

# *Microstrip Patch Antenna Loaded with Shapes of Triangle and Circle using Metamaterial Structure*

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**Abstract:** The proposed antenna structure incorporates concentric circular and equilateral triangular ring elements arranged about a common center, maintaining uniform separation and avoiding geometric overlap to ensure accurate numerical modeling. MATLAB's Antenna Toolbox and Partial Differential Equation (PDE) Toolbox are utilized for geometric construction, finite-element mesh generation, and comprehensive electromagnetic analysis. The performance of the antenna is assessed based on key parameters such as impedance behavior, reflection coefficient, radiation pattern, and directivity at an operating frequency of 915 MHz, which is widely used in RFID and other wireless communication systems. The simulated results confirm that the proposed antenna configuration achieves satisfactory radiation performance and structural compactness, thereby demonstrating the suitability of MATLAB as an efficient and reliable platform for antenna design, analysis, and optimization.

**Keywords:** Microstrip Patch Antenna, Metamaterial Structure, Triangular Patch, Circular Patch, Split Ring Resonator (SRR), Complementary Split Ring Resonator (CSRR),

## **1. Introduction:**

Microstrip patch antennas are among the most widely used antenna structures in modern wireless communication systems due to their low profile, light weight, compact size, and ease of fabrication. A typical microstrip patch antenna consists of a radiating metallic patch printed on one side of a dielectric substrate, with a ground plane on the opposite side. The patch can take various shapes such as rectangular, circular, triangular, or more complex geometries, depending on the desired operating frequency and radiation characteristics. These antennas are usually fed using techniques such as microstrip line feed, coaxial probe feed, aperture coupling, or proximity coupling. The popularity of microstrip patch antennas arises from their compatibility with integrated circuits and printed circuit board (PCB) technology, making them highly suitable for applications in mobile communication, satellite systems, radar, wireless local area networks (WLAN), and emerging 5G and Internet of Things (IoT) systems. Despite their advantages, microstrip patch antennas suffer from certain limitations such as narrow bandwidth, low gain, and relatively low efficiency. As a result, extensive research has been carried out to enhance their performance through techniques such as the use of different patch shapes, slotting,

stacked structures, metamaterial loading, and array configurations.

In recent years, microstrip patch antennas have gained renewed attention due to their adaptability to advanced design methodologies and novel materials. The incorporation of metamaterials, defected ground structures (DGS), and reconfigurable elements has significantly improved bandwidth, gain, and radiation efficiency while reducing antenna size. Owing to their versatility and continuous performance enhancement, microstrip patch antennas remain a key component in the development of next-generation wireless communication systems.

## **2. Related Work:**

Microstrip patch antennas have emerged as one of the most widely adopted antenna configurations in modern wireless communication systems owing to their compact size, low weight, low fabrication cost, ease of integration with microwave circuits, and conformal nature. Typically, the antenna design and performance evaluation process begins with electromagnetic simulation using commercial design software, followed by fabrication and experimental verification to validate the simulated results. A systematic and comprehensive review of previous research efforts is essential to identify research gaps and to establish a strong foundation for the proposed work. Accordingly, this chapter presents an extensive review of earlier investigations related to microstrip patch antennas, multiband operation, antenna miniaturization, and metamaterial-based performance enhancement techniques.

The first practical realization of a microstrip patch antenna was reported by Munson (1974), marking a major milestone in antenna engineering. Subsequently, Howell (1975) carried out one of the earliest analytical and experimental studies on practical microstrip antenna configurations. A significant theoretical breakthrough was achieved by Lo et al. (1979), who introduced the cavity model approach for analyzing microstrip patch antennas. The predicted theoretical results obtained using this model showed good agreement with measured data, thereby validating the accuracy of analytical modeling techniques.

Further advancements in microstrip antenna design were reported by Garg et al. (2001), who extensively studied various patch geometries suitable for microstrip antennas. Rectangular, circular, elliptical, and triangular patches were identified as the most commonly used shapes due to their design simplicity and predictable radiation characteristics. Pozar (1992) demonstrated that the performance of microstrip

antennas could be significantly improved by employing thick substrates with low dielectric constants, leading to enhanced bandwidth, radiation efficiency, and gain. The computation of far-field radiation patterns and radiation conductance parameters was further detailed by Derneryd (1979).

The influence of dielectric superstrates on the resonant frequency of circular microstrip patch antennas was investigated by Guha and Siddiqui (2003), and the proposed theoretical formulations were experimentally validated. To achieve multiband characteristics, Kuo and Wong (2003) introduced dual stacked monopoles and dual T-shaped monopoles, enabling operation over multiple frequency bands. More recently, Ashim Kumar Biswas and Ujjal Chakraborty (2019) proposed a wideband wearable antenna integrated into denim fabric using stub-loaded structures. The antenna supported WLAN applications at 2.4 GHz, 5.3 GHz, and 5.75 GHz, and also demonstrated suitability for C-band satellite communication. In a related work, the same authors introduced microstrip neutralization lines to achieve wideband performance for satellite and defense communication applications.

### 3. Methodology:

Design, analyze, and visualize antenna elements and antenna arrays

Antenna Design Toolbox provides functions and apps for the design, analysis, and visualization of antenna elements and arrays. It design standalone antennas and build arrays of antennas using either predefined elements with parameterized geometry or arbitrary planar elements.

Antenna Toolbox uses the method of moments (MoM) to compute port properties such as impedance, surface properties such as current and charge distribution, and field properties such as the near-field and far-field radiation pattern. It helps to visualize antenna geometry and analysis results in 2D and 3D.

It integrates antennas and arrays into wireless systems and use impedance analysis to design matching networks. Antenna Toolbox provides radiation patterns for simulating beam forming and beam steering algorithms. Gerber files can be generated from your design for manufacturing printed circuit board (PCB) antennas. It installs the antennas design on large platforms such as cars or airplanes and analyzes the effects of the structure on antenna performance. A site viewer enables you to visualize antenna coverage on a 3D terrain map using a variety of propagation models.

#### Design Specification

The objective is to design a **fully concentric multi-geometry structure** consisting of a **circular region enclosed by an equilateral triangle ring**, such that:

- All shapes share the **same center / centroid** at  $(x_c, y_c) = (0.4, 0.4)$
- The triangle ring is **outside the circle**
- There is a **uniform clearance (gap) of 0.05mm** between the circle and the triangle ring
- The triangle ring has a **uniform thickness of 0.05mm**
- The triangle is **equilateral and upright**
- No overlaps occur anywhere in the design

- The geometry is valid for **modeling, and numerical simulations**

### 4. Result and Discussion:

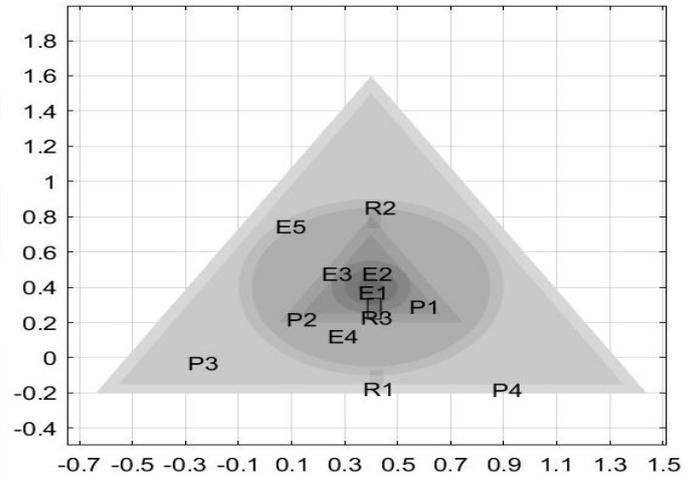


Figure 1: Antenna geometry

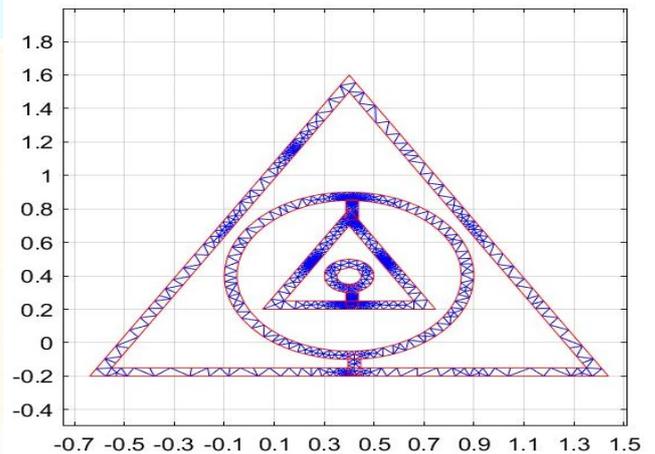


Figure 2: Antenna mesh

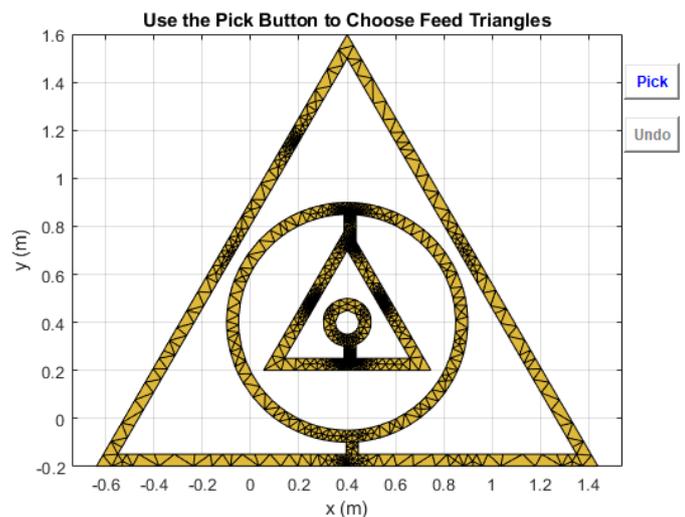


Figure 3: Loading plane

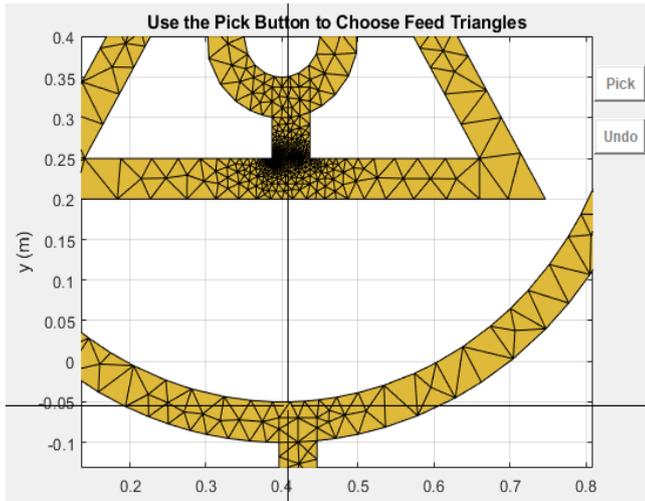


Figure 4: Input the feed point

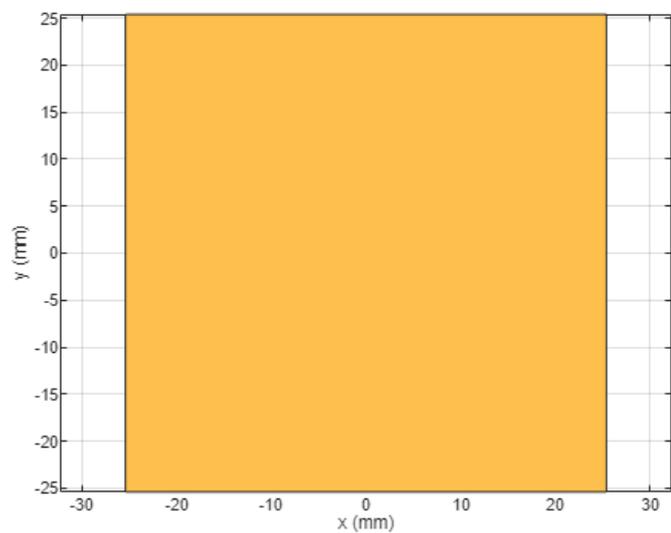


Figure 6: Design Board

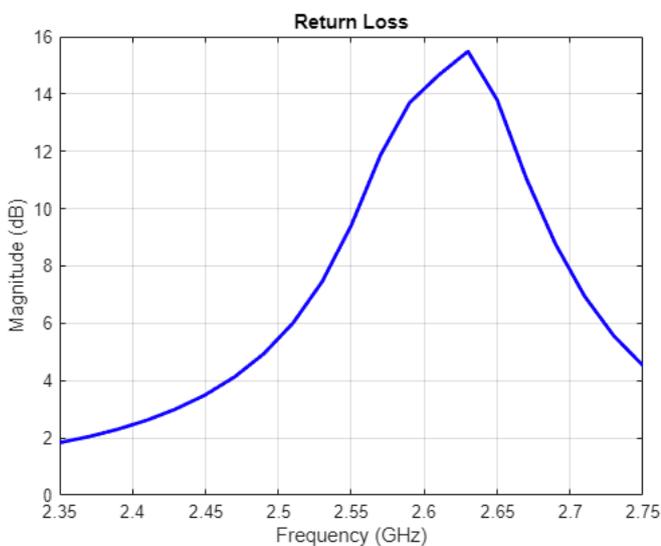


Figure 7: Return Loss

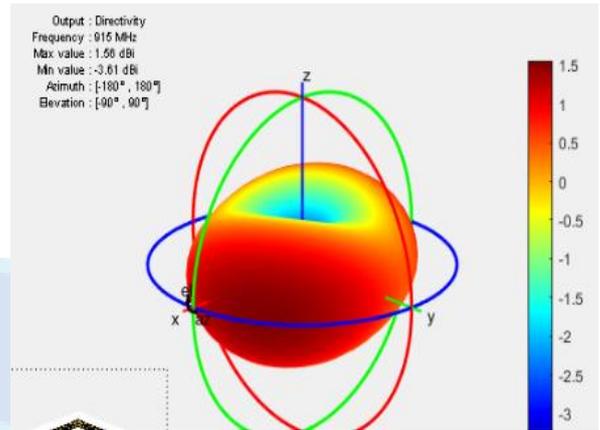


Figure 8: Directivity of the antenna

### 5. Conclusion:

This work successfully demonstrates the design and analysis of a concentric multi-geometry microstrip antenna using MATLAB. A precise geometric construction methodology based on inradius-controlled equilateral triangular rings and concentric circular elements was developed to ensure uniform spacing, concentricity, and numerical robustness. The PDE Toolbox enabled efficient creation and meshing of the complex antenna geometry, while the Antenna Toolbox facilitated accurate electromagnetic analysis using full-wave numerical techniques. Simulation results indicate that the antenna exhibits inductive impedance behavior with radiation characteristics suitable for short-range RFID applications at 915 MHz. The directivity and radiation patterns confirm adequate coverage in the desired plane, validating the operational feasibility of the proposed design. Overall, the study confirms that MATLAB provides an effective, integrated environment for antenna modeling, analysis, and performance evaluation, reducing design complexity and development time.

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