Design of Circular Microstrip Patch Antenna by Stacked Configuration

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Abstract - In this research paper, a novel design of circular patch antenna with a low weight and low-profile structure is introduced. The antenna incorporates a stacked-patch configuration, a coupled annular ring, and conductive vias to increase the impedance bandwidth. The circular stacked microstrip patch antenna is designed using HFSS Software. The measurement results demonstrate that the antenna achieves impressive impedance bandwidths of 2.35–2.43 GHz Moreover, the antenna boasts a compact structure with a height of only 0.24311024 inch (equivalent to a free-space wavelength). This design is particularly well-suited for applications such as wireless local area networks as the results indicated by HFSS Software. The antenna is perfect to improve the gain performance.

Key Words**: Low profile, circular patch, wireless local area network (WLAN), conductive vias**

1. INTRODUCTION

Wireless communication systems use electromagnetic waves to transmit and receive data, revolutionizing communication by enabling mobility, flexibility, and connectivity across various applications. Wireless communication systems involve a transmitter, receiver, channel, antennas, modulation, and multiplexing. The transmitter converts information into electromagnetic signals, modulates them, and amplifies them for transmission. The receiver captures and demodulates the transmitted signals, extracting the original information.

Channel characteristics, such as attenuation, noise, and interference, influence the system's performance. Antennas facilitate transmission and reception, and modulation techniques like AM, FM, and PM are employed. Multiplexing techniques enable efficient sharing of the same communication channel. Protocols and standards ensure interoperability, reliability, and security. Wireless communication systems are used in various fields, including mobile communication, IoT devices, wireless sensor networks, satellite communication, and wireless LANs.

Wireless communication is essential in today's world for its ubiquitous connectivity, mobility, IoT applications, remote access, digital transformation, emergency communication, smart cities, economic growth, education and healthcare, and environmental impact. It enables constant internet connectivity, allowing people to stay connected, work, communicate, and access information on the go. Wireless technologies drive digital transformation by enabling cloud computing, big data analytics, and artificial intelligence, improving operational efficiency and competitiveness categorize.

Wireless communication systems use various types of antennas, each designed for specific applications, frequency bands, and performance requirements. Common types include dipole antennas, Yagi-Uda antennas, patch antennas, parabolic reflector antennas, helical antennas, patch array antennas, log-periodic antennas, horn antennas, and omni-directional antennas. Dipole antennas are used in Wi-Fi routers, RFID systems, and amateur radio.

Yagi-Uda antennas provide high gain and directivity for long-distance communication. Patch antennas are compact and lightweight, ideal for limited space integration. Parabolic reflector antennas focus radio waves onto a smaller feed antenna, while helical antennas provide circular polarization. Patch array antennas offer high gain, beam steering capabilities, and polarization diversity. Antenna design plays a critical role in the performance and efficiency of wireless communication systems.

1.1 Objectives

The objective behind developing a low-profile low weight microstrip patch antenna for WLAN (Wireless Local Area Network) communications stems from the increasing demand for efficient and reliable wireless communication systems in both indoor and outdoor environments. With the proliferation of wireless devices and the growing need for high-speed internet access, WLAN technologies such as Wi-Fi have become ubiquitous in various settings including homes, offices, and public spaces. A this antenna is desirable for WLAN applications as it can operate at 2.4 GHz frequency band, providing flexibility and better coverage for different types of devices and environments.

2. Related Work

Design of Dual-Band Omnidirectional Cylindrical Dielectric Resonator Antenna [1], This letter looks at the design of a dual-band omnidirectional cylindrical dielectric resonator antenna (DRA) employing and modes. The frequency ratio limit is discovered, and methods for calculating the DRA's dimensions from two specified frequencies are presented. A dual-band omnidirectional cylindrical DRA working in the 5.8-GHz WLAN and 3.5-GHz WiMAX bands is constructed and tested in order to validate the idea. A decent degree of agreement between measurement and theory is noted as the reflection coefficient, radiation pattern, and antenna gain are examined (DRA).

Dual-Band and Dual-Sense Omnidirectional Circularly Polarized Antenna [2], In this letter, for dual-band applications, a circularly polarized (CP) dielectric resonator antenna (DRA) loaded with a modified circular patch is suggested. A probe feeds the antenna in the center, producing omnidirectional patterns with two bands of distinct circular polarization sensitivities. It is found that the dielectric resonator (DR) and patch, respectively, regulate the upper and lower bands, which makes dual-band antenna design quite simple. A prototype has been created, manufactured, and measured for demonstration purposes. The antenna has three-dB axial-ratio (AR) bandwidths of 3.16% and 18.03%, and 10-dB impedance bandwidths of 2.64% and 18.03%.

Dual Band Stacked Annular Slot/Patch Antenna for Omnidirectional Radiation [3], This letter provides the design for a novel omnidirectional antenna that operates in two bands, 2.5 GHz and 3.5 GHz, and is made up of an annular patch and annular slot stacked together. Simulations are used to show how the antenna characteristics affect dual band functioning. For demonstration purposes, a FR4 substrate was used to create a prototype of the suggested antenna. Dual band functioning is evident in the observed reflection coefficient.

A Dual-Frequency Broad-Band Design of Coupled-Fed Stacked Microstrip Monopolar Patch Antenna for WLAN Applications [4], For WLAN applications, a unique dual-frequency broad-band design of a stacked microstrip monopolar patch antenna is suggested. The antenna consists of a circular patch on the top layer and a via-loaded ring on the bottom layer, both of which are coupled-fed by a circular coupler. Converging the TM 01 and TM 02 modes of the via-loaded ring produces a broad bottom band and a broad upper band.

Omnidirectional Dual-Band Dual Circularly Polarized Microstrip Antenna Using and Modes [5], An investigation is conducted on an omnidirectional dual-band dual circularly polarized (CP) antenna that uses and modes to produce wide beam radiation patterns. The suggested antenna consists of a disk-loaded coaxial probe and a circular patch with eight curved slots. The currents flowing on the patch and the coaxial probe, respectively, yield the horizontal and vertical polarizations. At both resonant modes, omnidirectional CP fields can be produced when the two orthogonally polarizations have similar amplitudes and diverge by 90 degrees in phase. The suggested antenna has a broad beam width of 100 in the elevation with a low pro-file of 0.017.

3. Antenna Design

3.1. Antenna Geometry

The Proposed antenna consists primarily of the following components Substrate 1, Substrate 2, Annular ring, , Set of conductive vias, Ground plane, Coaxial probe ,Rp0 upper circular patch,Rp1 lower circular patch, The upper circular patch with radius of Rp0 and is placed on top of the substrate (substrate 1). The lower circular patch (Rp1) is placed on top of the substrate (substrate 2). The ground plane (RG) is placed on bottom of substrate 2. Two substrates used are : Taconic R-30 substrate with a relative permittivity (RP 3.0) Rogers 5870 substrate with a relative RP 2.33 .The thickness of the two substrates is H1 and H2.

The two substrate are hold together by 10 plastic screw with radius of 2.5mm which are symmetrically loaded around the z-axis with an angle of 36°from the center. The antenna is fed by a coaxial probe with a 50 ohm impedance and has a clearance hole of radius 2.0125 mm for impedance matching. The upper circular patch is surrounded by, a coupled annular ring, while the lower circular patch, is inserted by 19 conductive vias to achieve a wide bandwidth. The lower circular patch is shorted by 19 vias symmetrically loaded around the z axis.

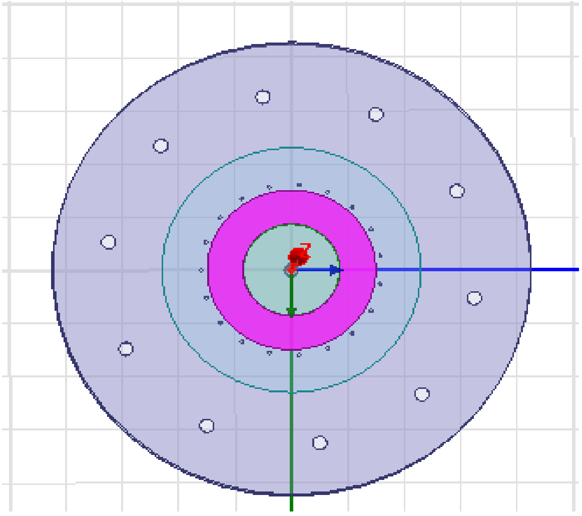

Fig -1: Geometry of the proposed antenna

3.2 Operating Principle

The stacked-patch structure connects the inner conductor of a coaxial probe to the upper circular patch, while the lower circular patch is fed through coupling with the clearance hole. The approach achieves dual-band performance by weak coupling between circular patch resonances. Adding a coupled annular ring broadens the antenna bandwidth in the high band, as both patches can be excited simultaneously. By adjusting the circular patch, annular ring size, and distance, a wide bandwidth can be achieved.

The effective radius of circular patch **(Reff)** and resonant frequency **f** of the antenna is calculated by

$$R_{\text{eff}} = R\sqrt{1 + \frac{2h}{\pi R\varepsilon r}\left(\ln\frac{\pi R}{2h} + 1.7726\right)}$$

$$\chi_{nm} = kR_{\text{eff}}$$

$$f = \frac{\chi_{nmc}}{2\pi R_{\text{eff}}\sqrt{\varepsilon r}}$$

Where **R** is the radius of circular patch χnm is the mth zero of J'_n **(χnm)** = 0, k and c are the wavenumber and velocity in the free space, separately.

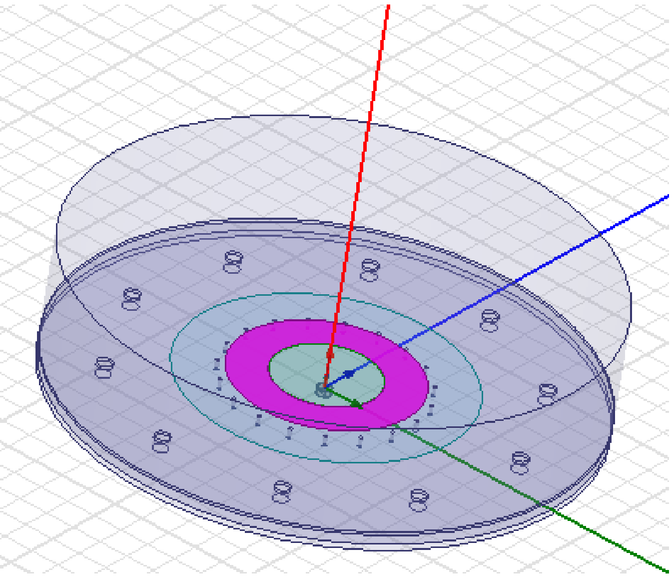

Fig -2: Side view of proposed antenna

4 Antenna Analysis

4.1 Annular ring

As Discussed by adding the angular ring around the upper circular patch it was observed that the bandwidth increased. This occurs as a result of the circular patch When activated, the annular ring may also be stimulated concurrently. via coupling of energy. Because of the variations in size between the the resonance frequencies of the annular ring and the circular patch are distinct from one another. By adjusting the circular patch's size, the annular ring's size and the space between them, It is possible to shift their resonance frequencies close to one another other, then a large bandwidth is achievable.

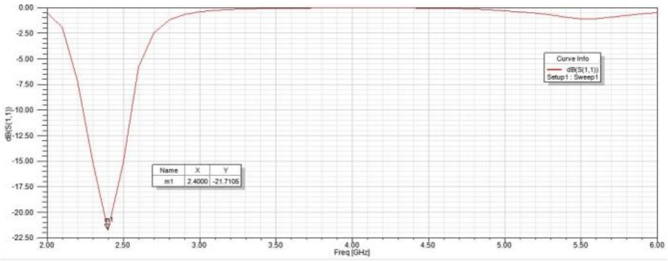

Fig -3: Simulated reflection coefficients with the annular ring

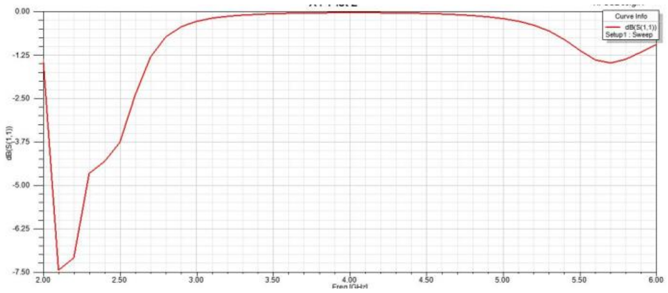

Fig -4: Simulated reflection coefficients with out annular ring

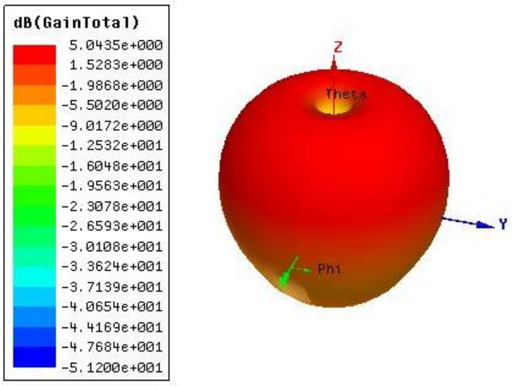

Fig -5 : Simulated radiation pattern without annular ring

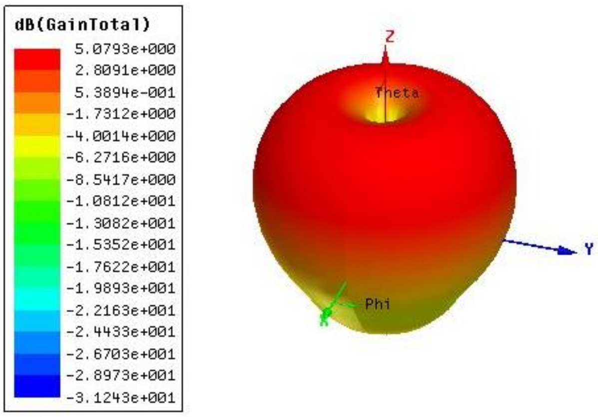

Fig -6 : Simulated radiation pattern with annular ring

4.1 Conductive vias

The antenna bandwidth significantly improved by adding conductive vias shorten the lower circular patch with the ground plane. The total of 19 conductive vias are shorted symmetrically loaded around the z axis. The vias hole was made up of 0.6 mm radius. The figure 7 and the figure 8 Shows the difference in the radiation pattern when there are no vias and with vias respectively. The figure 9 and 10 shows the difference of reflection coefficient with different number of conductive vias and with different radius size.

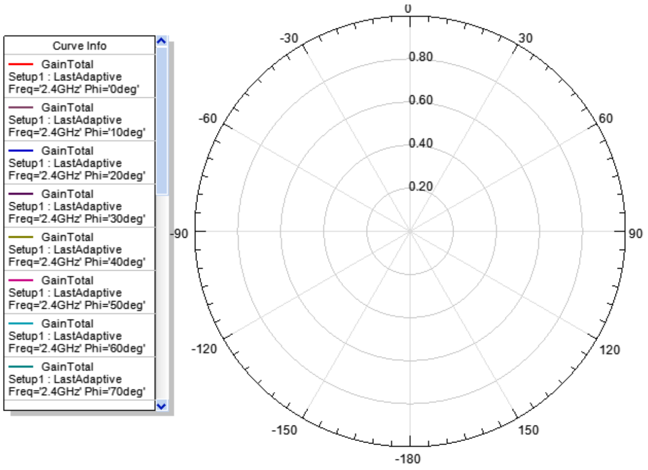

Fig -7: Simulated radiation pattern with no vias

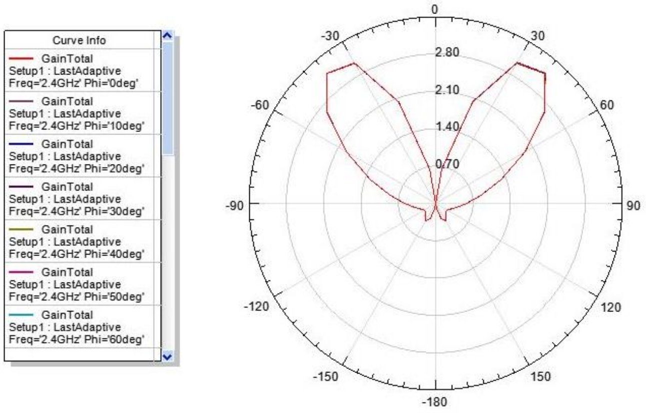

Fig -8: Simulated radiation pattern with vias

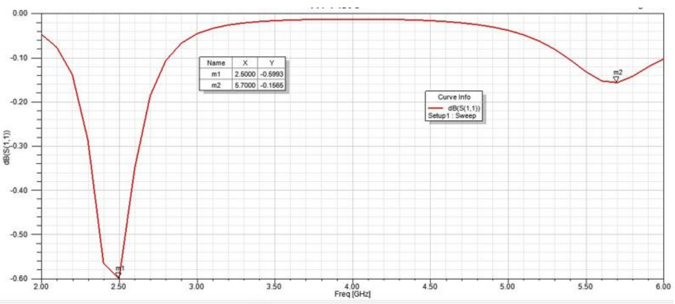

Fig -9: Simulated reflection coefficient with 23 vias of radius 1.5mm

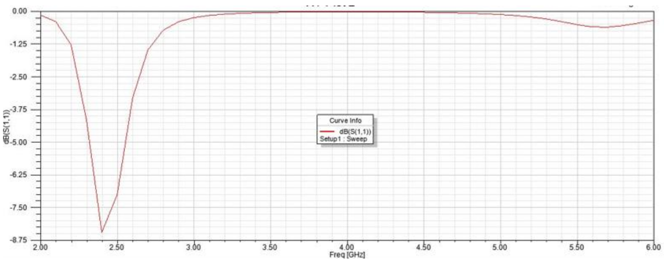

Fig -10: Simulated reflection coefficient with 18 vias of radius 0.9mm

4. Results

The circular microstrip patch antenna with stacked configuration was simulated by Ansys HFSS software . The reflection coefficients (S11), the antenna gains, the radiation patterns were measured. The number of conductive vias with the desired size of the radius shorted on the lower circular patch with the ground plane plays a important role in increasing the bandwidth by the lower circular patch .The annular ring placed around the upper circular patch which creates the coupling effect and increase the bandwidth also plays the important role. The Frequency achieved by this design of antenna is 2.4 GHz which is appropriate for WLAN application.

5. Conclusion

A novel stacked circular microstrip patch antenna has been designed for 2.4 GHz frequency and analyzed in Ansys HFSS software. This antenna design has a low profile and low weight structure. The antenna is a good candidate for broad-band WLAN applications. For future work antenna can be designed for wideband application. The number of stacks and shape of radiating patches can also be modified.

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