Design and Analysis of Circular Slot with Complementary Split Ring Resonator Antenna for 5G Applications

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Abstract

The proposed study will concentrate on the construction of a Microstrip antenna for 5G Midband operations. Microstrip structures were chosen because they have low mass and structural characteristics, making them easy to insert into the surface of consumer wireless goods such as mobile, Bluetooth devices, aeroplanes, missiles, and so on. The circular-slot antenna using CSRR technology presented reduces the antenna's size without losing performance. The suggested band operation is obtained by adjusting the parameters of a standard complementary ring antenna, building it appropriate for 5G midband applications below 6GHz. This design stimulates the antenna in a sophisticated order kind rather than the typical basic mode. This method reduced the return loss to less than 32dB at precise resonance frequencies of 3.5GHz

Keywords: Circular Slot with Complementary Split Ring Resonator, Ultra Wideband, Long Term Evolution, Half Power Beam Width, First Null Beam Width

1. INTRODUCTION

Microstrip patch antennas have gotten a lot of attention in recent wireless communications generations, such as Industry 4.0 and Internet of Things devices. Whatever one's personal passions are [1]. A microwave connection is a sort of communication system that uses microwave-frequency radio waves to transport video, audio and statistics amongst two sites that are hundreds of feet or metres apart, or miles or kilometres apart. It was difficult to imagine connections in Gigabits per second before to the arrival of 4G and LTE, let alone wired connectivity, but with the introduction of new technologies into frames, it is currently believable to link devices at Gbps rates [2]. Patch antennas suffer from a significant scheme imperfection in the form of limited bandwidth and moderate gain. Various ways for enhancing the narrow bandwidth of Microstrip patch antennas have been presented to solve the problem. 5G is the next generation of communications technology, with elaborative and creative services that have the ability to change society. It will take considerably more than novel wireless expertise to deliver next-generation 5G; it will necessitate the development of an altogether new technology, which will be a prime and optimal area for researchers [6, 7].

2. RELATED WORK

The hexagonal Triangular Fractal Antenna with Tapered Feedline and Reflector for 5G and UWB Submissions was detailed in detail by Pratiknyo Adi Mahatmanto [3] (2019). The suggested antenna has a number of advantages, including a compact design, low-profile material, broad bandwidth, and low-cost material. The antenna is built in a hexagonal three-sided fractal structure among many design architectures to achieve these benefits. The antenna has a hexagonal fractal design for 5G at 28GHz with a broad bandwidth spanning 2.4GHz to 30GHz. The antenna has a maximum gain of 7.65dB and is 35mm x 52mm. The planned antenna takes a broader bandwidth; however it has a significant loss. The hexagonal fractal has a greater capacitive impact, which affects the process of element surface current distribution.
Ashwini K. Arya [4] described the Shark-Fin antenna for railway communications in the LTE-R, LTE, and lower 5G frequency bands (2020). For train communication, the shark fin antenna is 3D printed and developed to work in three bands: LTE-R (700MHz), LTE (2100MHz), and the lower 5G frequency (3500MHz). The constructed antenna is 163mm x 61.9mm x 10mm in size and covers a extensive occurrence variety from 1.4GHz to 4.2GHz, with radiation efficiency of 71.7 percent, 92.6 percent, and 96.4 percent for the railway environment, respectively. The proposed antenna functioned for lower 5G applications, such as sub-6GHz, but it didn't meet the required standard of sub-6GHz bandwidth, and it was also quite massive. Ishteyaq I [5] (2020) demonstrated a sub-6 GHz double-band planar printed slot antenna for 5G wireless applications[6-7]. The constructed antenna includes a rectangular radiation slot on the top edge with an inverted stub to achieve a highest improvement of around 7.17dBi and is suitable for operation at sub 6GHz. It resonates with a bandwidth of 3.26–3.63GHz and 4.3–5.2GHz with a return loss of less than -10dB[8-12]. The antenna is 0.8mm thick and built on a FR4 epoxy substrate with 50 Ohm impedance matching. The surface current is affected by the proposed antenna's usage of an inversion stub in the radiating layer[15-16]. The antenna radiating layer had an unbalanced dispersion process, which resulted in the formation of back lobes.

3. PROPOSED WORK AND IMPLEMENTAION

The proposed Slotted Circular Patch with a complement split ring resonator antenna (CS-CSRR) works effectively in the sub-6 GHz frequency region, resonating at 3.5 GHz. In today's communication, being able to operate at frequencies below 6 GHz is essential. The improved CS-CSRR MTM ground works exclusively at sub-6 and 5G mid band frequencies, with a total gain of 4.6 dB. The ground-based utilization of the CSSRR structure improves the gain and effectiveness of essential sub-6 GHz applications.

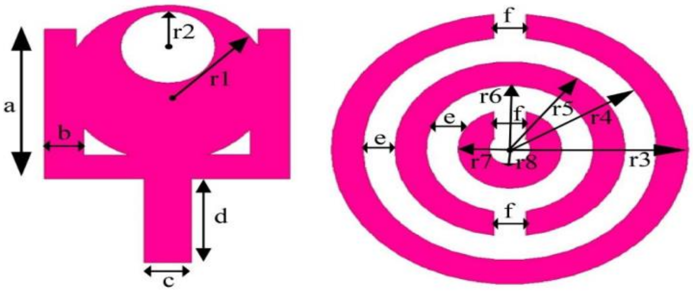


Figure 1: Simulated Structure of CS-CSRR

Table 3.1: Dimensions of CS-CSRR

Descriptions	Dimensions (mm)
a * b	1 x 8
c * d	3 x 10
r1	6.5
r2	3
r3	11.3
r4	9.3
r5	7.3
r6	5.3
r7	3.3
r8	1.3
E	2
F	3

3.1 Several Performance Parameters

The most important ones are briefly discussed below, including radiation array, return loss, gain, directivity, and radiation efficiency. The standards of these constraints are used to validate an antenna for practical applications.

Radiation Pattern

It's a two- or three-dimensional visual representation of the antenna's radiated power in spherical coordinates. Different zones of the radiation outline are denoted to as key lobes, side lobes, and rear lobes, as shown in Figure 2. The useable zone of the antenna is defined by the primary lobe, which contains the common of the radiated energy. The radiated energy is lost and does not contribute to communication in minor lobes and side lobes. As a result, the antenna's directivity is determined by the primary lobe.

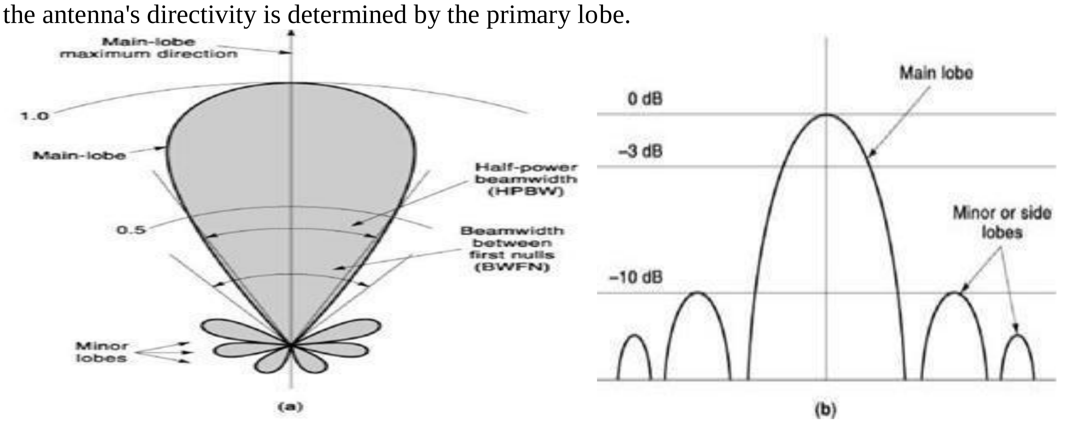


Figure 2: Radiation pattern of antenna in spherical (a) and Cartesian (b) coordinates

Half Power Beam width (HPBW), which is the angular width between the -3dB point in the main lobe, quantifies the angular region covered by an antenna. The first null beam width is the angular width between two nulls of the main lobe (FNBW). FNBW is mostly used to define an antenna's resolution. The capacity of an antenna to differentiate among two different targets or sources is described by its resolution[17].

Resolution of antenna=FNBW/2

The radiation pattern is also plotted using Cartesian or rectangular coordinates to provide further insight into the side lobes, as illustrated in figure 2 (b). The azimuth (horizontal) plane and elevation (vertical) plane are two major plane patterns that can be used to describe the radiation characteristics of an antenna without losing information. The yz plane (=90 degrees) is referred to as the elevation plane, whereas the xy plane (=90 degrees) is referred to as the azimuth plane in Figure 3.

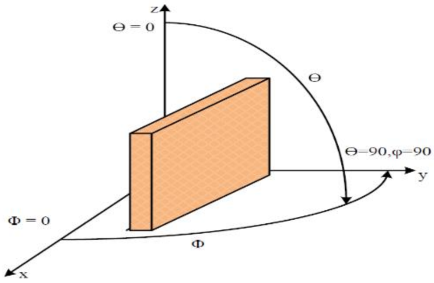


Figure 3: E plane and H plane in polar coordinates

Return Loss (S11)

It is calculated as the proportion of mirrored power to total input power applied to the antenna and reflects how much power is reflected from the antenna. All power is redirected from the aerial and no power is radiated if S11 is 0dB. A realistic antenna should have S11 less than -10dB in the working bandwidth.

$$S11 = P_{reflected(dB)}/P_{input(dB)}$$

Directivity & Gain

The proportion of the extreme radiation intensity in one direction to the average radiation intensity in all directions is known as directivity. The improvement of an aerial is the proportion of the radiated power in one direction to the total power applied to the antenna.

4. RESULTS

With a return loss of -34.16 dB, the suggested antenna performs well at 3.5 GHz. Although the CS-CSRR is a defective ground structure, it has a good return loss performance at sub-6 GHz, making it a viable model for 5G midband applications.

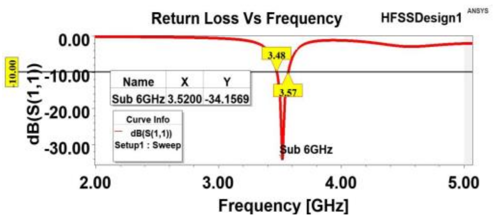
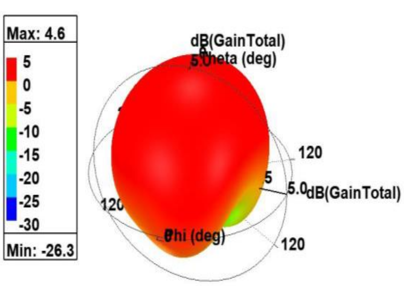


Figure 4: Simulated S parameter of CS-CSRR structure



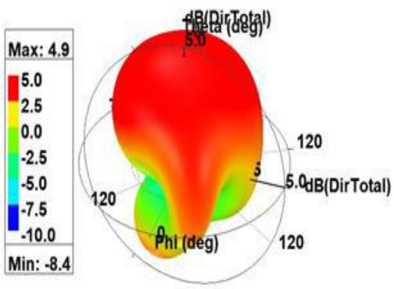


Figure 5: Simulated Gain of CS-CSRR structure	**Figure 6: Simulated directivity of CS-CSRR structure**

Gain and directivity are the most important factors to consider when calculating an antenna's efficiency. Figures 5 and 6 show the gain and directivity of the CS-CSRR, respectively. The CS-CSRR antenna geometry has the highest overall gain of 4.6 dB and directivity of 4.9 dB, as seen by the linear curve of the 3D gain figure. The effectiveness of the suggested antenna is 94.2 percent.

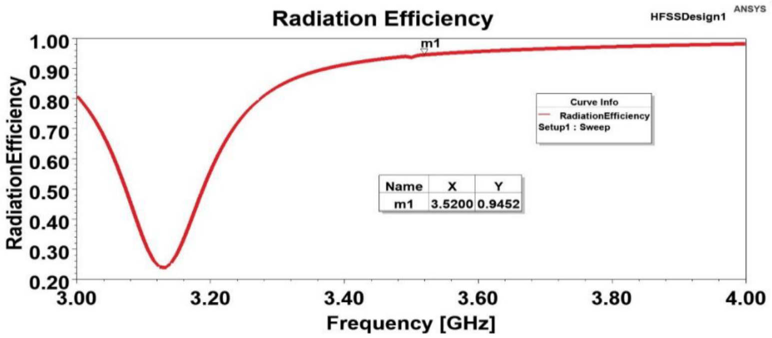


Figure 7: Simulated Radiation Efficiency of CS-CSRR structure

In figure 7, the emission effectiveness of the suggested antenna for Sub-6 GHz applications is investigated and depicted as a 2D plot. The emission efficiency of the suggested CS-CSRR MSPA at resonant frequency is comparable to the estimated value, according to the investigation's findings.

5. CONCLUSION AND FUTURE SCOPE

The circular-slot antenna using CSRR technology presented reduces the antenna's size without losing performance. The suggested band operation is obtained by adjusting the parameters of a standard complementary ring antenna, building it appropriate for 5G midband applications below 6GHz. This design stimulates the antenna in a sophisticated order style rather than the typical basic mode. This method reduced the return loss to less than 32dB at precise resonance frequencies of 3.5GHz.

The projected mid-band (Sub-6GHz, Sub-7GHz) would be used in fast-evolving wireless technology products, such as smart computing gadgets.

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Biographies

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