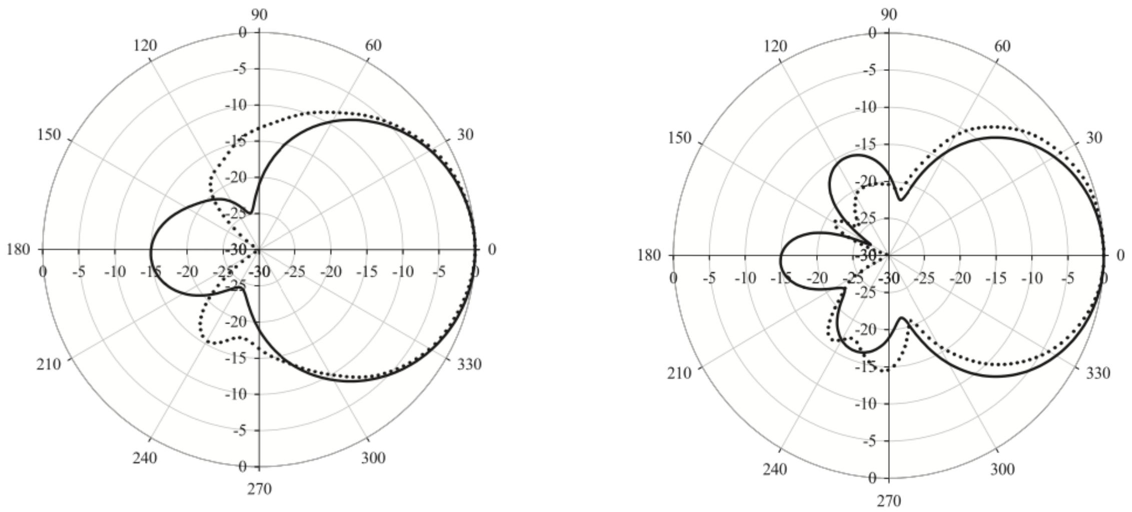
6.0	2.03	2.93	-4.91	-5.80

Table 2. Depicts the comparison between proposed anteena and some existing microstrip patch antennas

Parameter	**Proposed Work**	**[09]**	**[10]**
Antenna Type	Dual band patch antenna operating at 2.45/5 GHz WLAN bands	Dual band patch antenna operating at 2.45/5 GHz WLAN bands	Single band patch antenna operating at 2.45/5 GHz WLAN bands
S_{11} at 4.9 GHz	-1.9 dB	<-2 dB	-3 dB
S_{11} at 7.35 GHz	-2 dB	N/A	-6 dB
Peak Gain at 2.45 GHz	3.49 dBi	-2 dBi	N/A
Peak Gain at 5.8 GHz	5.03 dBi	-1.5 dBi	N/A
Gain enhancement technique	Yes	No	No

IV. RESULTS AND DISCUSSION



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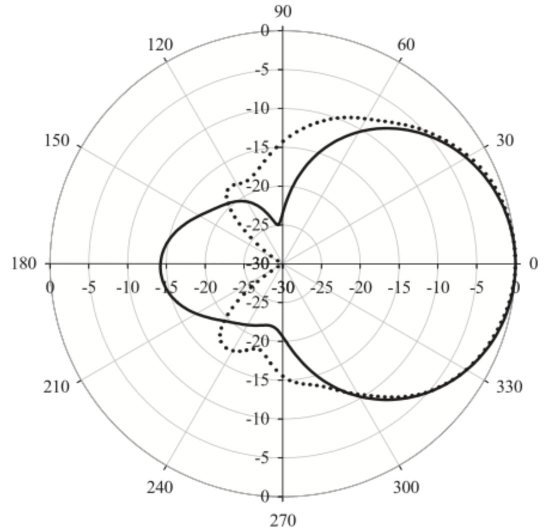

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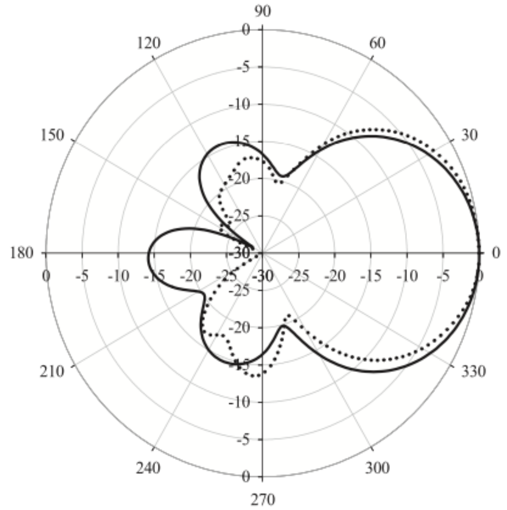

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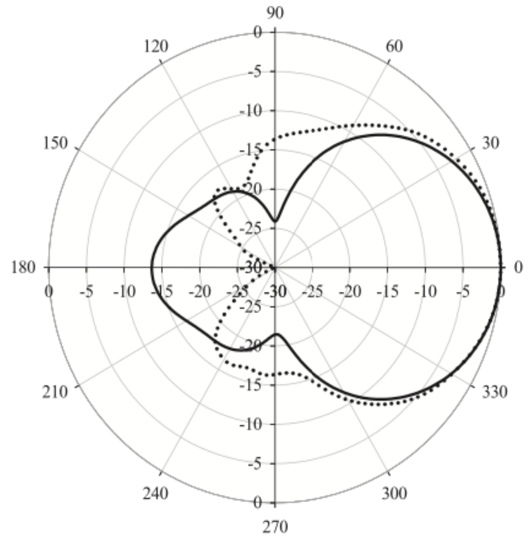

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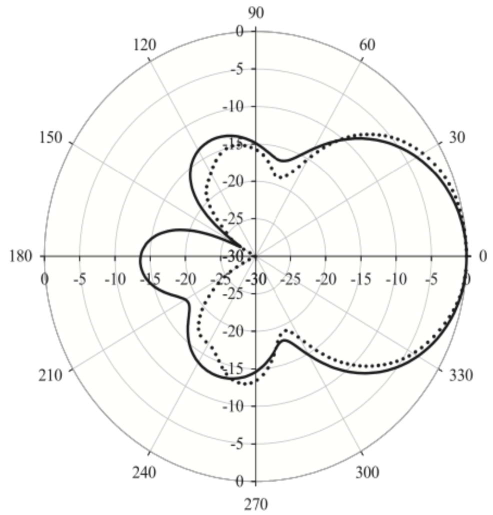

(f)

Fig. 2 (a) Measured and Simulation radiation pattern of the proposed antenna at 2.4 GHz in (a) XZ plane and (b) YZ planes. Measured and simulated radiation pattern of the proposed antenna at 2.45 GHz in (c) XZ plane and (d) YZ planes. Measured and simulated radiation pattern of the proposed antenna at 2.45 GHz in (c) XZ plane and (d) YZ planes.

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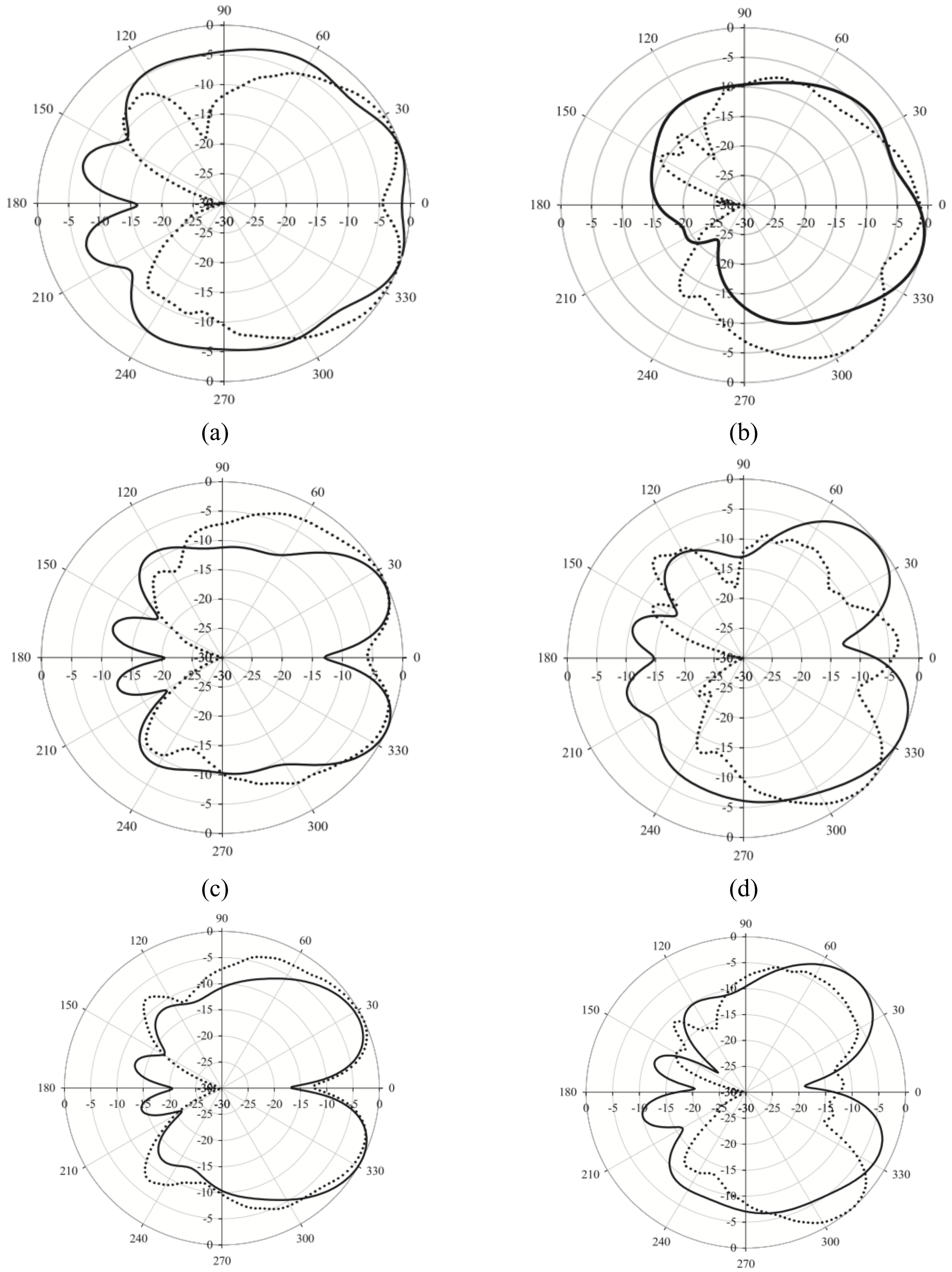

Fig. 3 (a) Measured and Simulation radiation pattern of the proposed antenna at 5 GHz in (a) XZ plane and (b) YZ planes. Measured and simulated radiation pattern of the proposed antenna at 5.2 GHz in (c) XZ plane and (d) YZ planes. Measured and simulated radiation pattern of the proposed antenna at 5.4 GHz in (c) XZ plane and (d) YZ planes.

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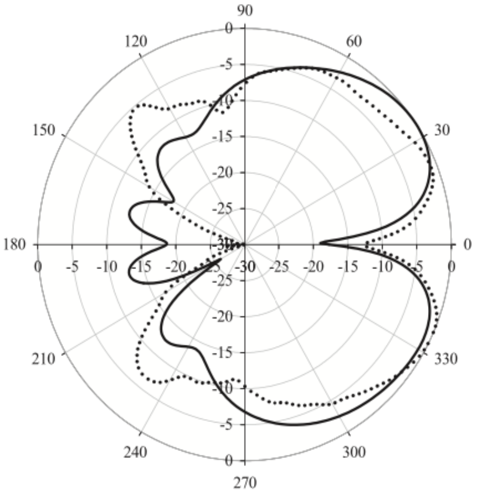
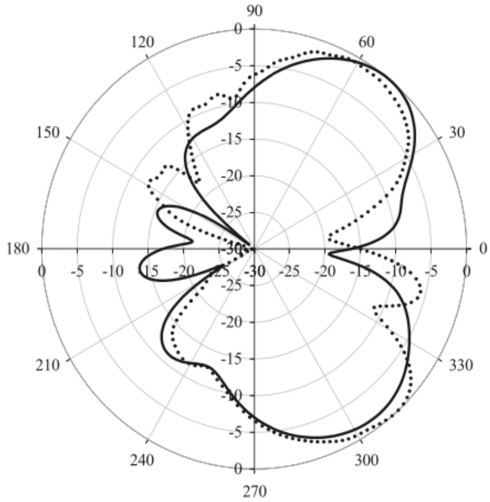


(a)



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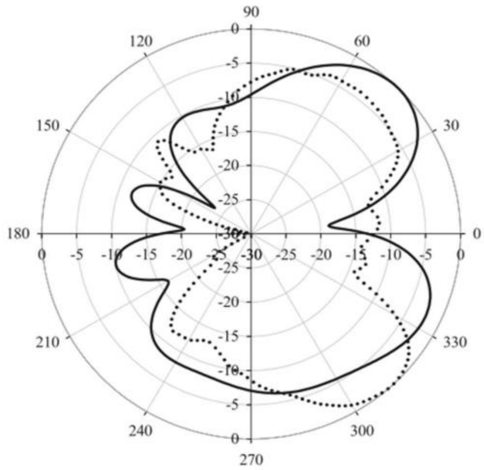

Fig: 4(c)

Fig. 4 (a) Measured and Simulation radiation pattern of the proposed antenna at 5.6 GHz in (a) XZ plane and (b) YZ planes.

The antenna radiation pattern drawn in Fig. 2, 3, 4 has shown excellent harmony at lower frequencies 2.4 GHz, 2.45 GHz, 2.5 GHz and at higher frequencies 5 Hz, 5.2 GHz, 5.4GHz and 5.6GHz. All the measured and simulated radiation pattern also shows excellent harmony at different lower-order higher-order frequencies. The small discrepancies present in the measured results at higher-order frequencies (above 5GHz to 5.6 GHz) have been removed in the simulation results. It can be observed in the radiation pattern results that the radiations are weak behind the ground plane. The excellent harmony between the simulated and measured radiations proved the proposed antenna very useful and applicable as the transmitter for real-world communicating IoT devices. The antenna radiation patterns depicted in Fig. 2, 3, and 4 exhibit remarkable consistency at both lower frequencies (2.4 GHz, 2.45 GHz, 2.5 GHz) and higher frequencies (5 GHz, 5.2 GHz, 5.4 GHz, and 5.6 GHz). Across various lower-order and higher-order frequencies, both the measured and simulated radiation patterns demonstrate strong agreement. Minor deviations observed in the measured results at higher-order frequencies (above 5 GHz to 5.6 GHz) have been rectified in the simulation results. Notably, the radiation patterns reveal weakened emissions behind the ground plane. The

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outstanding agreement between simulated and measured radiations underscores the practical utility of the proposed antenna as a transmitter for real-world IoT communication devices.

The measured and simulated antenna gains of the proposed antenna in Tables 1 and 2 present comparable [09-10] details. The measured and simulated radiation patterns are also comparable with the available literature. The proposed antenna shows its applicability as a good transmitter as well as a receiver in the present day's IoT devices. Applications of the proposed antenna in the IoT device will reduce the power consumption at every different node in the IoT wireless network. The applicability of the proposed antenna to the present day is the most remarkable achievement of this work with the aim to reduce the present power consumption in the future

V. CONCLUSION

The simulated and measured radiations of the Dual-band microstrip patch antenna provides bandwidth or frequency reconfiguration ability. The proposed antenna shows frequency reconfigurability because of the flexibility in designing its patch with two cuts at its two edges. The measured and simulated antenna gain and other improvements have been tabulated in Table 1. The antenna radiation pattern reconfigurability has shown at lower frequencies 2.4 GHz, 2.45 GHz, 2.5 GHz and at higher frequencies 5 Hz, 5.2 GHz, 5.4GHz and 5.6GHz. Across various lower-order and higher-order frequencies, both the measured and simulated radiation patterns demonstrate strong agreement. Minor deviations observed in the measured results at higher-order frequencies (above 5 GHz to 5.6 GHz) have been rectified in the simulation results. The most noteworthy accomplishment of this work lies in the applicability of the proposed antenna to contemporary needs, especially with the overarching goal of minimizing current power consumption for future advancements.

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