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Broadband Antenna Operating in Sub 6GHz Frequency for Long Range 5G Communication

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Abstract: A novel broadband antenna designed for long-range 5G communication in the sub-6GHz frequency band is presented. Through rigorous optimization and simulation, the antenna achieved high gain, low side-lobe levels, and uniform radiation patterns. Experimental validation confirms its efficacy, offering a compact and robust solution for advancing global connectivity in next-generation wireless networks

Index Terms: Antenna, CPW, 5G Technology, Compact Antenna, Broadband, Monopole Antenna.

I. INTRODUCTION

The evolution of wireless communication, particularly with the emergence of 5G technology, has transformed how in- formation is transmitted. 5G offers unparalleled data speeds, minimal latency, and the ability to connect numerous devices, revolutionizing businesses, enhancing customer experiences, and enabling advancements like autonomous systems and the Internet of Things (IoT). However, to fully utilize 5G, a critical component is essential: a broadband antenna capable of long- range communication in the sub- 6GHz frequency range. 5G communication utilizes various frequency bands, including sub-6GHz, crucial for extensive coverage due to its superior ability to penetrate obstacles. Designing a broadband antenna that efficiently operates in this spectrum is a complex task, requiring a careful balance between performance, compatibility with 5G standards, regulatory compliance, and practicality. This project aims to develop such an antenna, tailored to address these challenges and unlock the full potential of long-range 5G communication. In the field of printed antenna technology, as documented in [1]-[7], significant advancements have been made. [1] introduced a novel approach to using printed monopole antennas, demonstrating a compact design with wideband capabilities suitable for handheld mobile devices. [2] presented a CPW - fed planar printed monopole antenna with broadband circular polarization, achieving notable improvements in impedance bandwidth and axial ratio bandwidth. Similarly, [3] detailed a CPW-fed planar printed monopole antenna, incorporating specific design elements to achieve broadband circular polarization characteristics and expanded impedance and axial ratio bandwidths. [4] explored the integration of Split Ring Resonator (SRR) technology into a CPW-fed antenna, showcasing broadband performance across a wide frequency range. [5] focused on the design of a miniaturized super broadband printed antenna, featuring a compact structure and remarkable impedance bandwidth spanning from 1.9 GHz to above 100 GHz. Additionally,[6] discussed a broad- band microstrip-fed printed antenna, leveraging strip loading and slots for enhanced performance and minimal dispersion. Lastly, [7] described the development of a broadband patch antenna array tailored for Q-band applications, emphasizing cost-effectiveness and ease of integration with standard PCB technology.

Drawing inspiration from these diverse studies, this research aimed to push the boundaries of antenna design further. By synthesizing key aspects of these innovations, a compact CPW- fed broadband antenna optimized specifically for sub-6GHz frequencies in 5G communication networks is engineered. In the proposed antenna, a rectangular patch is fed by the CPW feedline, and both a vertical stub and a horizontal slit are embedded on the ground-plane. This antenna is poised to deliver enhanced performance, efficiency, and adaptability in meeting the evolving demands of modern wireless communication systems.

II. PROPOSED ANTENNA DESIGN

The design of an antenna significantly influenced its performance. Various methodologies can be employed to design an antenna. This research focused on designing a CPW fed broadband monopole antenna using FR4 Epoxy Substrate, which has a dielectric constant of 4.4 and a height of 0.5mm, to resonate at approximately 5GHz. The antenna geometry is shown in Fig. 1 and dimensions for the same have been listed in Table 1.

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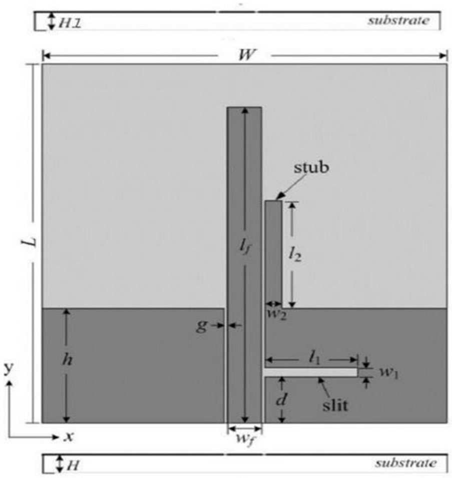

Fig. 1. Antenna Design

Table 1. Antenna design parameters

W	L	H	h	G	wf	H1
12	12.5	0.5	4	0.2	1	2
lf	d	l1	w1	l2	w2	wf
11	1.62	2.75	0.3	3.5	0.5	0.5

The monopole antenna length can calculated approximately using equations (1)-(3). An additional stub is used to improve the impedance bandwidth. The width of the monopole is chosen to be of 50 ohm line for the given substrate so as to match with 50 ohm feed. The dimensions of stub are taken to be approximatelyhalf of that of monopole and obtained through optimization.

$$L = \lambda_g / 4 \quad (1)$$

$$\text{Where } \lambda_g = \lambda_o / \sqrt{\varepsilon_{re}} \quad (2)$$

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-0.5} \quad (3)$$

A. Optimization of various Antenna Parameters

The antenna is optimized by using different methods to achieve improved bandwidth within the required operating band. Several design iterations were done by varying parameters like width of the antenna, its height, length of the monopole to 20%, 40% and 50% of the initial design. Through this, the antenna experienced different gain and directivity.

TABLE 2: COMPARISON OF DIFFERENT DESIGNS

DESIGN	GAIN	DIRECTIVITY
20%	0.8184	0.868
40%	0.6311	0.668
50%	0.2517	0.262

From the above table 2, reducing the size of an antenna by 20%, 40%, and 50% has varying effects on its performance metrics. A 20% reduction causes minor changes in gain and directivity, maintaining proportionality for effective signal transmission. However, a 40% reduction leads to more significant declines in gain and directivity, indicating compromised structural integrity.

A 50% reduction results in substantial deformation, significantly decreasing gain and directivity while increasing radiation efficiency. These effects highlight the intricate relationship between geometric modifications and electromagnetic principles in antenna design. Careful adjustments are crucial to maintain optimal performance. The degree of reduction directly impacts the antenna's ability to capture and emit electromagnetic waves efficiently, requiring thoughtful design modifications to achieve desired performance levels.

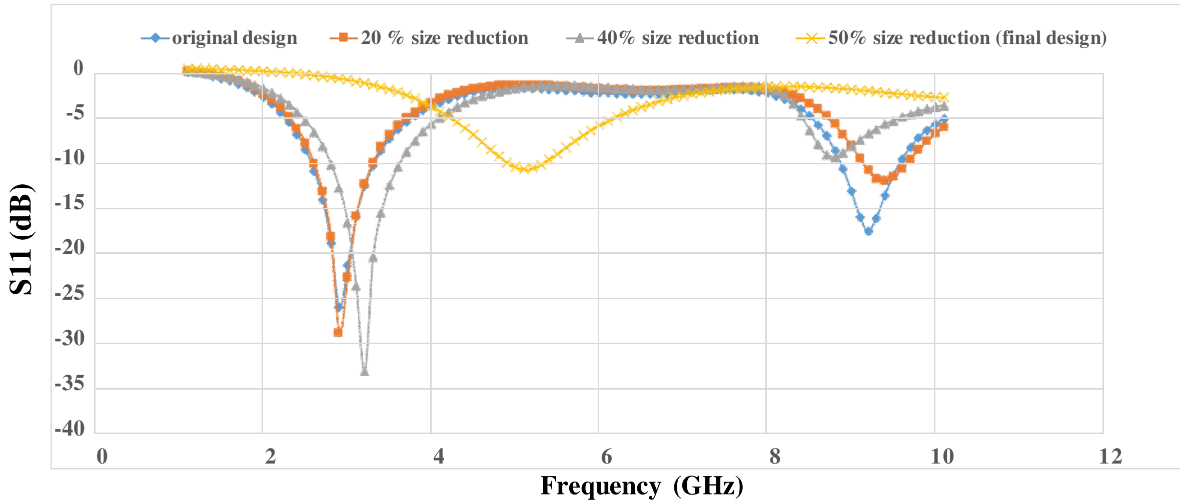

Fig.2. Simulated S11 response of proposed antenna for different length variations

Fig.2 showcase the different output responses by optimizing the design and reducing its dimensions by 20%, 40% and 50%. The output response is shifted towards 5GHz when it is being changed from 20% to 50%,50% design showed better response and a better bandwidth. To get a better output response the design is optimized by trying other parameters. The table 3 displays the results obtained by optimizing antenna parameters after reducing its dimensions, showcasing the effects on frequency and S(1,1) values. Four designs with different dimension reductions (reference design,20% reduced dimension, 40% reduced dimension, and 50% reduced dimension) were examined. The reference design operates at 2.6GHz with an S(1,1) of -27.54 ,20% reduced design operates at 2.8 GHz with an S(1,1) of -29.47 dB, while the 40% reduced design operates at 3.1 GHz with an S(1,1) of -33.81 dB. The 50% reduced design operates at 5 GHz with an S(1,1) of -16.33 dB.

B. *Effect of Superstrate*

A monopole antenna consisting of CPW-fed monopole and a stub is optimized. Many structural changes have been made in the initial design, in order to achieve improved final design. The initial design had only one substrate while the final one have two substrates i.e. FR Epoxy 4. The different antenna design parameters like length of the monopole, width of the antenna, its height etc. have also been changed and reduced to 50% of the initial one, to get the resonance at 5.2 GHz. To further improve antenna's performance it is loaded with a superstrate of same dielectric properties as the driven patch substrate. Fig.3 shows response of antenna with the superstrate stacked above it.

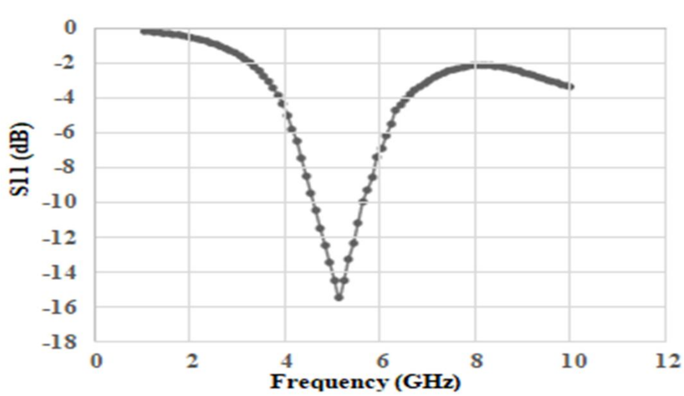

Fig. 3. Output Response for Final Antenna Design with Superstrate

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Table 3. Optimization Of Antenna Parameters

DESIGN	Frequency(GHz)	S(1,1)(dB)
Original Design	2.6GHZ	-27.54
Antenna Design 2	2.8GHZ	-29.47
Antenna Design 3	3.1GHZ	-33.81
Final Antenna Design	5.2GHz	-12.33
Final Antenna Designwith Superstrate	5.09 GHz	-15.88

III. RESULTS

Following numerous optimizations and adjustments to the antenna design, the finalized version i.e. with 50% reduction and stacked substrate was then fabricated. Throughout the fabrication process, meticulous attention is given to ensure precise replication of the dimensions, positions, and shapes of the slots. After the antenna is fabricated, measurements are done to evaluate the antenna's parameters. The final fabricated antenna and different measured parameters are shown in figures below. Fig.4 shows fabricated antenna without superstrate. A plane substrate of same material, as of the driven patch substrate, is placed above the driven patch. The results are shown in Figures 5-7. Fig. 5 displays measured S11 result of the proposed antenna without and with superstrate, while Fig. 6 displays plotted S11 response of proposed antenna with superstrate. The S11 response with superstrate shows frequency shift towards the lower side. Fig. 7 shows measured radiation patterns in E-plane and H-plane for co-polar and cross-polar patterns. The radiation patterns show omnidirectional pattern.

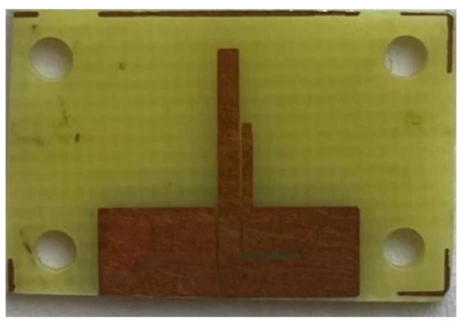

Fig. 4. Final Antenna Design Fabricated

Fig. 5. S11 Results for Fabricated Final Design a) without substrate and b) with superstrate

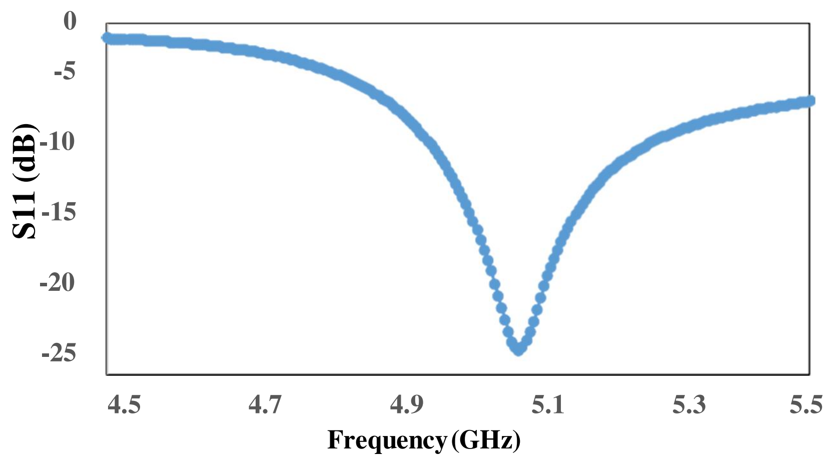

Fig. 6. Measured S11 of Proposed Antenna (Final Design with Stacked Substrate)

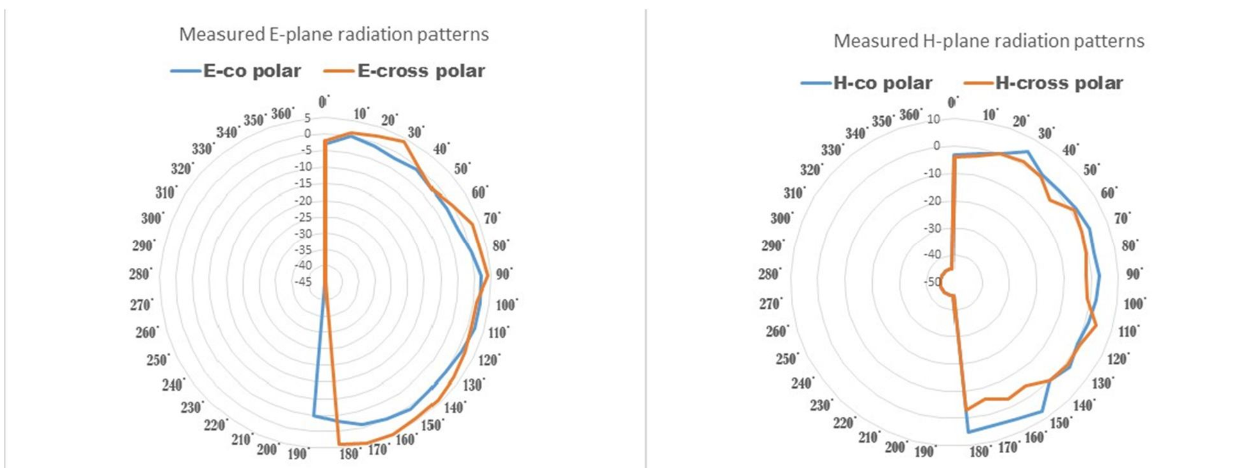

Fig. 7. Radiation Pattern of Proposed Antenna Design

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V. CONCLUSION

This research was centered on designing a CPW-fed antenna engineered for 5G band operation at a frequency of 5GHz. The antenna's production involved the utilization of the PCB Etching method, and its performance was evaluated through simulation using HFSS software. Results from the simulations revealed a bandwidth ranging from 4.5 to 5.6 GHz. The developed antenna boasts a compact size and demonstrated optimal performance, rendering it suitable for integration into forthcoming 5G mobile communication systems. Its compact form factor presents a significant ad- vantage, allowing for easy integration into devices such as smartphones, tablets, and wearables. Moreover, the antenna's wide bandwidth makes it suitable for various applications, including wireless communication, mobile broadband, and Internet of Things (IoT) devices. The simulation results offer valuable insights into the antenna's performance characteristics, including radiation pattern, impedance, and gain. This information can be utilized to refine the design and ensure that the antenna meets the desired performance specifications. HFSS software was employed for simulating the design, while the fabricated results provide information about the antenna's performance characteristics, such as return loss. The PCB etching method was utilized for fabricating the antenna.

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