Design and Simulation of Antenna Array Using Slotted Circular patch for 5g Applications

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Abstract

In this research, a linear 1x4 antenna array is introduced, featuring substantial gain through the utilization of a circular slotted patch. The antenna design is specifically crafted for 5G communication applications and optimized for operation at a frequency of 28 GHz. The antenna design is realized on a Rogers RT/Duroid 5880 substrate, featuring a dielectric constant of 2.2 and a thickness of 0.254 mm. Moreover, the study performs an exhaustive electromagnetic analysis of the antenna through the commercially available HFSS software, thereby advancing the understanding of the proposed concept.

Keywords—5G, micro-strip patch antenna, return loss, slot antenna, Ansof t HFSS.

Introduction:

Extensive research is being conducted to achieve practical implementation of 5G communication technology for various applications, driven by its rapid growth. Antennas hold a vital significance in communication networks, and their design parameters are contingent upon the targeted frequency band of operation. In the case of 5G millimeter wave signals, the frequency range typically spans from around 24 GHz to 54 GHz. Due to their lightweight construction, compact size, cost-effective fabrication, and ability to operate at multiple frequencies microstrip patch antennas are widely employed. These antennas maintain satisfactory gain and return loss characteristics while offering a compact structure. Moreover, microstrip patch configurations are highly suitable for designing high-frequency (GHz) antenna

The evolution of 5G has surpassed mere mobile demand, offering meticulously designed capabilities that have the potential to revolutionize various industry sectors. This advancement brings forth a higher degree of agility and flexibility, enabling the network to deliver customizable services that cater to diverse connection types and a wide range of users.

In order to meet the requirements of 5G, a significant allocation of new radio spectrum is necessary, with a particular emphasis on prioritizing the defragmentation and clearance of primary bands. Regulatory authorities are actively working towards providing an allocation of approximately 80 to 100 MHz of spectrum per user in the mid-bands of 5G, such as the 3.5 GHz range, and approximately 1 GHz per user in the millimeter-wave band, specifically in the 26/28 GHz range.The present-day mobile landscape witnesses a growing consumer demand for enhanced data speeds and reliable services. The upcoming era of wireless networks, known as 5G, guarantees to surpass the performance of its predecessors. 5G marks asignificant advancement in mobile and wireless broadband technology, delivering exceptionally fast speeds, exceptional reliability, and reduced latency. Mobile operators stand to gain significant advantages from the capabilities of 5G networks, designed to meet their evolving service needs.

ANTENNA DESIGN:

1*2 ARRAY ANTENNAS:

In the initial stage, double radiating patch is designed to function at a resonant frequency of 28GHz. The design of the patch antennas comprises multiple components, including the substrate, radiating patch, feed line, and inset feed gap. The subsequent section provides the design equations and calculations associated with these components.

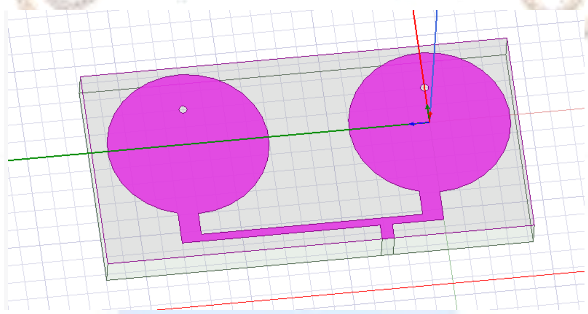
Substrate:

In order to minimize dielectric loss, it is important to select a substrate material with a very low loss tangent. Additionally, using a thinner substrate helps to reduce spurious radiations and suppress higher modes of operation, thereby minimizing radiation losses. To meet these requirements, the substrate RT/duroid5880 is chosen, which has a relative permittivity (εr) of 2.2 and a loss tangent (tan δ) of 0.0009.

The formula for determining the characteristic impedance (Z0) of a Quarter Wave Transformer is as follows: Z0 = √(ZL * Zin), where Z0 represents the characteristic impedance in ohms, ZL denotes the load impedance in ohms, and Zin represents the input impedance.

ANTENNA DESIGN:

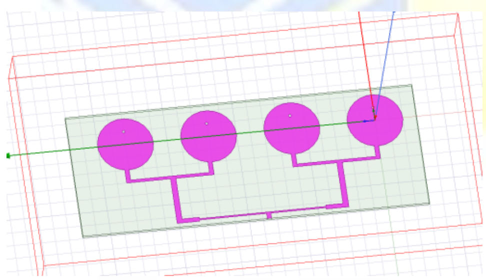
Fig: 1×2 slotted array antenna



In the provided figure, an antenna array model is presented, featuring a circular patch with dimensions of 6 mm (length, Lp) × 11 mm (width, Wp). The patch is constructed using RT Duroid 5880 substrate material with a relative permittivity of 2.2. The antenna's overall height, inclusive of the substrate thickness, measures 0.787 mm (h). HFSS software is utilized for simulating the design.

Proposed method:

Fig:1×4 slotted array antenna



To address the high gain requirements of 5G applications, a linear 1x4 array of the previously mentioned individual element is assembled for optimal gain achievement. A center-to-center spacing (d) of 6 mm is implemented between the array patches to efficiently mitigate interference. The array's central feeding utilizes a 50Ω microstrip feed line, illustrated in Figure 2. To enable feeding of the array configuration, a quarter-wave transition line is integrated at the center. The adoption of this symmetric series feeding methodology significantly contributes to the improvement of cross-polarization performance.

SIMULATION AND RESULT:

The simulation software Ansoft HFSS, also known as High Frequency Structure Simulator, is employed to model and analyze antennas. In this study, both a single patch antenna and a 1x4 array of antennas are simulated to assess their respective performances and make comparison.

Performance of the 1×2 slotted array antenna:

Fig: S_{11} plot of the 1*2 array antenna

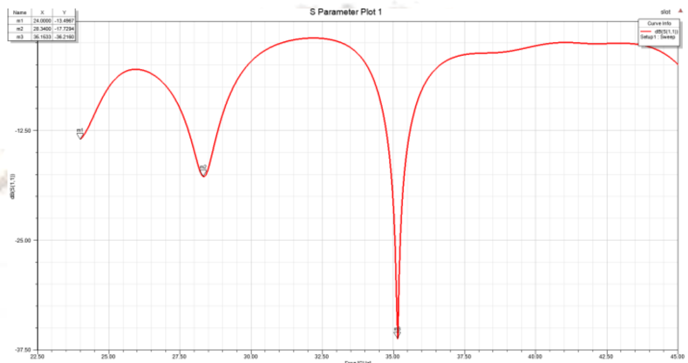


Fig: VSWR plot

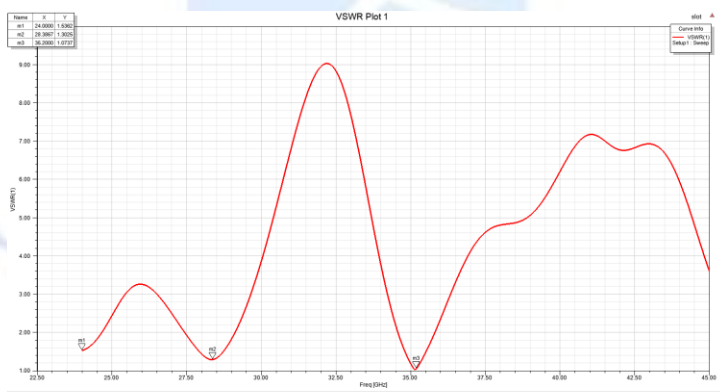


Fig: gain plot

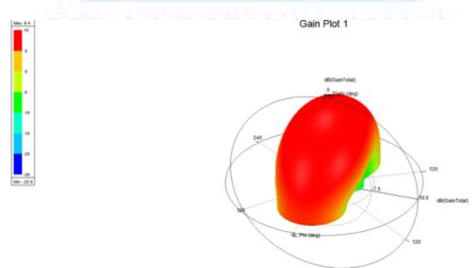


Figure presents the S11 (return loss) versus frequency plot for the 1x2 array antenna, revealing a resonant frequencies of 28,36and 41 GHz with a values of -13.49,-17.19 and 36.21 dB.

Figure complements this by showing the VSWR versus frequencies plot, indicating a value of 1.5,1.3 and 1.0 at 28,36,41 GHz. This VSWR value is within the desired range of being less than 2, signifying the antenna's optimal performance.

Figure 8 illustrates the 3D radiation pattern of the single patch antenna, showcasing a distinctive balloon shape with the main lobe's peak aligned along the Z-axis. At frequencies, the antenna achieves a gain of 9.4dB.

Performance of the 1×4 slotted array antenna:

Fig: S_{11} plot of the 1*4 array antenna

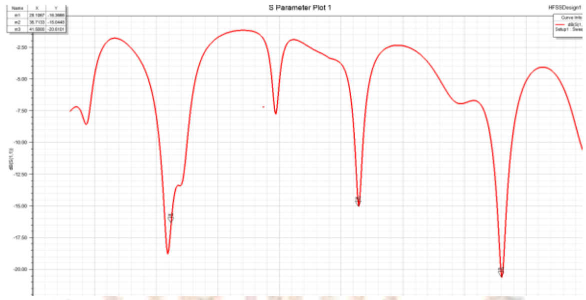


Fig: VSWR plot

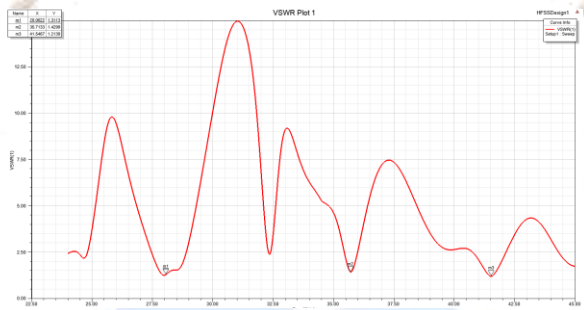


Fig: Gain plot

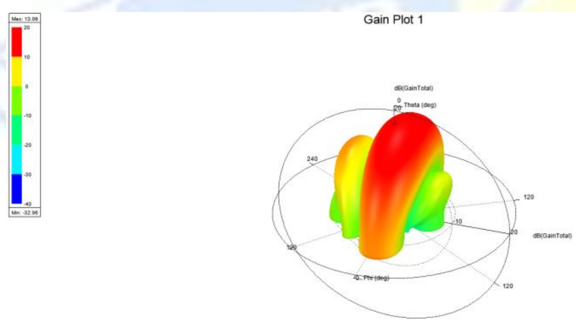


Figure 6 displays the S11 (return loss) versus frequency plot of the 1x4 array antenna, indicating a values of-16.3,-15.0,-20.49dB at the resonant frequencies of 28, 36, 41 GHz. Furthermore, Figure 7 illustrates the VSWR versus frequency plot of the antenna, with a value of 1.4,1.3,1.2 at 28,36,41 GHz, which is within the desired range of being less than 2, making it an optimal result.

The 3D radiation pattern of the single patch antenna is visualized in Figure 8, demonstrating a single balloon shape with the main-lobe peak aligned along the Z-axis. At 28,36,41 GHz, the antenna exhibits a gain of 13dB.

Comparison of the result parameters

A comparison of the result parameters between the 1*2 slotted patch array antenna and the 1*4 slotted array antenna reveals notable improvements in terms of s_{11} , VSWR and gain parameters in the array configuration. These enhancements are observed at the resonant frequencies of 28,36,41 GHz when compared to the array patch antenna.

Table: comparison of the result

s.n	parameters	1*2 array antenna	1*4 array antenna
1	S11	-13.0,-17.3,-36.7	-16.3,-15.0,-20.49
2	VSWR	1.5,1.3,1.0	1.4,1.3,1.2
3	Gain	9dB	13dB

CONCLUSION:

A proposed circular slotted patch antenna design, operating at 28,36,41 GHz, incorporates a 1*2 patch element with a 50-Ω microstrip feed line. The substrate material, Rogers RT/Duroid 5880, is chosen for its suitability in the Ka-band region. The main element exhibits a return loss of approximately -13,-17,-36.49 dB and a gain of 9 dB. Furthermore, a compact linear 1*4 slotted array antenna is constructed by combining four of these two element antennas using a series fed network. The array has overall dimensions of $9 \times 25 \times 1.274$ mm³. By employing a center series fed technique, in line with traditional array configuration methods, a maximum gain of 13 dB is achieved while maintaining a reflection coefficient below -10 dB. The measured and simulated results show excellent agreement, underscoring the antenna's viability for 5G applications.

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