# Design of a Dual Band Antenna with Concentric Ring Structure for Wireless Communication

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## Abstract:

In today world Microstrip patch antennas have gained major attention in modern wireless communication systems due to their small and compact size, low profile, simple fabrication, and cost-effectiveness. This work presents the design of a dual-band flexible microstrip patch antenna incorporating a concentric ring configuration and fed through a coplanar waveguide (CPW). The antenna is implemented on a lightweight, paper-based circular substrate with a dielectric constant of 3.55, which contributes to mechanical flexibility and reduced manufacturing costs.

The antenna is designed to operate efficiently at two resonant frequencies: 2.62 GHz and 5.5 GHz. Its electromagnetic performance is analyzed using Advanced Design System (ADS) software, focusing on key parameters such as return loss, gain, VSWR, and radiation pattern. With its dual-band operation and planar structure, this antenna is well-suited for integration into wireless communication systems supporting applications like WiFi, WLAN, Bluetooth, and satellite links.

**Keywords:** Dual-band antenna, concentric ring, CPW feed, flexible substrate, return loss, WiFi, WLAN, Bluetooth, satellite communication

## 1. Introduction:

The rapid development of wireless technology and the miniaturization of electronic components, the integration of compact and intelligent systems has significantly advanced across various smart applications. Recent research has focused heavily on body-centric and close-proximity wireless communication systems, enhancing the practicality of real-time sensing and data transmission in diverse environments [1]. These innovations enable seamless connectivity for a wide range of use cases such as industrial automation, smart wearables, and remote sensing.

One of the most impactful applications is the development of remote monitoring systems, which allow critical data to be gathered and transmitted without physical constraints. Wireless communication technologies serve as the backbone for such systems, enabling reliable, untethered data flow. Various systems make use of this technology such as the radar system for remote indoor fall detection [1] and wearable modules used for smart environmental or motion sensing [2]. A typical remote sensing module is composed of four core blocks:

(a) a sensing block to collect environmental or motion data
(b) a microcontroller to process and route this data
(c) a transceiver for wireless communication
(d) a power supply to drive the entire system.

For efficient data acquisition and unobtrusive usage, such modules are often embedded into garments, elastic materials, or flexible surfaces. These systems are expected to be lightweight, noninvasive, and conformal for integration into smart clothing or next-to-skin platforms.

The remote monitoring module is able to track real time information on physical condition as well as movement. Multiple sensors are integrated into textile, elastic band or directly adhered to human skin in combination with external devices for monitoring wirelessly heart rate [3], body temperature [4], electrocardiogram [5] and so on. A basic structure of a microstrip patch antenna is presented in Figure 1. The above intact monitoring module can transmit the measured the data through Bluetooth or WLAN or WiFi to the computer or a mobile device to store and analyze the data.

The antenna is a critical component that enables wireless connectivity within these systems. While single-band antennas are sufficient for basic communication, multiband antennas enhance operational flexibility by allowing communication over multiple frequency bands. This multi-standard capability supports communication across diverse protocols and networks, making such antennas essential in IoT, smart textile, and location-aware systems. Various wearable devices designed on flexible materials have been manufactured with multiband antennas to work with WiFi, Bluetooth or WLAN, even GSM mobile systems [6-8].

Among various antenna designs, microstrip patch antennas have emerged as a preferred solution for compact wireless devices due to their low profile, ease of integration, cost-effectiveness, and compatibility with flexible substrates. To further improve bandwidth and frequency agility, concentric ring structures are often employed in antenna geometry, as they support multiband operation by introducing additional resonant paths without significantly increasing the antenna's physical footprint.

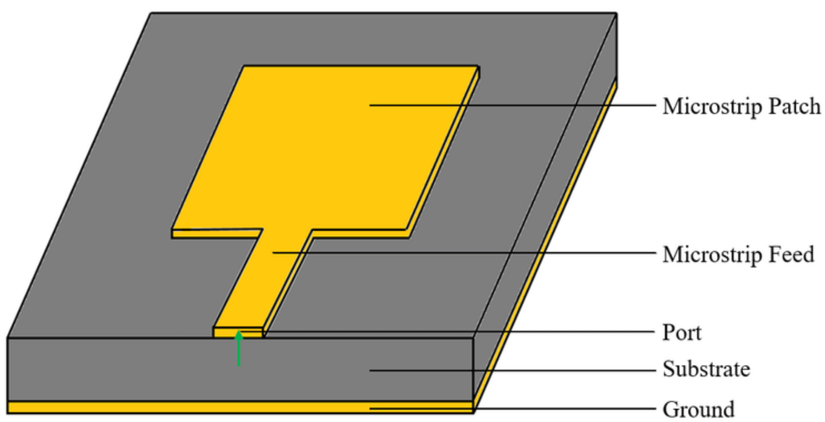



Figure 1: Basic Structure of Microstrip Patch Antenna

In this work, we present the design, simulation, and performance analysis of a dual-band antenna based on a concentric ring structure, optimized for operation in the 2.4 to 2.6 GHz and 5 to 5.5 GHz frequency bands. These bands cover widely used wireless standards including Bluetooth, WiFi (IEEE 802.11b/g/n/ac), WLAN, and some IoT communication protocols. The antenna is fabricated on a flexible, low-cost substrate, making it suitable for applications in next-generation wireless devices, smart environments, and embedded communication platforms.

The proposed design is evaluated us ing electromagnetic simulation tools, with key performance metrics such as return loss, voltage standing wave ratio (VSWR), gain, radiation pattern, and efficiency analyzed to validate its suitability for dual-band operation. The results demonstrate the potential of this antenna design to serve as a compact and reliable solution for flexible wireless communication systems.

## 2. Designing of Proposed Antenna Structure

### 2.1. Substrate Selection:

The antenna is built using PREPERM paper from the Premix Group, which has a relative permittivity of 3.55. This particular material was selected because it's flexible, thin, durable, and easy to print on, ideal qualities for wearable technology. To evaluate its performance, we used full-wave electromagnetic simulation in Advanced Design System (ADS) software, modeling the antenna with a substrate thickness of just 1.5 mm. Properties of the substrate materials are given below in Table 1:

Table 1: Properties of the Substrate Material used in the proposed Antenna:

| **Property** | **Value** |
|---|---|
| Relative Permittivity | 3.55 |
| Thickness | 1.5mm |
| Flexibility | High |
| Printability | Yes |
| Mechanical Robustness | High |
| Dielectric Loss Tangent | 0.005 |

The use of paper as the substrate material provides several advantages for the proposed antenna, including high flexibility, low profile, high mechanical robustness, and printability. The low dielectric loss tangent and relative permittivity of the material also contribute to the antenna's performance, allowing for efficient and effective transmission and reception of electromagnetic waves. The thickness of 1.5mm was chosen as a compromise between flexibility and mechanical robustness, and the antenna's electromagnetic properties were modeled and analyzed using Advanced Design System (ADS) software to ensure optimal performance.

### 2.2. Designing of Antenna:

A microstrip patch antenna is a simple, single-layer design made up of four key components: the patch, ground plane, substrate, and the feed mechanism. Once the operating frequency is set, characteristics like the radiation pattern and input impedance are essentially determined. The metallic patch itself can take on various shapes such as circular, rectangular, triangular, or even hexagonal, depending on the application. For the purpose of multiband in this article, several techniques have been used including fractal [9], meandering [10], modified ground plane [11], or slot techniques [12]. There are a few slot designs for bandwidth modification and size reduction in which the multiband and dual band existence is one of its functions. In general, split ring resonator (SRR) structure [13] is classified among left-handed materials besides photonic band gap (PBG) [14], electronic band gap (EBG) and artificial magnetic conductor. In this work, we specifically use a circular Split Ring Resonator (SRR) [9] configuration to achieve multiband functionality.

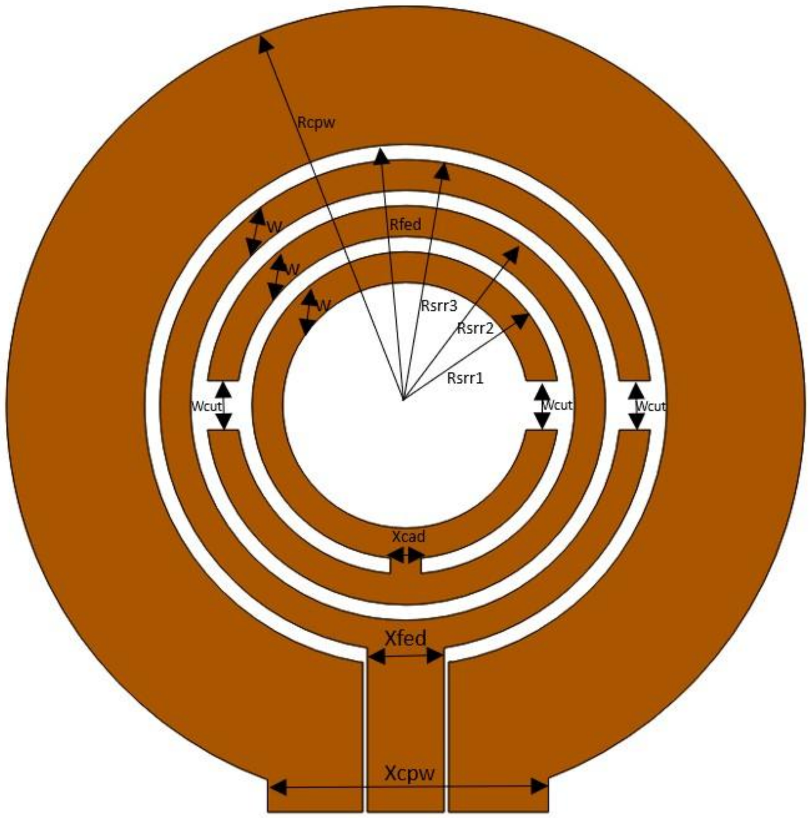



Figure 2: Geometry of Flexible Dual-Band Antenna

The above Figure 2 is the antenna design of CPW-fed circular dual band antenna with a split ring resonator-based radiating element in the center and all the dimensions are mentioned in the Table 2.

Table 2: Parameter and Dimension of the proposed Antenna

| **Parameter** | **Dimensions (mm)** | **Parameter** | **Dimension (mm)** |
|---|---|---|---|
| Rcpw | 26 | W | 2 |
| Rfed | 17 | Wcut | 3.2 |
| Rsrr1 | 10 | Xcad | 2 |
| Rsrr2 | 13 | Xfed | 5 |
| Rsrr3 | 16 | Xcpw | 18 |

Initially, a single-band antenna was created by placing a patch at the center of the substrate. To enable dual-band operation, this patch was later replaced with a configuration of three split-ring resonators (SRRs). The antenna is excited through a current probe connected to the outermost ring, which in turn induces surface currents in the two inner rings. The gaps between the ring labeled as W in Figure 2 allow electric charges to build up, creating a high capacitance that supports operation at two distinct frequency bands.

The antenna has a circular shape, making it easier to mount on various parts of the human body for wearable applications. Both the radiating elements and the ground plane are printed on the same side of the substrate.

This design choice frees up the opposite side for integrating other sensors, such as those for tracking temperature, humidity, or respiration rate without increasing the overall device footprint. Final view of Antenna Model in ADS software is shown in the Figure 3 give below:

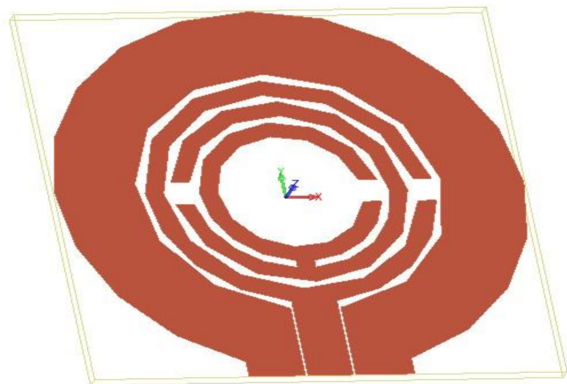


Figure 3: Final view of Antenna Model in ADS

## 3. Results and Discussion:

In the evolving landscape of wireless communication, microstrip patch antennas have gained prominence due to their compact structure, low cost, and ease of fabrication. Their ability to be integrated into flexible substrates makes them suitable for modern applications such as IoT devices, smart wearables, and embedded systems. Among various feeding techniques, the coplanar waveguide (CPW) feed is particularly advantageous because of its low radiation loss, planar configuration, and ease of integration into flexible designs.

This study presents a dual-band microstrip patch antenna incorporating a concentric ring structure, inspired by split ring resonator geometry, to support operation at 2.62 GHz and 5.5 GHz. These frequencies correspond to widely used wireless standards like Wi-Fi, Bluetooth, and WLAN, allowing the antenna to support multi-protocol connectivity. The antenna was designed on a flexible substrate, making it ideal for compact and conformal communication systems. The CPW feeding technique contributed to improved bandwidth and impedance matching, ensuring stable performance across both bands.

The design and performance analysis were conducted using Advanced Design System (ADS) software. Key parameters such as return loss, VSWR, radiation pattern, and 3D polar plots were evaluated. The antenna demonstrated return loss values below −10 dB at both target frequencies, indicating good resonance. Directional radiation characteristics were observed at both bands, with stable gain and radiation efficiency, confirming the suitability of the design for flexible, dual-band wireless communication applications.

### 3.1. Return Loss:

In this article, the measured return loss of this antenna is at 2.62 GHz and 5.5GHz frequency are shown in Figure 4. This range of frequency shows the applications of Wi-Fi, WLAN and Bluetooth. The return loss measured at the given frequencies are as given below:

- Resonant Frequency 2.62 GHz, Return Loss 13.228dB
- Resonant Frequency 5.5 GHz, Return Loss 27.496dB

The reflection coefficients at both frequencies express the value below -10dBf.

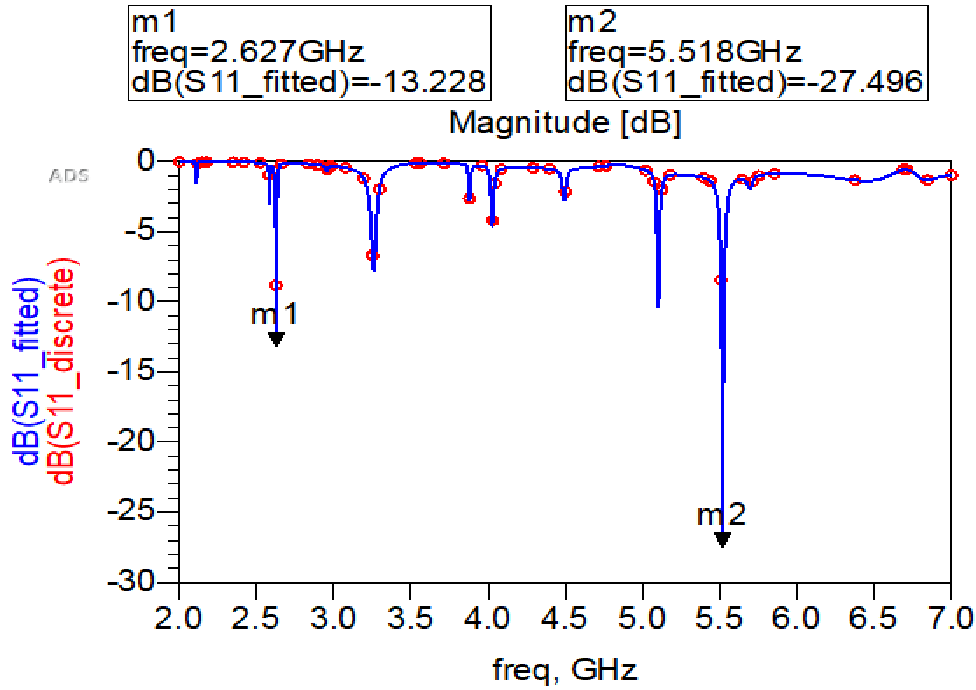



Figure 4: Return Loss Measurement or S (1,1) Parameter

### 3.2. Current Distribution:

The current distribution on the surface of an antenna provides valuable insight into how the antenna radiates and operates at specific frequencies. The direction arrows in the figure indicate the surface current flow, which helps identify resonant modes and detect any feed-related issues. Analyzing this distribution ensures that the antenna is properly excited and radiating efficiently. Figure 5 given below shows the surface current distribution of the proposed antenna at one of its resonant frequencies. The figure highlights regions of strong current concentration, especially around the feedline and the inner rings, confirming effective excitation and resonance behavior in the designed structure.

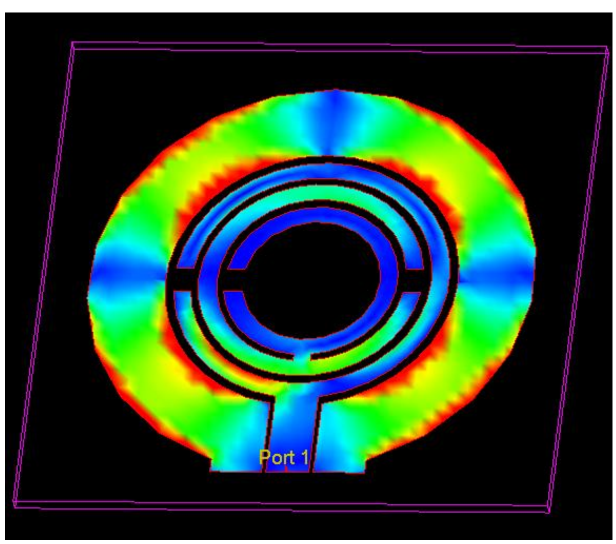



Figure 5: Current Distribution of proposed Antenna

### 3.3. Directivity:

The amount to which an antenna focuses energy in a particular direction is known as its directivity. Directivity (D) is directly proportional to gain (G), as all antennas emit in all directions, gain is defined as amount of power that may be gained in one direction at expense of power lost in all other directions. The graph for directivity is shown in Figure 6. The peaks in the graph correspond to the operating frequencies where the antenna radiates more directionally.

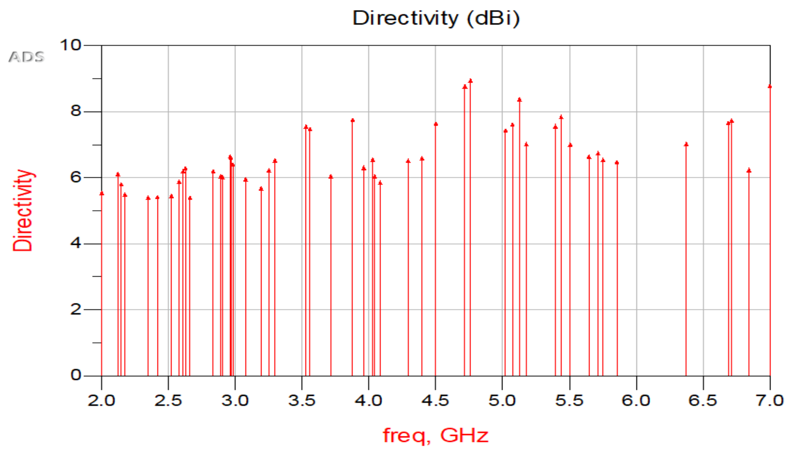



Figure 6: Graph Obtained for Directivity

### 3.4. Efficiency:

Antenna efficiency is defined as the ratio of the power radiated by the antenna to the total power accepted at its input. It accounts for losses due to conduction, dielectric materials, and mismatch. A high-efficiency antenna radiates most of the accepted power, making it more effective for wireless communication.

For the proposed antenna structure, Figure 7 given below illustrates the efficiency variation over the operating frequency range. As seen in the figure, the antenna maintains a relatively high efficiency across both targeted frequency bands.

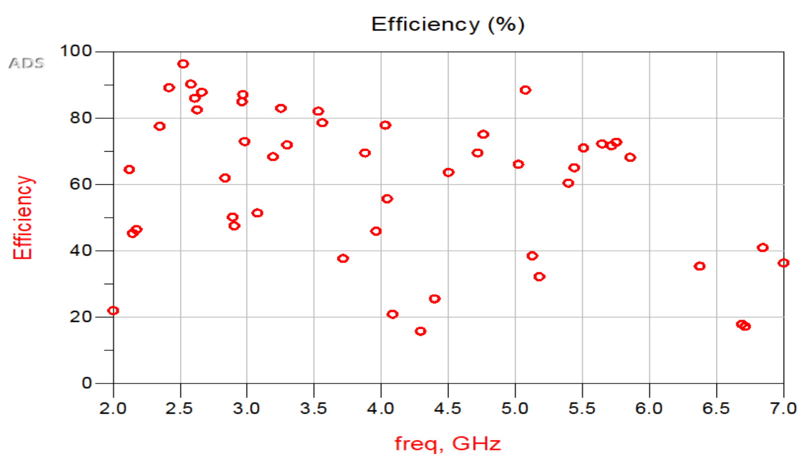
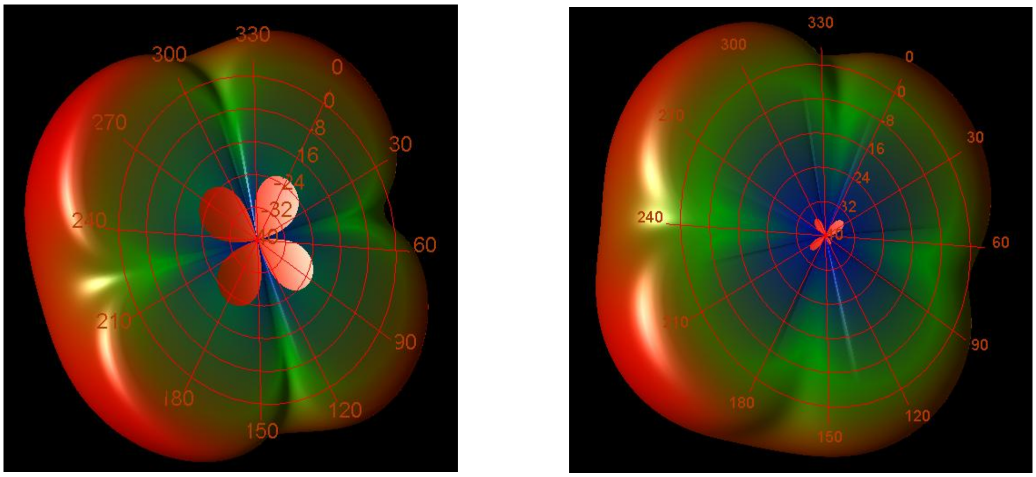



Figure 7: Efficiency Pattern

### 3.5. Radiation Pattern:

The radiation pattern of an antenna describes how it emits or receives energy in space. For the proposed design, the radiation pattern was analyzed at both resonant frequencies—2.62 GHz and 5.51 GHz. The radiation pattern is a three-dimensional figure and represented in spherical coordinates (φ, y, θ), where its origin lies at the center of the spherical coordinate system.

Radiation patterns are the diagrammatical representations of the distribution of radiated energy into space, as a function of signal direction. The radiation pattern is used to measure the emission and reception of wave of the antenna. Figure 8(a) and 8(b) give below represent the 3D radiation pattern of the antenna at resonant frequencies 2.62 GHz and 5.51 GHz respectively.




8(a) 2.62GHz

8(b) 5.51GHz

Figure 8: 3D Radiation Pattern

## 4. Conclusion:

The development of a dual-band antenna based on a concentric ring structure marks a significant advancement in antenna engineering, especially for compact and wearable wireless communication systems. As the demand for high-speed connectivity and device miniaturization continues to rise, this design addresses the critical need for multi-band performance within limited space. By leveraging two concentric rings, the antenna can independently resonate at 2.62 GHz and 5.5 GHz, enabling dual-band communication suitable for applications like heaalthcare monitoring, IoT devices, and personal wireless gadgets. The use of a flexible, low-cost paper substrate with a dielectric constant of 3.55 not only supports compactness and performance but also aligns with the push for environmentally friendly electronics.

Simulation results using Advanced Design System (ADS) software validate the antenna’s effectiveness, showing excellent return loss values and stable radiation patterns across both frequency bands. The antenna’s consistent performance in both near-field and far-field conditions, combined with its planar and flexible design, makes it highly suitable for wearable and conformal use cases such as smart clothing, biomedical sensors, and military applications. Compared to more complex structures like stacked patches or fractals, the concentric ring antenna stands out for its simplicity, ease of fabrication, and adaptability without sacrificing performance. This makes it a strong candidate for integration into next-generation wireless technologies where efficiency, portability, and versatility are essential.

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