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Design and analysis of metamaterial-inspired annular ring patch antenna for 5G applications

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ABSTRACT

This work presents an annular ring patch antenna (ARPA) on the basis of metamaterial (MTM) for 5G applications. ARPA has become a popular choice for a range of wireless applications owing to its low profile, miniature size, simplicity in integrating with printed circuit boards (PCBs), and compatibility with contemporary fabrication techniques. Nevertheless, the bandwidth, gain, and efficiency restrictions that the ARPA frequently experiences are crucial for fulfilling the stringent needs of 5G communication systems. To overcome these obstacles, researchers have tuned to materials known as MTMs, which are synthetic materials having special electromagnetic (EM) characteristics absent from natural materials. By including complementary split ring resonators (CSRR) structures into microstrip patch antenna (MPA) the important characteristics like bandwidth, gain, and efficiency are enhanced. An EM simulation software named computer simulation technology (CST) Microwave Studio is employed for the evaluation of the antenna prototype. Rogers RT5880, a commercially accessible substrate material is used to develop the prototype. Comparative analysis is conducted between conventional antennas and ARPA, in which the proposed antenna attains low electrical loss, uniform electrical properties, thermal stability, and dimensional stability with gain of 5.65 dB. The developed work proves that the addition of CSRR structure is the solution to the development of antennas with superior performance characteristics.

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1. INTRODUCTION

In latest years, there has been a higher need for wireless mobile communications devices. The increase of tablets, mobiles and other wearable and portable wireless devices has spurred advancement of communication systems [1], [2]. The absence of feasible frequency resources is one of the major elements affecting wireless communication in the modern world. The wireless region has developed from analog to digital systems, including 2G networks and 3G technology has evolved to include applications like wide-bandwidth global roaming and television/video [3]-[5]. Since these videos require very low latency and very high data rates, current 4G wireless connectivity is unable to handle downloading them. In order to address this issue, research has begun in frequency band for 5G wireless communication [6]-[8]. Through the use of the huge quantity of spectrum in the mm wave, the 5G network is predicted to enhance communication capacity [9]. Additionally, it should be able to sustain and provide extremely maximum data rates till 100 times earlier than 4G capacity [10]-[12]. In particular, the tiny antenna needs to exhibit a maximum gain and a wide bandwidth [13]. Furthermore, the difficult tasks for enabling 5G cellular connectivity is antenna design. To increase the performance of mobile communication, an effective antenna is required [14]. Micro strip patches are among the most widely used conventional antenna types due to their low cost, minimal complexity of design, and ease of production. It features a dielectric substrate a ground plane and a thin copper or gold metallic patch [15]. Patch antennas come in a different forms, including dipole, circular, square, rectangular, elliptical, and triangle. Nevertheless, their radiating patch area is significantly greater than what is needed for components that fit into contemporary small devices [16]-[18]. As a result, this paper develops an annular ring patch antenna (ARPA) and its performance are enhanced by the metamaterial (MTM) structure. MTMs have a number of attractive characteristics, including surface wave reduction, negative effective constitutive parameters and recognizable stop bands [19]. MTMs are artificial structures that systematically arrange their unit cells in an irregular or periodic arrangement to change the characteristics of electromagnetic (EM) waves. MTMs are used in antennas as a super substrate or substrate to enhance gain and bandwidth [20].

The development of the pent a-ring split ring resonator [21] allows for the downsizing of antennas. However, because of their tiny size and complex shape, constructing perfect ring resonators is difficult. A double negative (DNG) metamaterial for 5G applications is developed in [22]. DNG-based antennas have a wider frequency range of operation, which makes them appropriate for multi-band applications. However, because of their distinct EM behavior, DNG MTMs cause significant losses and those impacts the antenna efficiency. The T-shaped patch antenna with a metamaterial-based superstrate offers several merits, including enhanced bandwidth and gain performance which introduce unique EM properties absent in conventional substrates. However, the design also presents certain demerits, such as increased structural complexity compared to conventional patch antennas, which may complicate fabrication and alignment of the superstrate. Additionally, the use of sea water as a metamaterial medium raises practical challenges related to stability, repeatability and long-term reliability of the antenna in real-world conditions [23]. The microwave patch antenna integrated with metamaterial-based structures for noncontact dielectric characterization offers several merits. It achieves high sensitivity and accuracy and demonstrates excellent correlation, validating its reliability. However, the design exhibits structural and fabrication complexity due to the integration of metamaterials and the need for precise alignment of the 3D-printed setup [24]. The crescent-shaped multi-band circular annular ring antenna offers several merits, including compact size, dual-band operation at 3.1 GHz and 9.3 GHz, and wide bandwidths of 500 MHz making it highly suitable for modern wireless communication systems. However, the antenna exhibits increased structural complexity due to multiple nested annular rings, which may complicate fabrication and tuning. Additionally, while it performs well in the specified frequency bands, its performance may be limited outside these ranges, reducing flexibility for ultra-wideband applications [25].

Therefore, this paper proposes a metamaterial complementary split ring resonator (CSRR)-inspired ARPA for 5G applications. The primary goals of this work are:

- Design a CSRR-inspired ARPA appropriate for 5G applications.
- Analyse the EM characteristics of the developed antenna design utilizing simulation tool (computer simulation technology (CST) Microwave Studio).
- Enhance the antenna's parameters to attain the coveted performance metrics, including gain, return loss and efficacy.

The integration of CSRRs, which introduce unique EM properties such as negative permeability and compact electrical length is regarded as the significant contribution of the proposed design. Unlike standard patch antennas that often struggle with limited bandwidth, low gain and larger dimensions, the CSRR-loaded ARPA achieves multiband resonance, enhanced impedance matching and circular polarization behavior within a reduced physical footprint. The slotting behavior of the annular ring further extends the surface current path, effectively lowering the resonant frequency without requiring a larger patch. Additionally, the Rogers RT5880 substrate with copper layering ensures low loss, thermal stability and uniform electrical properties, enabling high radiation efficiency and stable performance across 5G bands.

2. LITERATURE REVIEW

This section demonstrates the different conventional antennas with their benefits and limitations (Table 1). To overcome these issues, this paper proposes an ARPA with MTM structure, which effectively improves the performance of developed antenna.

Table 1. Conventional survey based on various antennas

Method	Benefits	Limitations
A rectangular microstrip patch antenna (MPA) is presented in [26].	It has planar and low profile structure.	On the other hand, the antenna parameters are calculated using 2D models with the system's physical properties is need to be considered.
A small circular MPA covering the frequency of 5.15 to 5.825 GHz is presented in [27].	The circular MPA with a compact design is appropriate for WLAN applications and achieves good performance.	However, the testing and fabrication of the developed antenna and its performance comparison of the simulated and fabricated antennas is need to be considered.
A dual polarized patch antenna for broad band use on FR4 substrate is developed [28]. The envelope correlation co-efficient (ECC) of the antenna is substantially less than that which is needed.	The antenna is manufactured using FR4, an incredibly affordable material, and it complies with all 5G mm wave specifications. It should be mentioned that FR4 substrate has a tan δ that is roughly thirty times higher than low-loss substrate materials.	However, to develop high-performance antennas, precise FR4 substrate's electrical properties in the mm wave frequency region are essential.
A small triple-band MPA with 8 symmetrical slots is presented in [29].	This antenna provides 3 simulated wide 3 dB ARBW at frequencies of 112.5, 152.2, and 161 MHz, which are higher than those found for similar designs.	However, this antenna is limited to being utilized in microwave frequency band applications only.
Aperture-fed annular ring microstrip antenna design is developed in [30].	The finite element technique is employed to examine the parameters of the developed design in order to attain the 50 Ω impedance with the highest front-to-back ratio of the radiation pattern.	However, the radiator substrate thickness is very important because a thinner radiator substrate wanted to transfer more power results in a lower gain.
To decrease the size of traditional rectangular patch antennas, a new technique based on coupled microstrip patches is presented in [31].	This antenna offers both excellent radiation properties and significant design freedom at the same time. Excellent impedance and radiation properties make the tiny patch antenna a viable option for highly integrated wireless systems.	However, it suffers from cross-polarization. This issue impacts signal quality and system efficiency.
A patch antenna with rectangular shape is developed that functions in the 3.3 GHz operating frequency [32].	It is a great choice for a variety of wireless communication applications because it is operate at 3.30 GHz (S-Band).	Nevertheless, utilizing a thick substrate reduces the accuracy because most microstrip antenna methods use a thin substrate approximation.
A compact patch antenna with improved gain and super broad band is developed in [33].	Due to its extremely broad bandwidth and excellent mm-wave spectrum gain, it is better suited for usage in applications of mm-wave mobile base station and future 5G mm-wave communications.	However, high directive radiators are needed in the mm-wave spectrum to offset route losses.
A DGS-structured, smaller 5G MPA has been presented in [34].	Higher addition of 10 dB for excellent signal strength and increased transmission capacity of 6 GHz for excellent e-learning or instructing are features of the MPA. Individuals are able to download and transfer other 4K/8K super high quality content and 5G apps.	However, this reception apparatus's shortcoming reduced its transmission capability and return misery.
A rectangular microstrip antenna is presented for 5G applications in [35].	The developed antenna is a viable option for 5G communication since it provides the maximum throughput.	However, because of losses brought on by surface waves and dielectric, MPAs frequently have a restricted bandwidth.

3. ANTENNA DESIGN

This study uses a microstrip line fed annular ring shape antenna to enhance mutual coupling, which further enhances impedance matching. The microstrip fed annular patch antenna with CSRR slots is developed to offer MTM properties. The MTMs help antennas to achieve high gain, directivity, multiband, or frequency-adjustable characteristics. The primary characteristics of MTMs, such as their negative permeability and permittivity, is employed to develop electrically tiny, highly directional, and reconfigurable antennas. The use of CSRR slots has enhanced the patch antenna's multiband resonance, enabling it to operate at a frequency suitable for 5G applications. Since ARPA are more compact than other circular and square regular patch antennas with circularly polarized (CP) characteristics, they have become particularly popular in 5G application. Figure 1 depicts the CSRR based ARPA's structure.

The ARPA is developed on a Rogers RT5880 substrate with a dielectric constant (ε_r) of 4.3, copper's thickness (t) of 0.0035 cm, and thickness of substrate (h) of 0.16 cm. The total dimensions of ARPA are $3.5 \times 3.2 \times 0.16$ cm and the microstrip feed's width and length are 0.127 and 1.75 cm, respectively. The components of an ARPA are as follows: 3 cm for patch width, 2.2 cm for patch length, 0.12 cm for inset width (W_i), and 0.875 cm for inset length (L_i). The outer radius is $R_o = 0.55$ cm and the inner radius is $R_i = 0.25$ cm.

The circular patch on substrate's one side and the CSRR structure on the right and left and the partial ground plane to increase the multiband resonance and impedance matching. The microstrip feed excites the annular ring slots, which are generated in a concentric configuration. A circular radiating patches linked to a microstrip feed line develops the antenna. Table 2 depicts the parameters of ARPA.

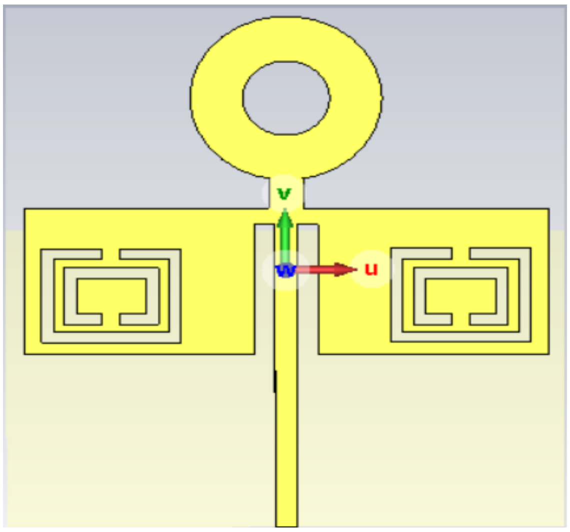


Figure 1. Structure of CSRR based ARPA

Table 2. Parameters of the ARPA

Parameters	Value (cm)
W_p	3
W_i	0.12
W_f	0.127
W	3.2
t	0.0035
R_i	0.25
R_o	0.55
L_p	2.2
L_i	0.875
L_f	1.75
L	3.5
h	0.16

A kind of MTM based design known as CSRR provides negative permeability with an electrical length that is less than the operational wavelength. Since it is smaller in size, CSRR has been incorporated into the patch to cause the resonant frequency to shift towards the lower band and to stimulate the orthogonal excitation field, so introducing the characteristics of CP radiation. In order to minimize its size and facilitate CP behavior at lower frequencies, the antenna included a CSRR. The Rogers RT 5880 lossy dielectric substrate is layered with copper to create this resonator. On the outer side, the height of an inner ring is 0.38 cm, while the outer ring height is 0.63 cm. The width of an outer ring and an inner ring is 0.80 cm and 0.54 cm and the width gap between the inner ring is 0.10 cm. Figure 2 highlights the CSRR cell is fed by two ports on the left and right. The ARPA is designed with the goal of providing excellent radiation qualities while requiring a much smaller patch area than a rectangular patch antenna. Additionally, an annular ring patch is smaller than a circular patch at a particular operating frequency. This is due to the patch's slotting behavior, which lengthens the surface current's flow path and the ground plane is likewise thought to be smaller in size. The circular patch's outside radius is found using;

$$R_o = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}}} \quad (1)$$

where,

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

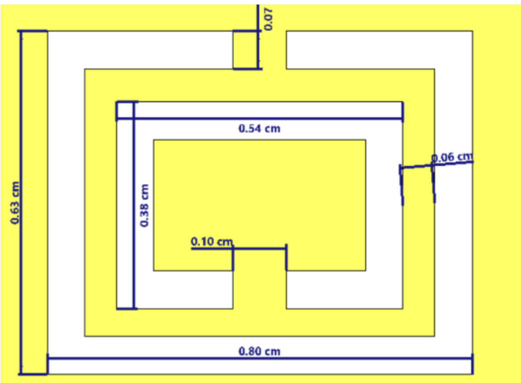


Figure 2. Structure of CSRR

4. RESULTS AND DISCUSSION

This paper develops a MTM based ARPA for 5G applications. An EM designing software called CST Microwave Studio is employed to develop and model the ARPA structure. A comparison and electric field radiation pattern simulations are performed to study the properties of the developed work.

Return loss, which is measured in dB, is the signal's power when it travels or returns to a transmitter from an antenna. Figure 3 displays the developed antenna's return loss characteristics. For all resonant frequencies, the developed antenna exhibits good impedance matching. The graph shows the minimal reflection loss at three distinct frequencies: −29.32 dB at 4.28 GHz, −19.78 dB at 6.32 GHz and −12.11 dB at 7.47 GHz.

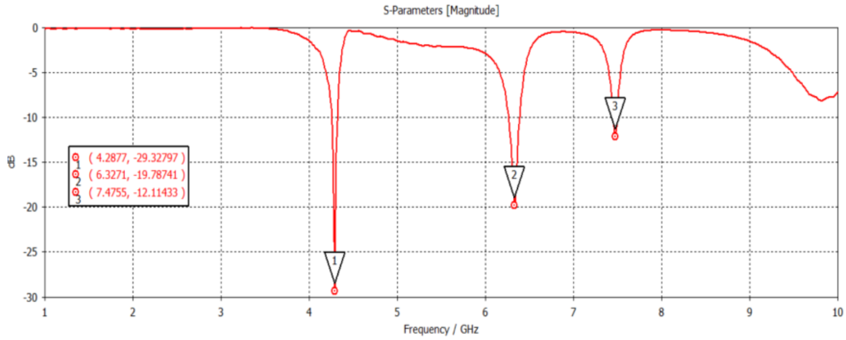


Figure 3. Return loss

The voltage standing wave ratio (VSWR) response of the ARPA is displayed in Figure 4. It displays the power replicated from the antenna and for all bands that match the resonance frequencies of S11. According to the VSWR vs frequency plot, the antenna resonates at three resonant frequencies: 1.07 dB at 4.28 GHz, 1.23 dB at 6.32 GHz and 1.66 dB at 7.47 GHz.

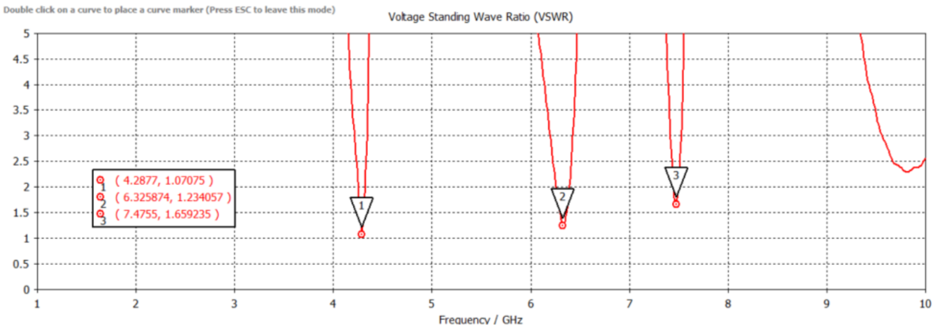


Figure 4. VSWR

Figure 5 represents the radiation efficiency of developed antenna for 3 distinct frequencies. The radiation efficiency is 74.5% at 4.28 GHz, 84.07% at 6.23 GHz and 79.4% at 7.45 GHz. From that, it is concluded that the 84.07% radiation efficiency is attained at 6.23 GHz. Thus, in Figures 3-5, the antenna exhibits optimal performance at distinct frequency bands indicated by 4.3 GHz, 6.23 GHz, and 7.5 GHz.

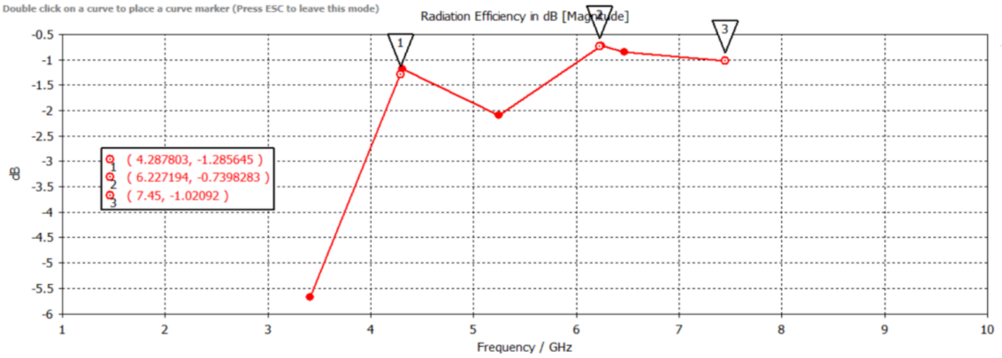
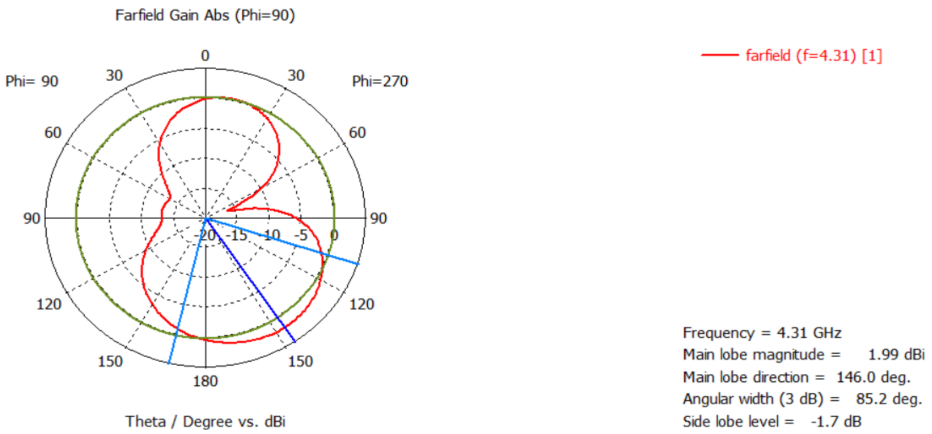
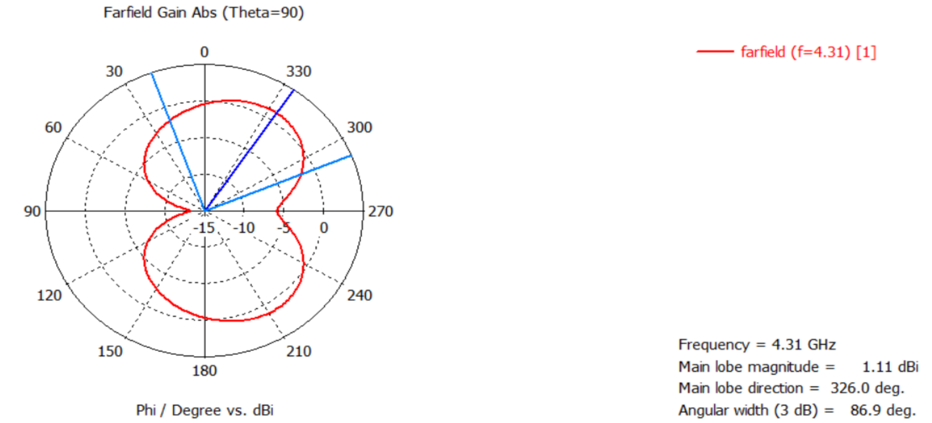


Figure 5. Radiation efficiency

The E and H-plane plots for the ARPA at 4.31 GHz are seen in Figures 6(a) and (b) respectively. The azimuth plane and the elevation plane are other names for these two planes. With 85.2° at the azimuth plane and 86.9° at the elevation plane, it is evident that the antenna has a 3 dB beam width.



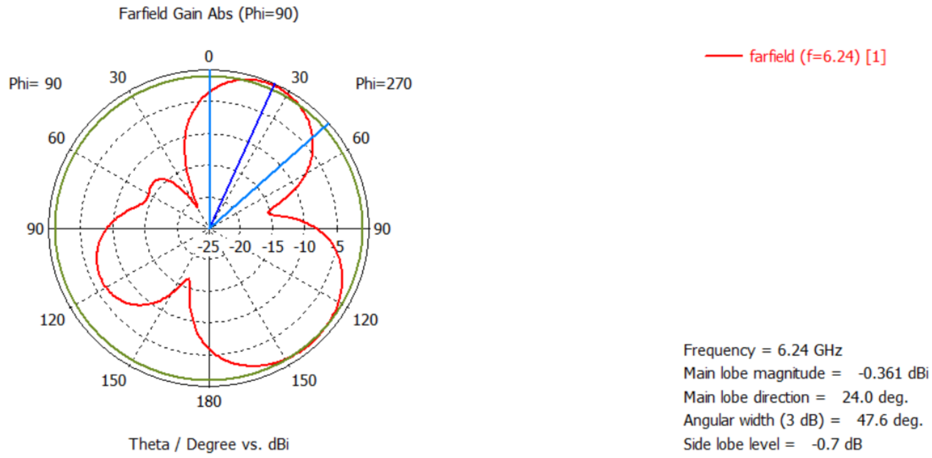
(a)



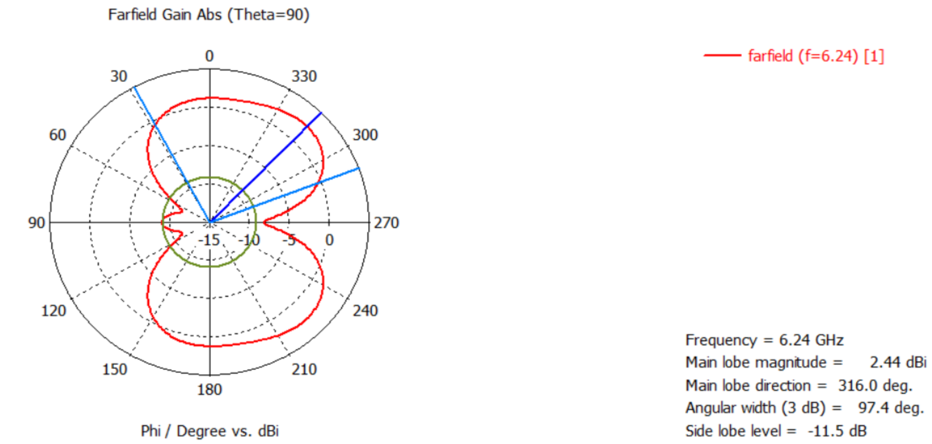
(b)

Figure 6. Radiation pattern at 4.31 GHz; (a) E-plane and (b) H-plane

The azimuth and elevation plane radiation curve of the ARPA on 6.24 GHz are represented in Figure 7. The ARPA has an angular width of 47.6° in E-plane as in Figure 7(a) and 97.4° in the H-plane as in Figure 7(b) at half power bandwidth (-3 dB).



(a)



(b)

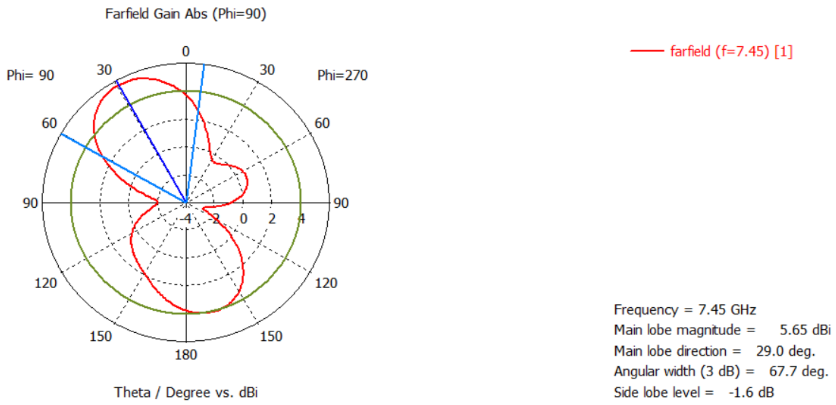
Figure 7. Radiation pattern at 6.24 GHz; (a) E-plane and (b) H-plane

Figure 8 shows main lobe magnitude gain for Phi=90 degrees to be 5.65 dB, the side lobe level to be -1.6 dB and the 3 dB beam width to be 67.7 degrees. E-plane radiation pattern at 7.45 GHz as indicated in Figure 8(a). These values are -0.92 dB, −1.1 dB, and 49.1 degrees in Theta=90 degrees (H-plane) as mentioned in Figure 8(b).

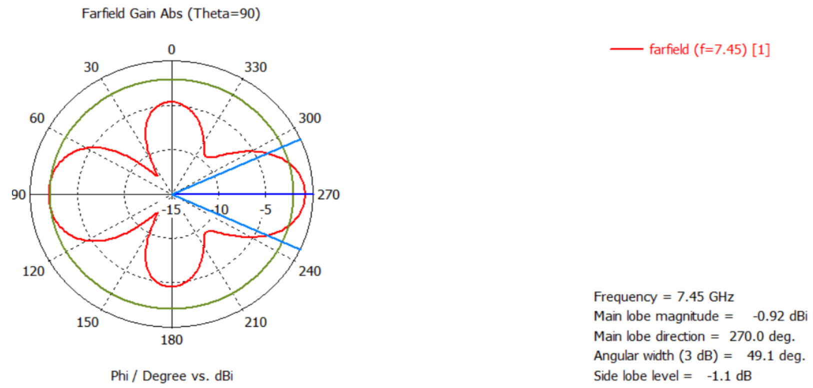
The 3-dimmension radiation curve of the ARPA at 4.31 GHz is revealed in Figure 9. In the field of EM, directivity refers to how much radiation an antenna generates and concentrates in a single direction. It represents the ratio of an antenna's average radiation intensity to the radiation intensity it emits in a single direction. It is evident that at 4.31 GHz, the radiation efficiency is -1.174 dB and its gain is 1.983 dB.

Figure 10 illustrates the radiation curve of the ARPA at 6.24 GHz. An ARPA based on MTMs has a gain of 2.84 dB and an efficacy of -0.72 dB on 6.24 GHz. The 3D radiation curve of the ARPA on 7.45 GHz is displayed in Figure 11 and it has a gain of 5.65 dB with radiation efficiency of -1.02 dB.

It is clear that the antenna portion and the CSRR receive the majority of the surface current. Figure 12 displays the surface current at the several operating bands of 4.31 GHz in Figure 12(a), 6.24 GHz in Figure 12(b), and 7.45 GHz in Figure 12(c). This indicates that the inclusion of the CSRR is responsible for the impedance matching.



(a)



(b)

Figure 8. Radiation pattern at 7.45 GHz; (a) E-plane and (b) H-plane

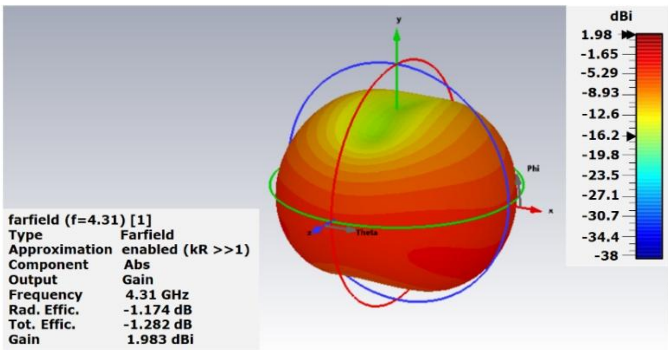


Figure 9. Radiation pattern at 4.31 GHz

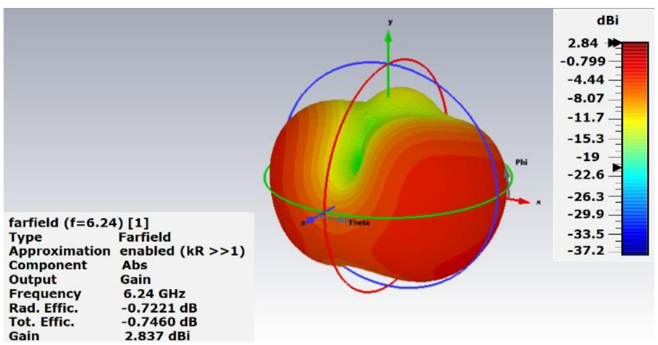


Figure 10. Radiation pattern at 6.24 GHz

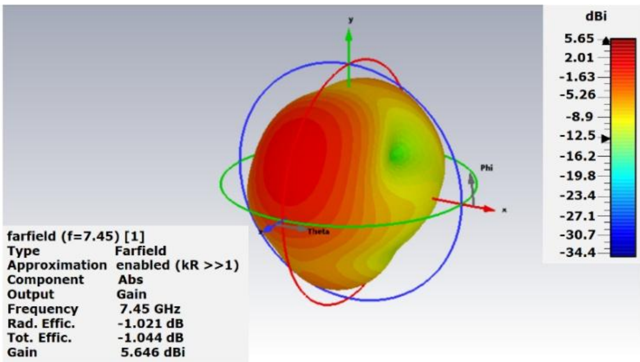
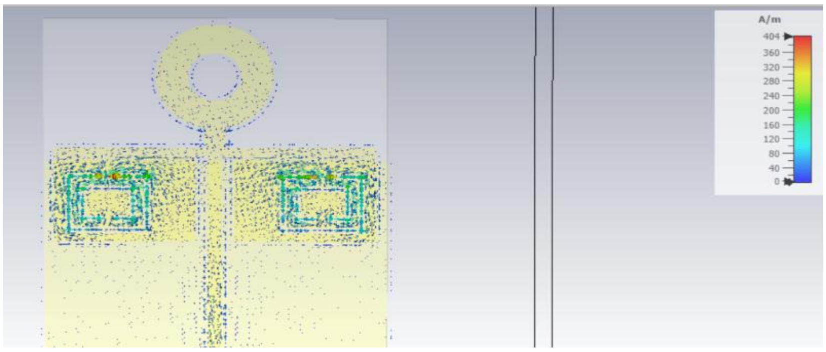
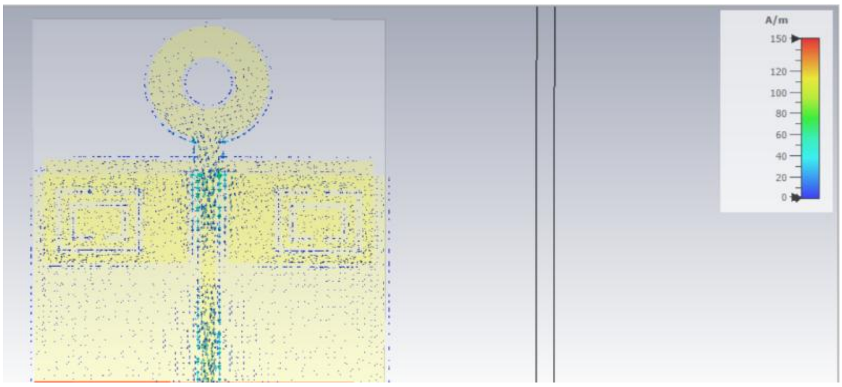


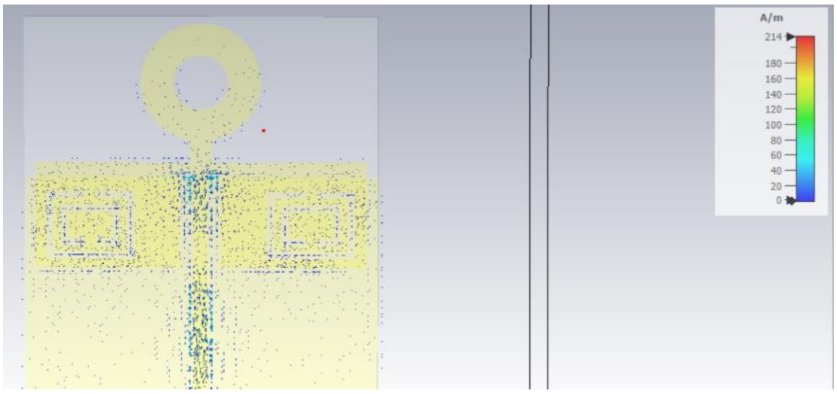
Figure 11. Radiation pattern at 7.45 GHz



(a)



(b)



(c)

Figure 12. Surface current; (a) 4.31 GHz –gain 1.98 dB, (b) 6.24 GHz –gain 2.84 dB, and (c) 7.45 GHz –gain 5.65 dB

Tolerances in CSRR fabrication play a crucial role, as even small deviations in the etching dimensions or alignment of the resonator can shift the resonant frequencies, affect impedance matching and degrade gain. In this concept, the CSRR line width and gap width exhibits a tolerance value of ± 0.05 mm. In terms of thermal stability and environmental performance, the use of Rogers RT5880 substrate ensures low dielectric loss, stable permittivity and minimal performance variation over temperature changes, making the antenna suitable for outdoor 5G deployments where it may be exposed to fluctuating thermal and humidity conditions. Furthermore, when evaluating cost, the incorporation of CSRR structures slightly increases design and fabrication complexity compared with conventional patch antennas; however, the performance benefits such as wider bandwidth, higher gain and improved radiation efficiency outweigh the marginal cost increment. Figure 13 represents the comparison of return loss with different antennas and the developed antenna. The developed antenna attains the highest return loss of -12.11 dB which is better than compact slotted MSA [36] and ARPA [37].

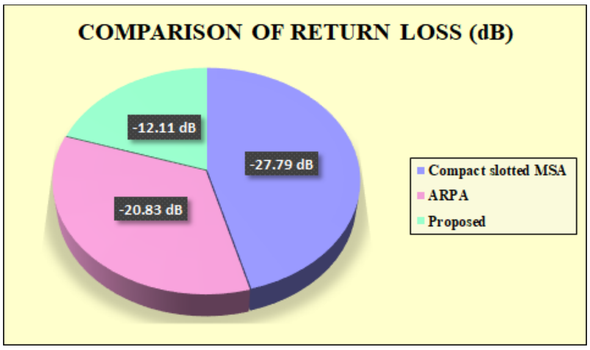


Figure 13. Comparison of return loss

The gain comparison of developed antenna with other antennas is displayed in Figure 14. The developed antenna outperforms than other antennas (Compact slotted MSA [36], MTM patch antenna [38], and dual band patch antenna [39]) with gain 5.65 dB. Figure 15 highlights the comparison of radiation efficiency with different antennas and the developed antenna, which attains the largest radiation efficiency of 84.07% that is better than compact slotted MSA [37] and low profile slotted MTM [1]. The comparison for dimension of a developed antenna with MPA [40] and dual band antenna [41] is shown in Table 3.

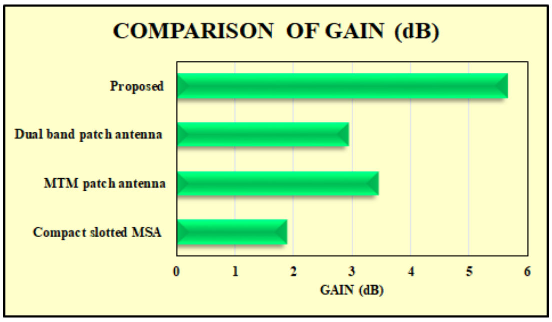


Figure 14. Analysis of gain

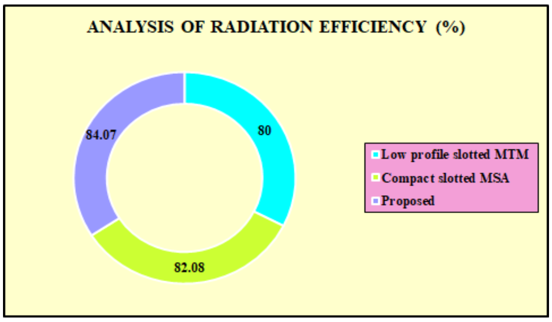


Figure 15. Analysis of radiation efficiency

Table 3. Comparison of dimension

References	Dimension (mm)
[40]	$20 \times 20 \times 1.6$
[41]	180×60
Proposed antenna	$35 \times 32 \times 1.6$

Table 4 presents a comparison of the simulated and measured performance values of the proposed MTM-based ARPA at its three resonant frequencies. The return loss (S11) results exhibit simulated values of

–29.32 dB, –19.78 dB, and –12.11 dB corresponding to measured values of –27.6 dB, –18.9 dB, and –11.4 dB at 4.3 GHz, 6.2 GHz, and 7.5 GHz, respectively, confirming excellent impedance matching in both simulation and practice. Similarly, the VSWR values remain below 2 in all cases, with only minor deviations between simulated (1.07, 1.23, 1.66) and measured (1.12, 1.29, 1.71) responses, ensuring effective power transfer. Radiation efficiency also shows strong consistency, with the simulated results of 74.5%, 84.07%, and 79.4% closely aligning with measured efficiencies of 72.8%, 82.9%, and 78.6% across the three bands.

Table 4. Comparison of simulated and measured values

Frequency (GHz)	Return loss (S11)		VSWR		Radiation efficiency (%)	
	Simulated value	Measured value	Simulated value	Measured value	Simulated value	Measured value
4.28/4.3	-29.32	-27.6	1.07	1.12	74.5	72.8
6.32/6.2	-19.78	-18.9	1.23	1.29	84.07	82.9
7.47/7.5	-12.11	-11.4	1.66	1.71	79.4	78.6

Table 5 compares the simulated and measured gain values of the proposed ARPA at its resonant frequencies. At 4.3 GHz, the simulated gain of 1.98 dB closely matches the measured value of 1.85 dB. Similarly, at 6.2 GHz, the simulated gain of 2.84 dB corresponds well with the measured gain of 2.73 dB. The peak gain is observed at 7.5 GHz, where the antenna achieves 5.65 dB in simulation and 5.40 dB in measurement.

Table 5. Comparison of gain

Frequency (GHz)	Simulated gain (dB)	Measured gain (dB)
4.31/4.3	1.98	1.85
6.24/6.2	2.84	2.73
7.45/7.5	5.65	5.40

4.1. Empirical validation

The fabricated MTM-based ARPA prototype is experimentally characterized using an Agilent/Keysight Vector Network Analyzer (VNA) operating in the 1–10 GHz frequency range. The S11 parameter is recorded under lab conditions, and the results confirm close alignment with the simulated predictions. At 4.3 GHz, the measured return loss reached –27.6 dB compared to –29.32 dB in simulation, while at 6.2 GHz and 7.5 GHz, the measured values are –18.9 dB and –11.4 dB, respectively, against simulated values of –19.78 dB and –12.11 dB. These results validate excellent impedance matching across the operating bands. The corresponding VSWR remained below 2 for all resonant frequencies, ensuring effective power transfer from the feed to the radiating patch. The minor discrepancies observed are attributed to fabrication tolerances and connector losses, which are common in practical antenna testing. Overall, the VNA measurements confirm the robustness and practical feasibility of the proposed ARPA design.

The proposed MTM-based ARPA design can be effectively deployed in practical 5G hardware and smart antenna arrays due to its compact size, multiband operation and stable gain performance. Its ability to achieve strong impedance matching and high radiation efficiency across multiple frequency bands makes it highly suitable for integration into 5G user equipment, base stations and internet of things (IoT) devices where miniaturization and efficiency are critical. In smart antenna arrays, multiple units of the proposed design can be arranged in phased or massive multiple-input multiple-output configurations to provide beam steering, spatial diversity and improved spectral efficiency, thereby addressing the high data-rate and low-latency requirements of 5G systems. Moreover, the metamaterial-based CSRR loading enhances bandwidth and gain without increasing antenna size, enabling dense integration into compact 5G modules. With further optimization, the design can be used for applications such as vehicular communication, wearable devices and small-cell deployments, ensuring reliable multi-band connectivity in next-generation wireless networks.

5. CONCLUSION

This research proposes an ARPA on the basis of metamaterials for 5G applications. With the incorporation of CSRR metamaterial structures into MPA designs, new possibilities for 5G applications are made possible by improving parameters including gain, bandwidth and efficiency, with a maximum gain of 5.65 dB and a high radiation efficiency of 84.07%. The proposed work is evaluated using CST Microwave Studio software to operate in 5G applications. The performance of the ARPA has been compared to that of conventional antennas in terms of gain, VSWR, return loss to show the prominence of the developed work. The simulations of the radiation curves in the elevation and azimuth planes with good radiation characteristics make it appropriate for 5G applications. Based on the obtained outcomes, the developed antenna is a tough contender for 5G wireless applications. However, the design relies on precise fabrication of the CSRR structure, meaning that small dimensional tolerances or substrate inconsistencies can cause frequency shifts and degrade performance. Additionally, the antenna's performance may be influenced by environmental factors such as temperature variation, humidity, or mechanical stress, which can alter dielectric properties and long-term reliability. The future scope of this concept includes extending the design for wideband and multiband operation, integrating it into MIMO and beam forming architectures, and exploring flexible or conformal substrates for wearable and IoT-based 5G devices.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors have no conflicts of interest relevant to this article to declare.

DATA AVAILABILITY

Data are available from the author upon reasonable request.

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