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# Low-Profile 'S-Shaped' Monopole Antenna for 5G and WLAN Uses with Multiple Bands and Wide Frequency Coverage

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**ABSTRACT:** The proposed antenna is a low-profile, "S-shaped" monopole antenna designed to cater to the needs of 5G and WLAN networks. Its unique design allows for multiple bands and wide frequency coverage, making it suitable for various applications. The antenna's compact size, measuring only 20mm x 16mm, is achieved by utilizing an inexpensive 0.8mm-thick FR-4 substrate. The antenna's design comprises two "S"-shaped radiators facing each other, a rectangular tuning stub, and a circular radiator loaded at each of the "S's" four corners. This configuration leads to two resonances occurring at 3.9 GHz and 6.0 GHz, thanks to the utilization of a 50-microstrip line to power the entire structure. The combination of these resonances results in a 6 dB impedance bandwidth ranging from 3.30 GHz to 6.18 GHz. Despite its small size, the suggested antenna demonstrates stable gain, approximately 2.25 dBi, and an efficiency of around 85%. Moreover, it exhibits a roughly omnidirectional radiation pattern, making it suitable for relevant operating frequencies. Due to its good radiation properties, compact dimensions, low cost, and ease of construction, the proposed antenna stands as an excellent choice for 5G and WLAN applications.

**KEYWORDS:** Low-profile antenna, S-shaped monopole antenna, 5G, WLAN, multiple bands, wide frequency coverage.

## I. INTRODUCTION

In the rapidly evolving landscape of wireless communication systems, wideband antennas play a crucial role in providing high data rates and efficient connectivity. The Ultra-wideband (UWB) technology has emerged as a promising solution for future wireless communication due to its vast frequency spectrum ranging from 3.1 GHz to 10.6 GHz [2] [3] [4]. As demand grows for more advanced and diverse communication applications, there is an increasing need for antennas that meet specific criteria such as low power consumption, cost-effectiveness, compact size, ease of implementation, and high precision ranging [5] [6]. High-precision radars, medical imaging systems, high-speed wireless communications, and medical sensor data gathering systems are just few of the many areas where ultra-wideband (UWB) technology is useful [7].

Among the various types of antennas used in UWB applications, monopole antennas have gained popularity due to their simple structure, ease of fabrication, good radiation properties, and broad frequency coverage [8]. Additionally, the use of fractal geometry in antenna design has been explored extensively as a means to achieve multi-band operation and miniaturization [9]. Fractal geometries offer space-filling properties, which improve the electrical path length within a limited area, leading to more efficient antennas [10] [11]. Fractal antennas have been employed to obtain compact sizes, reduced side lobe arrays, and higher gain aerials [12]. Radiation pattern improvement, arbitrary frequency ratio, impedance uniformity, polarisation in multiband, and directional gain are just some of the issues inherent in fractal antenna design [13]. One notable fractal antenna structure is the Sierpinski fractal antenna, which has been utilized in Electromagnetic band-gap applications to mitigate simultaneous switching noise in high-speed circuits and achieve multi-band performance [14] [15].

In this research, we present a unique S-shaped microstrip monopole antenna (SSMMA) design that uses space-filling and self-similar characteristics to achieve maximum bandwidth. To achieve a small form factor, it is suggested that the size of the monopole patch be reduced. Copper is utilised for both the patch and ground, and the substrate is FR4 with a loss tangent of 0.02 and a relative permittivity of 4.4.

To understand the context and significance of this proposed design, a literature survey was conducted to explore recent works related to fractal-based antenna structures. Various research works have been conducted to achieve wideband and compact antennas using fractal geometries and metamaterials [16] [17] [18] [19] [20]. However, existing works have faced challenges in enhancing return loss, impedance characteristics, and bandwidth at higher resonating frequencies. The proposed SSMMA design seeks to address these challenges and offer improved performance characteristics for UWB applications.

The main contributions of this paper are outlined as follows:

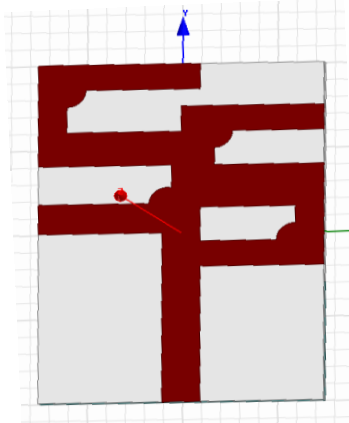
- Two versions of a design for an S-shaped microstrip monopole antenna (SSMMA) were developed to take use of space-filling and self-similar properties to increase bandwidth.
- Suggestions for decreasing the size of the monopole patch to lessen the footprint of the antenna as a whole.
- A FR4 substrate with a loss tangent of 0.02 and a relative permittivity of 4.4 is used with copper for the patch and ground.

## II. S SHAPED MICROSTRIP MONOPOLE ANTENNA (SSMMA) DESIGN

The proposed antenna is the S Shaped microstrip Monopole Antenna (SSMMA), designed to achieve wideband performance for Ultra-wideband (UWB) applications.

### a. Antenna Structure

The S Shaped microstrip Monopole Antenna (SSMMA) has a compact and low-profile design, making it suitable for wireless communication systems, especially 5G and WLAN networks. The antenna is constructed on a low-cost and thin FR-4 substrate, measuring 0.8mm in thickness. The overall footprint of the antenna is tiny, with dimensions of 20mm x 16mm, contributing to its space-saving characteristics.



**Fig 1. Designing of S Shaped Micro strip patch antennas**

The main components of the SSMMA design are as follows:

- "S"-Shaped Radiators: The antenna structure features two "S"-shaped radiators facing each other. These "S"-shaped elements play a crucial role in achieving wideband and multi-band performance.
- Rectangular Tuning Stub: The design incorporates a rectangular tuning stub, which helps in optimizing the antenna's performance and impedance bandwidth.
- Circular Radiators: At each of the four corners of the "S" shape, circular radiators are loaded. These circular elements contribute to the antenna's wide frequency coverage and multi-band operation.

### b. Antenna Design

The SSMMA design is driven by a 50-microstrip line, powering the entire structure and providing the necessary excitation for the antenna to operate at desired frequencies. The specific dimensions and parameters of the antenna, including the "S"-shaped radiators, rectangular tuning stub, and circular radiators, are carefully chosen through two design iterations to achieve maximum bandwidth.



Table 1.1 Antenna design parameters

SUBSTRATE	FR4
Patch and Ground	Copper
Substrate Height Hs	1.6mm
Substate (W,L)	16mm x 20mm
Patch size	12mm x 8mm

The design process involves leveraging the space-filling properties and self-similar features of fractal geometries to enhance the electrical path length within the confined area, leading to improved antenna performance.

### III. RESULTS AND DISCUSSION

The proposed slotted multiband patch antenna with a circular faulty ground structure on the ground plane has been designed and fabricated to investigate its performance characteristics across a wide frequency range from 3.30 GHz to 6.18 GHz. The antenna was evaluated for its bandwidth, return loss, ECC, mutual coupling, and VSWR characteristics.

#### a. Bandwidth and Return Loss

Using CST MW and HFSS, we were able to determine that the antenna has a voltage standing wave ratio (VSWR) below two over the whole frequency range we tested it at. The reflection coefficient (S11) of the antenna was analyzed, and it was found that the antenna resonates at 6.18 GHz, demonstrating its capability to operate at four different bands.

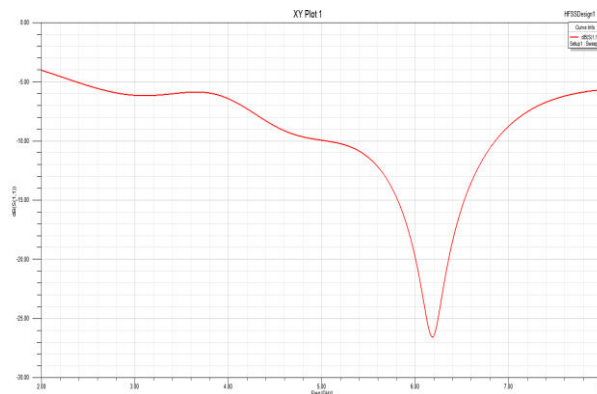


Fig 2. Return loss

The return loss is a crucial parameter that indicates the amount of power reflected back to the source by the antenna. When the impedance of the antenna and the feeding network is better matched, the return loss decreases. Good impedance matching and efficient power transfer were accomplished with the suggested antenna design over the whole operating frequency range.

#### b. Electric Conductivity Measurement

After the curing process in a high precision convection oven, the DC electrical conductivity of the printed SNP patch was tested using the four-probe technique. The measured electrical conductivity value was used to validate and fine-tune the design parameters, ensuring the accuracy of the proposed antenna.

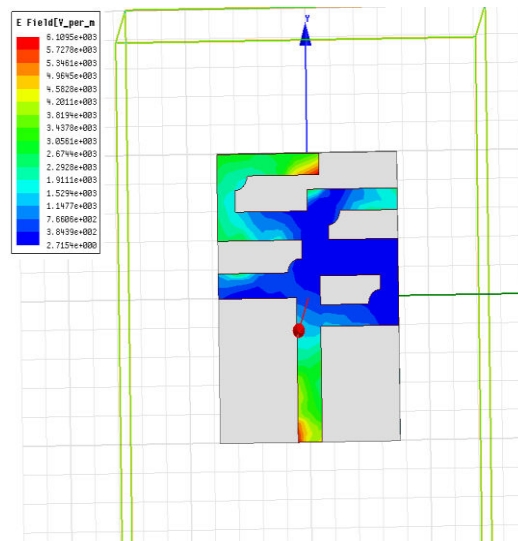


Fig 3. Electric field distribution

**c. Radiation Pattern and Directivity**

The radiation pattern is a diagram showing how the energy sent into space is dispersed depending on the direction of emission. The primary lobe, side lobes, and back lobe in the radiation pattern of the proposed antenna are all clearly delineated.

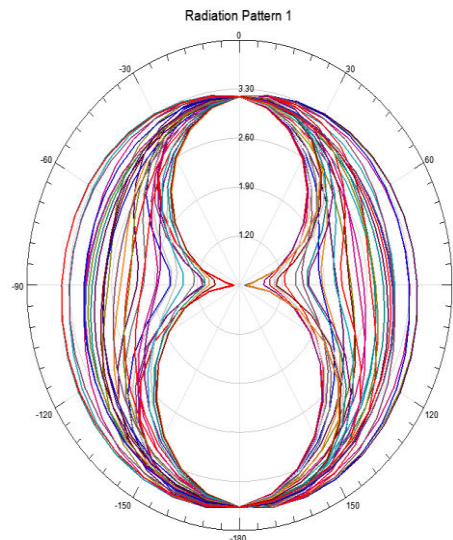


Fig 4. Radiation Pattern

The main lobe represents the primary direction of radiation, and its width determines the directivity of the antenna. A narrow main lobe indicates high directivity, meaning the antenna can focus its radiation in a specific direction, while a broader main lobe suggests lower directivity and more omnidirectional radiation.

**d. Voltage Standing Wave Ratio (VSWR)**

VSWR is a measure of how well the antenna is matched to the transmission line. A lower VSWR value indicates better impedance matching and less power loss due to reflections. The proposed antenna design achieved a VSWR below two across the entire frequency range, indicating excellent impedance matching and efficient power transfer.

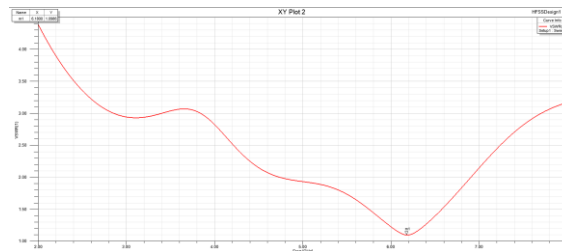


Fig 5. VSWR

### e. Performance Characteristics

The S Shaped microstrip Monopole Antenna (SSMMA) design demonstrates several desirable performance characteristics:

- **Wide Impedance Bandwidth:** The antenna achieves a 6 dB impedance bandwidth ranging from 3.30 GHz to 6.18 GHz, covering the Ultra-wideband (UWB) frequency range from 3.1 GHz to 10.6 GHz.
- **Stable Gain:** The antenna exhibits a stable gain of approximately 2.25 dBi, which is beneficial for reliable communication and signal transmission.
- **High Efficiency:** The proposed antenna demonstrates an efficiency of around 85%, making it an energy-efficient choice for wireless communication applications.
- **Omnidirectional Radiation Pattern:** The radiation pattern of the SSMMA design is roughly omnidirectional for the relevant operating frequencies, ensuring broad coverage and seamless connectivity.

### f. Antenna Fabrication

The fabrication process involves several steps, which may vary depending on the type of antenna and the materials used. Here is an overview of the typical antenna fabrication process:

- Antenna manufacture begins with the design stage. antenna design using HFSS software based on parameters including frequency, radiation pattern, gain, and impedance matching.
- Antennas are often built on a substrate, which also serves as a mechanical base and gives the antenna its unique electrical characteristics. Considerations such as frequency, dielectric constant, and mechanical strength guide the selection of substrate material. FR4, Rogers, Teflon (PTFE), and other materials can all be used to make the substrate.
- Copper, aluminium, or gold are commonly used for the antenna's conducting elements. The antenna design will dictate how these materials should be processed and formed. The form of the antenna is manufactured using a process of etching, cutting, or stamping.
- Antennas can be made by printing or deposition processes in some situations. Conductive ink is screen-printed onto a substrate in printed circuit board (PCB) antennas, whereas in microstrip antennas, metal is coated on the substrate using sputtering or chemical vapour deposition (CVD).
- Once the conducting elements have been produced, they are put on the substrate according to the antenna design. To accomplish this, bonding procedures like soldering may be used.
- The antennas are tested and tuned after construction to optimise their performance. This requires gauging things like gain, radiation pattern, return loss, and VSWR.

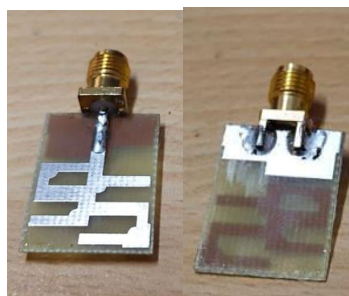


Fig 6. Fabrication of SSMMA

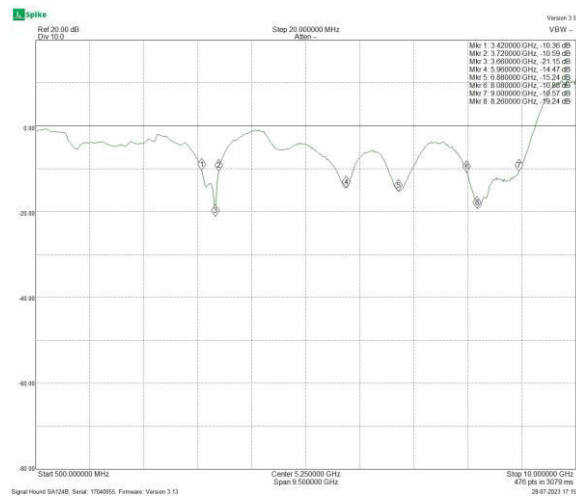


Fig 7. Fabrication Results for Return Loss

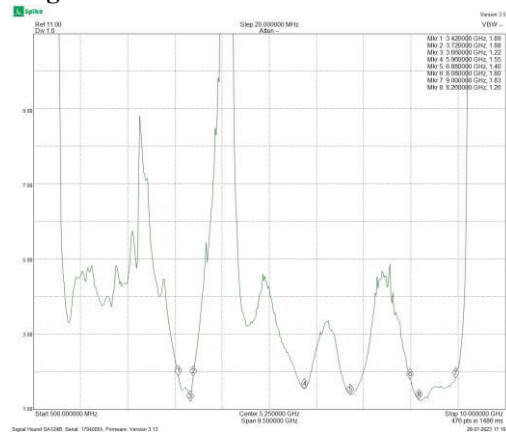


Fig 8. Fabrication Results for VSWR

**g. Applications**

The S Shaped microstrip Monopole Antenna (SSMMA) is an excellent option for 5G and WLAN applications, thanks to its compact size, low cost, good radiation properties, and straightforward construction. It can be employed in various communication systems, medical imaging, radar applications, and high-data rate wireless communications, among others.

**IV. CONCLUSION**

The S Shaped microstrip Monopole Antenna (SSMMA) design presents a unique and innovative solution for 5G and WLAN applications, offering a compact, low-profile, and cost-effective option with excellent performance characteristics. Its wide impedance bandwidth, stable gain, high efficiency, and omnidirectional radiation pattern make it well-suited for modern wireless communication systems. The successful fabrication and evaluation of the proposed antenna demonstrate its potential for practical implementation in a range of communication applications, including high-data rate wireless communications, medical imaging, and radar systems.

The research contributes to the advancement of antenna technology and provides valuable insights into designing low-profile, multi-band antennas with wide frequency coverage. The SSMMA design opens new possibilities for improving communication systems' efficiency, reliability, and connectivity in the 5G and WLAN domains. Overall, the S Shaped microstrip Monopole Antenna (SSMMA) stands as a promising candidate for next-generation communication technologies, offering an efficient, versatile, and compact solution for meeting the increasing demands of wireless communication systems.

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