



A Wide Band Annular-Ring Loaded Circularly Polarized Microstrip Antenna

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Abstract. The wireless device market is expanding rapidly nowadays as a result of the rapid advancements in technology in recent years. The antenna is the most crucial part of a wireless device since it facilitates communication and data transfer. In this paper a small microstrip antenna with dual circularly polarized bands is presented. The antenna is small and compact with dimensions 24 mm × 22 mm × 1 mm. The patch is loaded with an annular-ring slot and contains a quarter circle cut on one end. Two slits of varying length and width are also etched in the radiating patch on one side of patch opposite to each other for fine tuning to achieve better circular polarization. A rectangular defected ground structure is used for improving the radiation characteristics. The designed antenna shows good wide bandwidth, gain and circular polarization with dual circularly polarized bands for use in wireless communication (WLAN, WiMax) and satellite communication applications.

Keywords: annular-ring · circularly polarized · Defected ground structure · microstrip

1 Introduction

The continued development of numerous wireless connection technologies, including satellite technology, mobile communications, and wireless sensor systems, is currently being driven by significant breakthroughs in microwave and radio frequency integrated circuit technology. One portable device typically contains multiple interface systems, whereas others that can work on different frequency bands must be kept apart for safety reasons. As a result, the system always needs numerous antennas to provide the transceiver functions. It is challenging to combine different antennas in a single system, nevertheless, because of the limited space in mobile devices. Additionally, the use of multiple antennas contributes to a coupling effect between antenna elements, which could negatively impact the system's ability to receive signals and its signal-to-noise ratio. This coupling effect can also cause issues with the antennas' structure and

RF circuit front-ends. Since wideband is used in many communication applications, UltraWideBand (UWB) is one of the potential solutions once more for multiantenna systems. Its dimensions can actually be significantly lowered in tiny quantities without the coupling effect at the same time [1, 2].

However, despite these advantages, the UWB antenna's use has been constrained by its obvious Linear Polarization (LP) properties. With the added benefits of reducing multipath effects, enhancing signal reliability, reducing polarization losses among transmitting and receiving antennas, and optimizing the weakness of antenna directivity, the Circular Polarization (CP) antenna tends to draw more and more attention as a solution to the issue. UWB CP antennas are frequently utilized in wireless communication systems [3–9] due to the benefits listed above. Due to its exceptional qualities, the CP antenna is utilized in multiple applications. The CP antenna appears to be utilized frequently in a range of application settings due to its exceptional qualities. For instance, it is employed in radar systems to prevent cloud and rain interference [4].

The CP antennas might interact with and detect multiple distinction and elliptically polarized radio waves in electronic countermeasures. The CP antenna would certainly properly receive information in airplanes with tough environments [5, 6]. The CP antenna could actually solve the ghosting issue within the television broadcasting system [8]. With all these benefits, there has been a lot of study done on CP UWB antennas, and several constructions have recently been proposed and designed. To reduce the area and widen the current route, the electric dipole is changed to a folded square ring. By attempting to connect a 90° hybrid coupler, CP is gained. The fractional bandwidth at 3 dB Axial Ratio (AR) is 1.7 GHz. In [9], a waveguide spacer polarizer-based horn double circularly polarized broadband millimeter wave antenna is proposed. In order to achieve duplex, the antenna may in fact simultaneously receive and broadcast orthogonal CP waves. The two architectures both exhibit strong CP radiation performance [9], a wide AR bandwidth, and high gain. However, the antennas appear to be a three-dimensional (3D) construction, intricate, large, and difficult to produce. They truly aren't suitable for use on mobile devices in their current forms.

2 Antenna Design Approach

The patch, substrate, and ground make up the three components of the suggested antenna. The patch is the topmost layer, with the substrate in the middle and the ground plane on the opposite side. Patch and ground plane thicknesses are not significant, therefore only the substrate thickness is considered. The proposed antenna's dimensions are $(24 \times 22 \times 1)$ mm and its substrate is FR4 with a relative permittivity of 4.4 and a loss tangent of 0.02. The feeding line is connected to the radiating patch, which has the Fig. 1 dimensions.

The ground plane as shown in Fig. 2 is a defected ground structure taken with measurements of width same as substrate (22 mm) and length equal to the length of feed line (i.e. 3.5 mm). The two edges on the side of feed line are tapered for better impedance matching of antenna. The patch is loaded with an annular-ring slot for increasing bandwidth and a quarter of circle is cut from one end of patch on the side opposite to feed line for circular polarization. An L-shaped strip is introduced on one side of the patch to help with inducing circular polarization and fine tuning it.

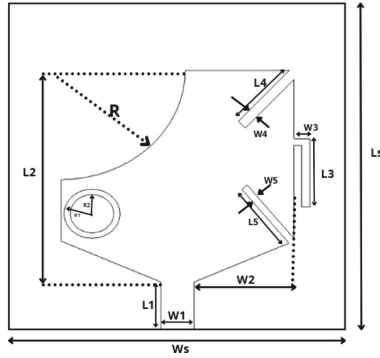


Fig. 1. Top view of Proposed Antenna

The bottom view of an antenna reveals a distinctive feature in the form of a defective ground structure, which spans a length of 3.5 mm and occupies one side of the ground plane. This unique design element is integrated to strategically manipulate the antenna’s electromagnetic properties, contributing to its specialized functionality within the proposed structure.



Fig. 2. Bottom view of Proposed Antenna

The Table 1 indicates the dimensions of proposed antenna structure in mm. This tabulated information is essential for gaining a detailed understanding of the antenna’s construction. The table includes the following dimensions for specific components:

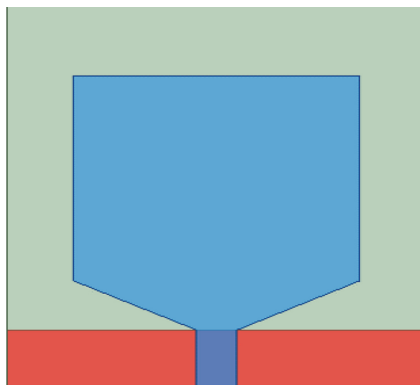
Due to two square rings in the ground plane, the antenna resonates at two separate frequencies; the stub aids in the overlapping of two resonant frequencies to form a single resonating band. By combining the inductance of the outer square ring and the collective capacitance caused by capacitance coupling between the two square rings, out of band filtering has become feasible.

Table 1. Parameters of proposed antenna

Parameters	Value (mm)
Ls	24
Ws	22
L1	3.5
W1	2.12
L2	15.5
W2	7.29
L3	5
W3	1
L4	5.5
W4	0.7
L5	5.5
W5	0.5
R	8
R1	1.8
R2	1.4
Lg	3.5

3 Evolution of Design

Initial antenna structure shows in Fig. 3. it represents the rectangular patch and defective ground structure. For the Fig. 3. Structure gives impedance bandwidth of 4GHz and it ranges from 4.76GHz to 8.71GHz. The axial ratio of the structure in Fig. 3 is infinite because the orthogonal components of the field are 0 for pure linear polarization. As a result, the antenna is linearly polarized.

**Fig. 3.** Initial evolution of antenna.

Antenna structure shows in Fig. 4 it represents the rectangular patch and defective ground structure. For the Fig. 4 structure gives impedance bandwidth of 3.69 GHz and

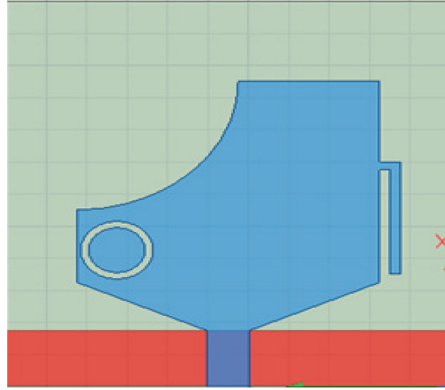


Fig. 4. Antenna Structure with stub & ring slot.

it ranges from 4.73 GHz to 8.42 GHz. Figure 4 structure axial ratio bandwidth is 1.22 GHz and it is ranging from 6.08 GHz to 7.30 GHz.

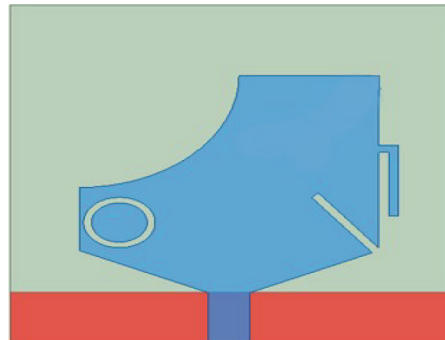


Fig. 5. Antenna Structure with quarter circle cut, ring slot, stub & slit.

Antenna structure shows in Fig. 5 it represents the rectangular patch and defective ground structure. For the Fig. 5 structure gives impedance bandwidth of 3.84 GHz (4.38 GHz to 8.22 GHz) and 150 MHz (8.61 GHz to 8.76).

Figure 6 presents an intriguing antenna structure featuring a distinctive design incorporating several key elements to optimize its performance. This figure comprises two parts, (a) and (b), each contributing to the understanding of the antenna’s construction and its real-world manifestation.

(a) Antenna Structure with Quarter Circle Cut, Ring Slot, Stub, and Slits: In this part of the figure, the detailed schematic representation of the antenna structure. The antenna is composed of several carefully crafted components that play a pivotal role in shaping its functionality. These components include:

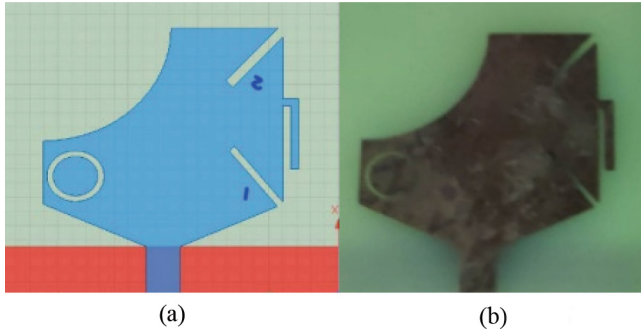


Fig. 6. (a) Antenna structure with quarter circle cut, ring slot, stub & slits (b) Photograph of Fabricated antenna

1. **Quarter Circle Cut:** At the core of the antenna structure is a quarter circle cut, a unique feature that significantly impacts its radiation pattern and resonance properties. The precise dimensions and placement of this cut are crucial to the antenna's performance.
2. **Ring Slot:** Surrounding the central quarter circle cut is a ring slot, a circular opening in the antenna's material. This slot is strategically positioned to enhance the antenna's bandwidth and impedance matching capabilities.
3. **Stub:** A stub, which appears to be an additional protrusion or extension from the antenna structure, is incorporated to fine-tune the antenna's resonance frequency and improve its impedance characteristics.
4. **Slits:** The antenna features slits or narrow openings in its structure, which may serve various purposes, such as tuning the radiation pattern or reducing unwanted reflections.

(b) Photograph of Fabricated Antenna: This part of the figure provides a tangible view of the antenna as it has been realized in the physical world. It is a photograph showcasing the actual fabricated antenna, demonstrating how the theoretical design elements described in part (a) have been translated into a real device. The photograph allows us to observe the physical dimensions, materials, and workmanship that have gone into the antenna's construction.

Together, these two components of Fig. 6 offer a comprehensive understanding of the antenna's structure and appearance, providing valuable insights into the innovative design and the practical realization of this antenna, which may have various applications in the field of wireless communication and antenna technology.

4 Simulation and Results

Figure 5 shows an antenna structure without top slit is placed over radiating patch. And the remaining structure of antenna is kept same as proposed antenna. On these modifications below results were obtained.

For the proposed structure Fig. 5, the simulation result of S11 characteristics or return loss of the above antenna structure is shown in Fig. 7 thereby it is observed two

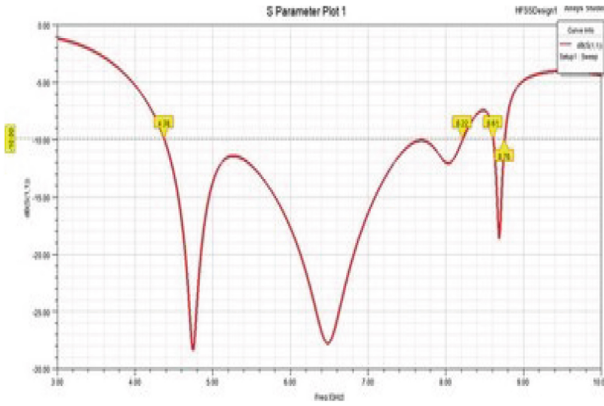


Fig. 7. Simulation result of S11 of Fig. 5.

useful bands of frequencies i.e. the first band is ranging from 4.38 GHz to 8.22 GHz and second band is ranging from 8.61 GHz to 8.68 GHz and their calculated or achieved Bandwidth are 3.84 GHz, 150 MHz.

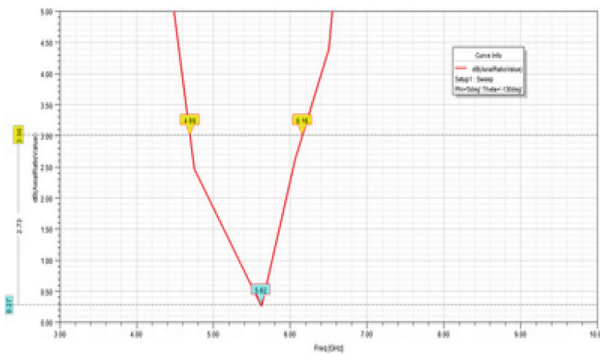


Fig. 8. Simulation result of Axial Ratio of Fig. 5

The simulation outcome of the antenna structure’s AR for the antenna depicted in Fig. 7 is presented in Fig. 8. It is noted that a band of frequencies and the frequency range associated with it have AR values between 4.69 GHz and 6.16 GHz that are less than 3 dB, an AR bandwidth of 1.47 GHz, and an accomplished minimum axial ratio of 0.3 dB. The Fig. 1 shows the final proposed antenna structure. Below results were obtained from the modifications.

For the proposed antenna structure, the simulation result of S11 characteristics or return loss is shown in the Fig. 9. It is observed antenna is operating at three bands of frequencies i.e. the first band is ranging from 4.38 GHz to 7.18 GHz and second band is ranging from 7.18 GHz to 7.66 GHz and third band is ranging from 8.21 GHz to 8.76 GHz and their calculated or achieved bandwidths are 2.8 GHz, 1.03 GHz, 160 MHz respectively.

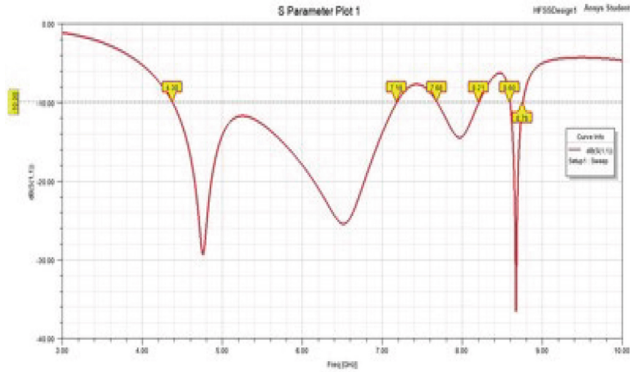


Fig. 9. Simulation result of s11 of Fig. 1

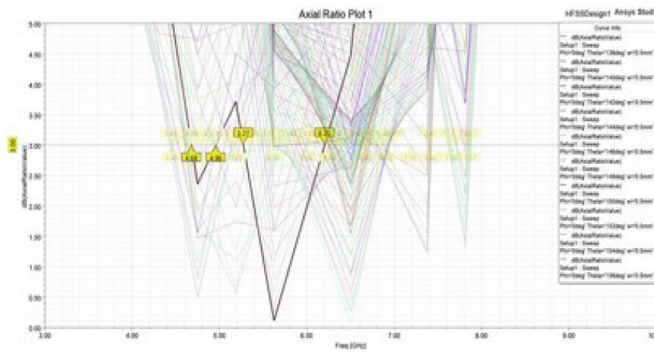


Fig. 10. Simulation result of AR of Fig. 1

For the proposed antenna structure, the simulation result of AR is shown in Fig. 10. It is observed antenna is providing circular polarization in two bands of frequencies with first band ranging from 4.66 GHz to 4.96 GHz. And the second band ranging from 5.27 GHz to 6.20 GHz. The AR bandwidths are 280 MHz and 930 MHz respectively with minimum axial ratio 0.1dB.

5 Conclusions

The work presented in this paper is a new UWB CP antenna. Here on FR4 substrate, the antenna configuration with cutting-off fraction ring on the edge of the patch antenna is purposely designed. To effectively execute CP radiation, an annular-ring slot as well as a reversed L-shaped microstrip are incorporated into the structure. In addition the patch is tapered on lower-side to achieve impedance matching. Radiating patch as well as feed line enthused by a one feed are used to achieve great impedance matching in a broader frequency spectrum. Eventually, the impacts of the important structural specifications

on polarisation performance are discussed. This proposed antenna is the best candidate for satellite communication where CP with wide bandwidth is required.

Applications

The antenna's simplicity makes it perfect for usage in portable wireless devices. The primary uses for our antenna are radar-related applications, weather balloons, and earth sensing satellites. As wind and marine radio navigation remain within the antenna design bandwidth range, they could also be employed with it. The proposed filtering antenna can also be a good configuration in applications where space is limited due to its small, compact configuration, wide bandwidth, and strong out of band filtering selectivity.

Future Scope

By including metamaterials and a wider frequency range into the EBG structure, this study can be improved to offer better gain.

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