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Abstract - Achieving excellent efficiency in wireless communication necessitates the use of a wideband antenna. Numerous techniques have been employed to enhance antenna bandwidth, including the use of low permittivity substrates, increased substrate thickness, and different radiating patch shapes. However, these methods have proven inadequate for achieving wideband capabilities. To address this issue, a metamaterial-based microstrip antenna is proposed, featuring a metamaterial unit cell loaded on both the top patch and bottom ground plane. The top unit cell comprises a square loop with a Complementary Split Ring Resonator (CSRR), while the bottom unit cell is a Square Shaped Cross-Slot (SSCS), loaded on the patch and ground, respectively. The objective is to design a compact metamaterial-loaded antenna with enhanced radiation characteristics suitable for wideband applications, specifically targeting 5G NR FR1 and Wi-Fi 6E.

Key Words: Metamaterial, wideband.

1. INTRODUCTION

Antennas play a crucial role in wireless communication systems as they facilitate the transmission and reception of signals through the conversion of electromagnetic waves. These devices operate based on Maxwell's equations, which fully characterize their transmitting and receiving functions.

2. LITERATURE REVIEW

Various research studies have been conducted in the field of wideband antennas and metamaterials. Neeshu and Tiwary proposed a microstrip patch antenna loaded with metamaterial, achieving a wideband radiation from 2.88 to 14 GHz. Wu et al. developed a self-shape fusion algorithm to enhance the bandwidth of a printed microstrip wide-slot rotating antenna. Hossain et al. introduced a compact flexible planar monopole antenna integrated with a Negative Index Nonagonal-CSRR Meta Unit Cell Array (MTMUCA) for ultra-wideband applications. Dey, Mondal, and Sarkar designed a circularly polarized antenna using Complementary Split Ring Resonators (CSRRs). Rao and Basarkod presented a complementary slot split ring resonator truncated arc antenna with enhanced performance.

3. PROPOSED WORK

This section is subdivided into two parts.

3.1. Strip line feeding

3.2 Geometry of designed antenna

3.1 Strip line feeding

This feeding technique involves directly attaching a narrower conductive strip to the edge of the microstrip patch. One advantage of this arrangement is that the feed can be etched on the same substrate, resulting in a planar structure. This feeding scheme facilitates easy fabrication and offers simplicity in housing and impedance matching. However, using a thicker dielectric substrate leads to an increase in surface wave spurious feed radiation, which ultimately restricts the antenna's bandwidth.

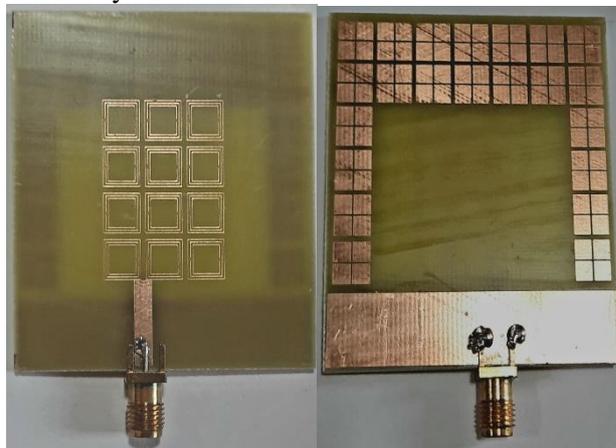


Fig -1: Fabricated antenna top & bottom view

3.2 Geometry of Designed Antenna

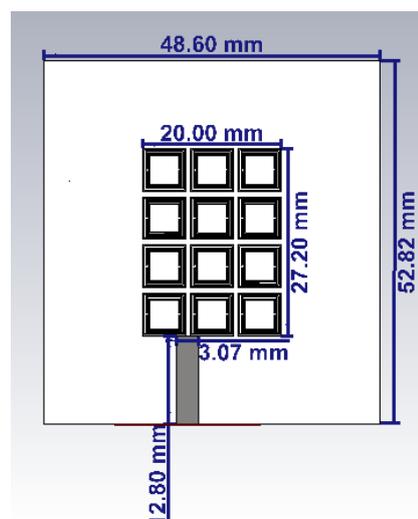


Fig -2: Top View

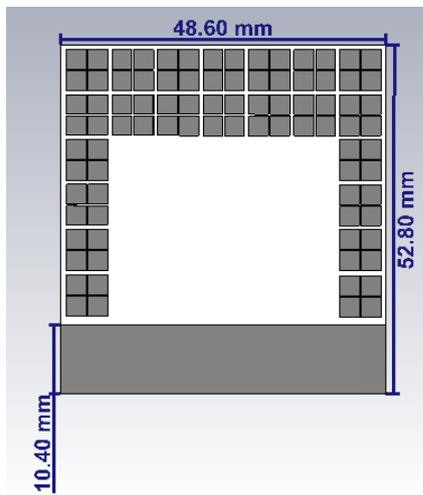


Fig -3: Bottom View

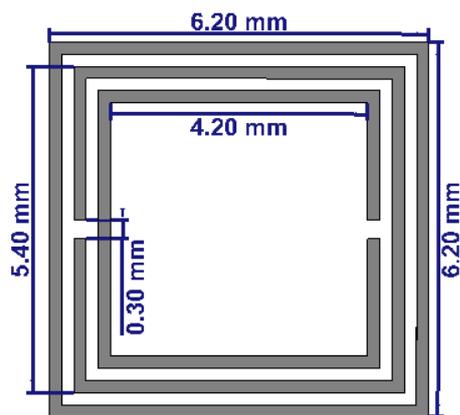


Fig -4: Top unit cell

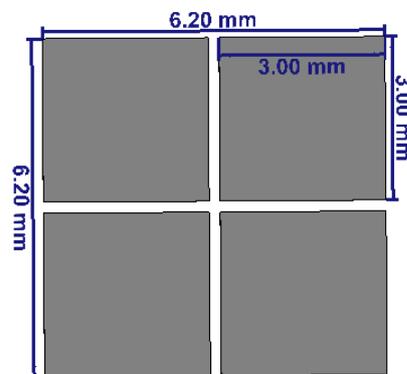


Fig -5: Bottom unit cell

The dimensions of the proposed unit cell as shown Fig-4, are $L = 6.20\text{mm}$, $W = 6.20\text{mm}$ which gives a wide response. Three square rings are designed in each unit cell. The difference in size of each square ring is 0.8mm . The top unit cell consists of a square loop with Complementary Split Ring Resonator (CSRR). The bottom unit cell is square-shaped with a cross-slot (SSCS) is loaded on the patch and ground respectively.

A metamaterial loaded planar patch antenna is proposed and shown in Figure 2 & 3 has a top view and bottom view, respectively. The FR4 substrate of relative permittivity $\epsilon_r = 4.4$, loss tangent 0.025 , and thickness (h) 1.6mm is used to fabricate the proposed antenna of size $48.6\text{mm} \times 52.8\text{mm}$. This antenna comprises loading of CSRR and SSCS in the patch and ground plane,

respectively. The partial ground plane of length 12.8mm underneath the input port of the antenna. Top patch of antenna is loaded with 4×3 CSRR unit cells and to improve the radiation efficiency, a window is etched on the backside of patch antenna. The optimized dimensions of antenna are $W = 48.6\text{mm}$, $L = 52.8\text{mm}$,

4. RESULTS AND DISCUSSION

4.1 Return loss

Return loss is a parameter that is interconnected with both the Standing Wave Ratio (SWR) and reflection coefficient. When the return loss increases, the SWR decreases. Return loss serves as an indicator of the level of matching between equipment or transmission lines. A high return loss signifies a good match, which is desirable as it results in lower insertion loss.

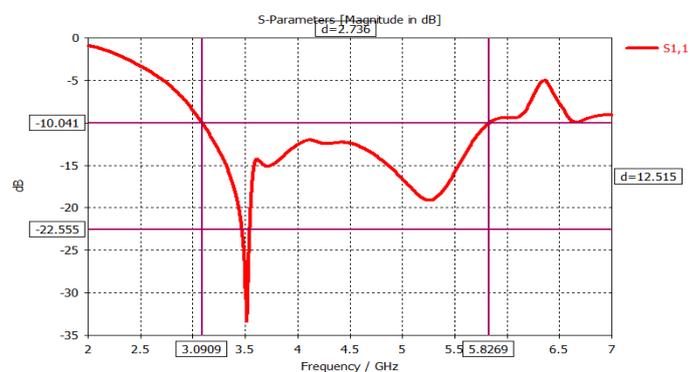
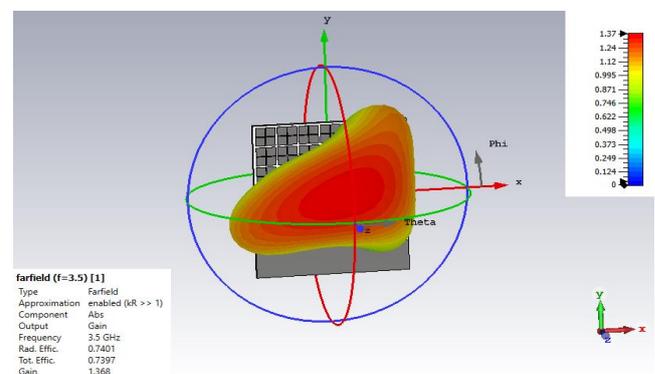


Fig -6: Return loss

Figure 6 shows us the simulated results shows that, the antenna operates at 7.5GHz with the return loss of -18.519 respectively.

4.2 Gain

An isotropic antenna radiates evenly in all directions. An isotropic radiator is considered 100% efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation.



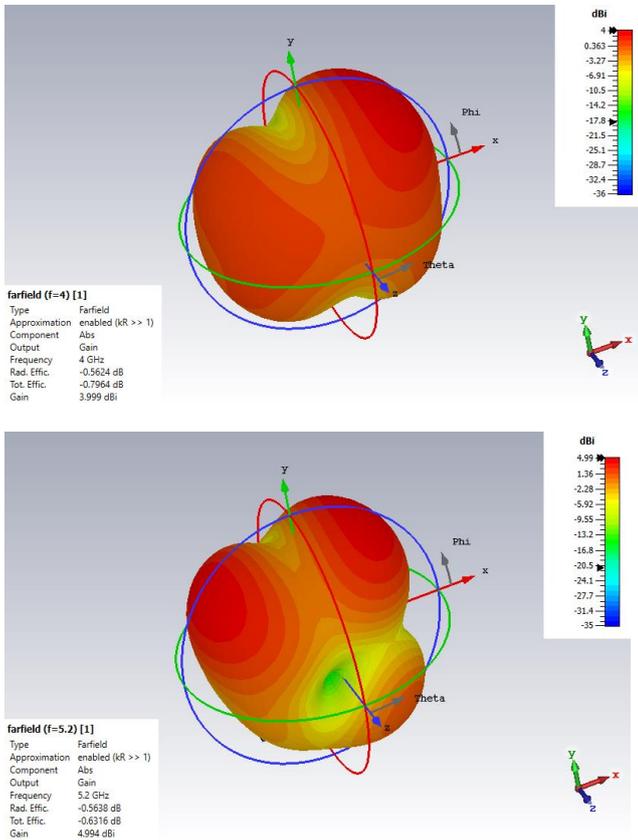


Fig -7: Gain when f = 3.5 GHz, 4 GHz & 5.2 GHz respectively.

4.3 Directivity

Directivity measures the power density radiated by an antenna in the direction of its strongest emission, compared to the power density radiated by an ideal isotropic radiator emitting the same total power.

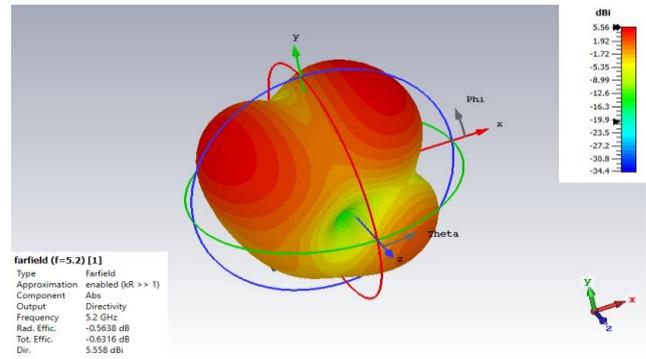
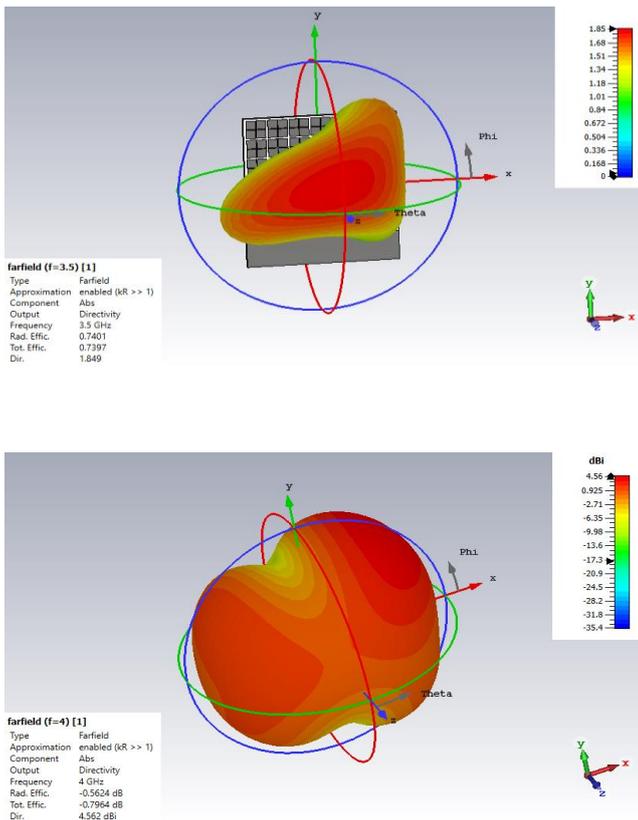


Fig -8: Directivity when f = 3.5 GHz, 4 GHz & 5.2 GHz respectively.

4.4 VSWR Measurement

VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna.

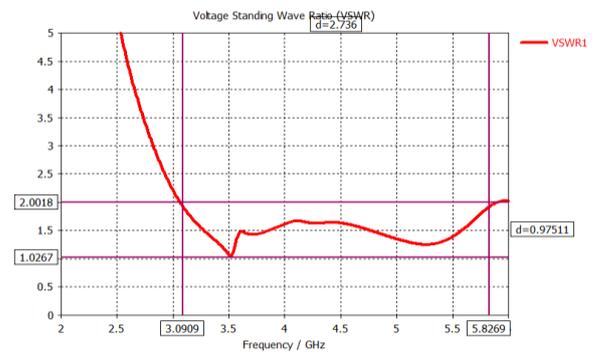


Fig -9: VSWR Measurement

Figure 9 depicts the antenna yields minimum VSWR value of 1.269.

FREQUENCY	GAIN	DIRECTIVITY
3.5 GHz	1.319 dBi	2.613 dBi
4 GHz	4.013 dBi	4.578 dBi
5.2 GHz	5.021 dBi	5.585 dBi

Table -1: Gain, Directivity & Efficiency when f = 3.5 GHz, 4 GHz & 5.2 GHz respectively.

After analyzing the data presented in Table 1, it can be discerned that there is a discernible pattern in which gain and directivity show an upward trend with increasing frequency, implying a positive correlation between these parameters and the varying frequencies under consideration

5. CONCLUSION

In conclusion, the need for wideband antennas with excellent efficiency in wireless communication systems has been addressed. While previous approaches to enhance antenna bandwidth have limitations, the proposed metamaterial-loaded antenna demonstrates wideband performance and high gain characteristics. Consequently, it is well-suited for applications in 5G NR FR1 and Wi-Fi 6E systems, where wideband communication is critical.

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