A Slotted Circular Patch Antenna with Defected Ground Structure for Sub-6 GHz 5G Communication

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Abstract— **In this study, a Slotted Circular Patch Antenna (SCPA) coupled with a Defected Ground Structure (DGS) for sub-6 GHz 5G communication is designed and simulated. The goal of the design is to reduce the size of the antenna without sacrificing acceptable performance. The original design of a Conventional Circular Patch Antenna (CPA) on a FR-4 substrate (εr = 4.4, thickness = 1.6 mm) was to resonate at 2.49 GHz. The SCPA is formed when a slot is added, shifting the resonance to 2.34 GHz. The resonance is shifted to 1.17 GHz by additional DGS augmentation, resulting in a size reduction of about 53%. ANSYS HFSS (v18.2) is used to simulate the antenna and assess its S11, VSWR, impedance, gain and radiation properties. The findings show strong agreement and compatibility for wireless, IoT and small 5G communication systems.**

Index Terms— **Microstrip antenna, Slotted patch, Defected Ground Structure (DGS), 5G, Sub-6 GHz, Miniaturization, HFSS.**

I. INTRODUCTION

Microstrip antenna downsizing has gained popularity due to the increasing need for small, high-performance antennas in contemporary wireless systems, including smartphones, IoT devices, and 5G networks. Because of their low cost, low profile, and PCB compatibility, microstrip patch antennas are commonly utilized. They do, However, have certain drawbacks, including a limited bandwidth, a moderate gain and a high physical size at lower frequencies.

Techniques like slotting and Defected Ground Structures (DGS) are used to improve impedance matching, increase electrical length, and decrease resonant frequency in order to overcome these difficulties. In order to achieve significant size reduction for sub-6 GHz 5G connectivity, this work presents a Slotted Circular Patch Antenna with DGS.

II. PROBLEM STATEMENT

Compact 5G devices cannot use conventional microstrip and circular patch antennas because they need to have huge physical dimensions in order to function at lower frequencies. Additionally, these antennas have restricted impedance matching, moderate return loss and a narrow bandwidth. An antenna that maintains good S11, VSWR, gain, and radiation stability while achieving lower resonance frequencies without growing in size is required. Slotting and DGS-based miniaturization are used in this work to overcome these constraints.

III. LITERATURE REVIEW

- Elftouh et al. DGS can increase bandwidth and efficiency in microstrip patch antennas, as demonstrated
- Pandhare et al. showed that DGS lowers surface waves and increases antenna array gain.
- Swetha & Naidu created small dual-band antennas using DGS and meander architecture.
- Kumar & Guha improved radiation properties by introducing asymmetric DGS for circular patch antennas.
- Ali et al. used DGS and innovative slot architectures to reduce size by 84%.
- Shashi Kumar & Suganthi In order to achieve about 53% downsizing studied a slotted circular

patch antenna with DGS particularly for sub-6 GHz 5G communication.

These investigations verify that DGS and slots are useful techniques for creating small antennas without appreciably reducing performance.

IV. AIM AND OBJECTIVES

Aim

In order to accomplish antenna downsizing, a slotted circular patch antenna coupled with DGS for sub-6 GHz 5G communication must be designed and simulated.

Objectives

- To create a circular patch antenna that can operate at frequencies lower than 6 GHz.
- To implement DGS and slotting for size reduction and resonance shifting.
- S11, VSWR, impedance and gain are the characteristics used to analyze antenna performance.
- To use HFSS to check simulation findings.
- To assess suitability for integration with a small 5G system.

V. METHODOLOGY

First Design (CPA)

FR-4 substrate is used to construct a circular patch for 2.49 GHz. TM11 mode equations are used to calculate patch radius.

Slotting (SCPA)

To lengthen the present path, a slot is added to the radiating patch. Resonance changes to 2.34 GHz.

Ground Structure Defect (SCPA-DGS)

A flaw is introduced to change the ground plane. By doing this, resonance is further shifted to 1.17 GHz without requiring an increase in antenna size.

Configuring the Simulation

ANSYS HFSS v18.2 models every design using:

- Border of radiation
- Port feeding in lumps
- Adaptive meshing
- Calculations of far-field radiation

S11, VSWR, Z-parameters, gain and radiation patterns are examples of simulation parameters.

VI. RESULTS AND DISCUSSION

Resonant Frequencies

Antenna Type Resonant Frequency S11 (dB)

CPA 2.49 GHz -28.7

CPA 2.34 GHz -31.32

SCPA-DGS 1.17 GHz -11.01

With an acceptable return loss, The SCPA-DGS reduces size by 53%.

Return Loss (S11)

At resonance, the SCPA-DGS displays S11 = -10 dB, signifying approximately 90% power transmission.

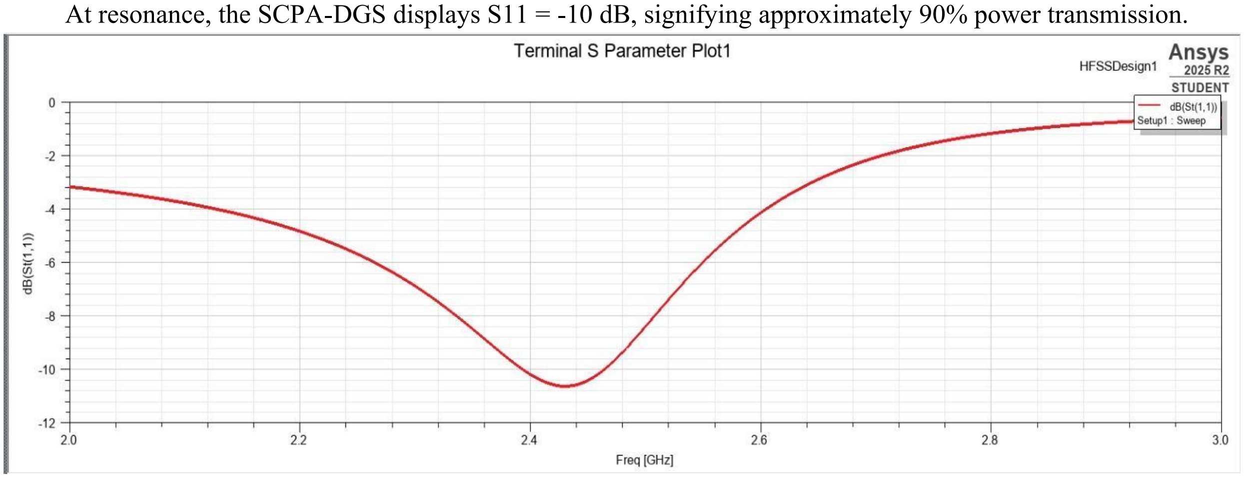

Fig 1: Terminal S Parameters VSWR

At the resonant frequency, VSWR = 3 indicates moderate matching that is suitable for small devices.

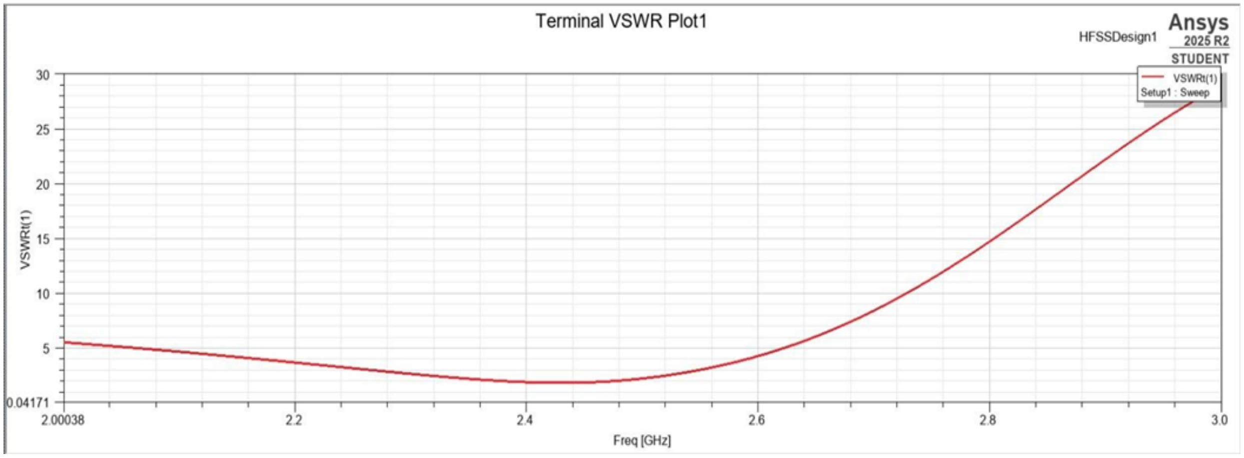

Fig 2: Terminal VSWR Plot

Input Impedance

- At resonance, the real impedance is around 27-28 Ω.
- At 2.4 GHz, the imaginary impedance crosses zero, Signifying resonance.

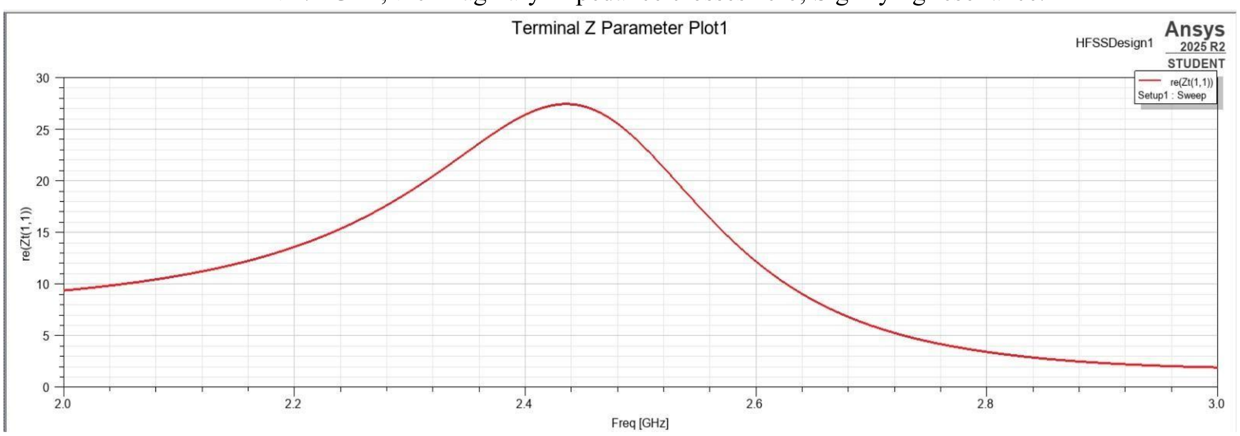

Fig 3: Terminal Z Parameter Plot

Gain and Radiation Pattern For short-range wireless and Internet of Things applications, The maximum gain .is around 2.14 dBi. There is a broadside radiation pattern.

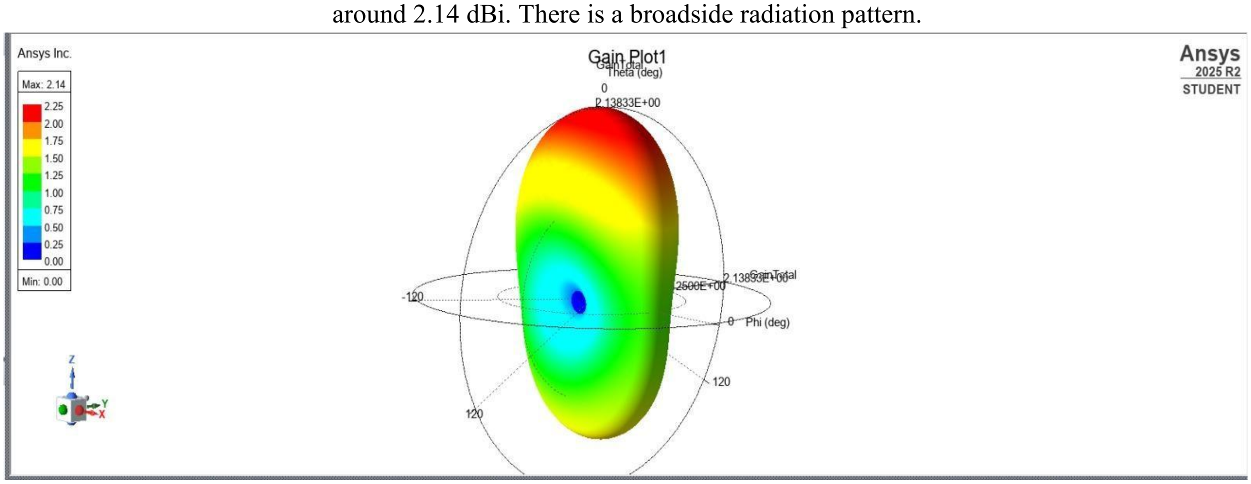

Fig 4: Gain plot

VII. APPLICATIONS

- Sub-6 GHz 5G systems.
- IoT and smart home appliances.
- Networks of wireless sensors.
- Bluetooth, WLAN, and Wi-Fi modules.
- GPS units.
- Drones and UAVs.
- Communication from Vehicle to Everything (V2X).
- Wearable and biological devices.
- Remote sensing and short-range radar.
- Military communication that is tactical.

VIII. ADVANTAGES

- Small and unobtrusive construction.
- Economical FR-4 substrate.
- Easy fabrication and straightforward geometry.
- Good matching of impedance.
- Stable radiation properties.
- Possibility of multiband functionality.

IX. CONCLUSION

For sub-6 GHz 5G communication, a slotted circular patch antenna with a faulty ground structure was created and simulated. Nearly 53% downsizing was achieved by successfully shifting the resonance frequency from 2.49 GHz to 1.17 GHz using slotting and DGS. Compact 5G, IoT and portable communication devices can benefit from the antenna's acceptable S11, VSWR and gain.

X. FUTURE SCOPE

- Using low-loss substrates (like Rogers) to increase gain.
- Multiband or dual-band extension.
- Reconfigurable antennas with varactors or PIN diodes.
- Increased 5G throughput through MIMO integration.
- Validation of real-world experiments with VNA.
- Combining flexible and wearable electronics.

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