IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Design and Simulation of Micro strip Antenna Array For 5G Applications

U.Anitha[1] G. Padma Ratna[2]

[1]M. tech scholar, Dr. Y.S.R ANU college of Engineering &Technology, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur

[2]Assistant, professor, Dr. Y.S.R ANU college of Engineering,

Abstract: A research paper presents a 5G communication application, specifically a high gain linear 1*2, 1*4 antenna array that utilizes a circular patch. The designed antenna operates at a frequency of 28 GHz and employs the micro strip feed technique for feeding the array. The antenna is constructed on a Rogers RT/Duroid 5880 substrate with a thickness of 0.254 mm and a dielectric constant of 2.2. The paper also includes a comprehensive electromagnetic analysis of the antenna using the commercially available HFSS software.

Keywords—5G, micro-strip patch antenna, return loss, Ansoft HFSS

Introduction:

As the demand for faster data speeds and greater bandwidth continues to rise, researchers and scientists are actively exploring advancements in mobile communication to meet the needs of future generations. The limitations of 4G (Long Term Evolution) technology have prompted these efforts, leading to the development of the fifth generation (5G) of mobile networks. 4G offered impressive features such as data rates ranging from 100 to 300 megabits per second, ample bandwidth, improved connectivity compared to 3G, and enhanced network security, all at affordable prices. However, one significant aspect that 4G failed to fully deliver on was reliable connectivity. Due to the limitations of 4G, consumers were compelled to switch to expensive broadband connections, making them inaccessible for many individuals.

To accommodate a broad range of applications in the millimetre wave frequency, various frequency bands ranging from 24 to 86 GHz have been allocated for 5G deployment. The millimetre-wave band offers significant advantages, including the ability to support diverse applications and enable antenna miniaturization. his new technology offers data rates three times faster than the previous generation. Xiaomi, a mobile company, is actively developing phones that are compatible with both 4G and 5G spectrums. One of the key aspects of the fifth generation is the Internet of Things (IoT), where every device will be able to synchronize with each other. With 5G, data rates of at least 1 Gigabit per second will be possible, enabling seamless connectivity for electronic gadgets.

The upcoming generation of communication technology holds tremendous potential for diverse applications, including industry, healthcare, and more. Realizing these possibilities relies on 5G's ability to provide large bandwidth, low power consumption, high data rates, and latency less than 1ms. Antennas serve as the fundamental component for implementing the new generation of mobile technology. These antennas should provide high speed, enhanced bandwidth, and significant gain. The selection of suitable materials for antenna design, tailored to specific applications, is crucial. Various dielectric materials such as Rogers RT Duroid, FR-4, and Polyamide are available for this purpose. Microstrip Antennas (MSA) are particularly advantageous due to their low profile. As 5G requires high gain, the development of an array consisting of single-element antennas becomes necessary. circular antenna design by introducing circular slots to excite higher modes, and an inset feed is implemented to improve impedance matching. Furthermore, to achieve high gain, we present a linear array of slotted circular patch antennas designed for a center frequency of 28 GHz.

ANTENNA DESIGN:

1. Design single patch antenna

In the initial stage, a single radiating patch is designed to function at a resonant frequency of 28GHz. The design of the patch antenna 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.

2. 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.

3. Widtha of the antenna:

The width (W) of the radiating patch plays a crucial role as it influences the directivity and radiation resistance, thereby impacting the bandwidth and efficiency of the patch antenna. Therefore, it is important to select an optimal value for 'W'. The equation for determining the width of the microstrip patch antenna is provided below.

$$w \leq \frac{c}{2fr}\left(\frac{\epsilon+1}{2}\right) - {}^{1}/_{2}$$

In the given equation, c represents the speed of light (3x10^8 m/s), and fr is the resonant frequency at which the antenna is designed to operate. For this specific design, the resonant frequency fr is set at 28 GHz. Applying the equation, the resulting width of the patch is determined to be mm.

4. Length of the patch:

The length 'L' of the radiating patch is determined by the effective dielectric constant (εeff) of the substrate and the resonant frequency (fr).

$$\varepsilon_{e} = \left(\frac{\varepsilon r+1}{2}\right) + \left(\frac{\varepsilon r-1}{2}\right)\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}}$$

$$L = \frac{c}{2fr\sqrt{\varepsilon e}} - 2\Delta L$$

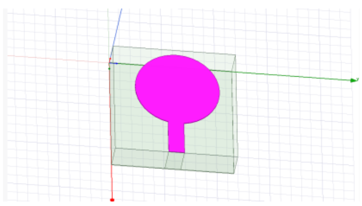
The effective dielectric constant (εeff) is determined using the above equation. Subsequently, the effective length 'L' is calculated using the above equation, which includes the term accounting for the fringing effect (2δ), computed using the above equation.

5. Micro strip line feed

A commonly used method involves feeding the microstrip antenna through a microstrip line, which is connected to the antenna at the center of one of its edges. The microstrip line can be linked to a feeding circuit or directly connected to a signal source, spanning across the microstrip line and the ground plane.

Single antenna design:

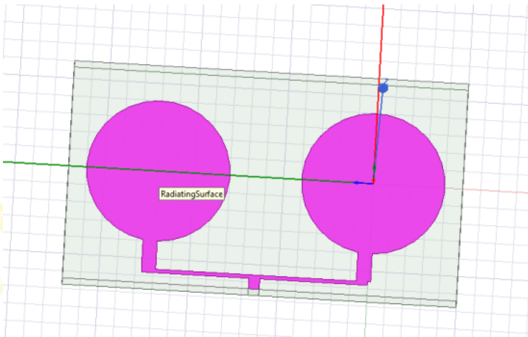
Fig 1:single antenna



Depicted in Fig1 . The antenna model utilizes a circular patch with dimensions of 6 mm (Lp) × 5.8 mm (Wp). The patch is constructed using RT Duroid 5880 substrate material with a relative permittivity of 2.2. The overall height of the antenna, including the substrate thickness, is 1.27 mm (h). The design is simulated using HFSS software.

1×2 array antenna design:

Fig 2:1×2 array antenna



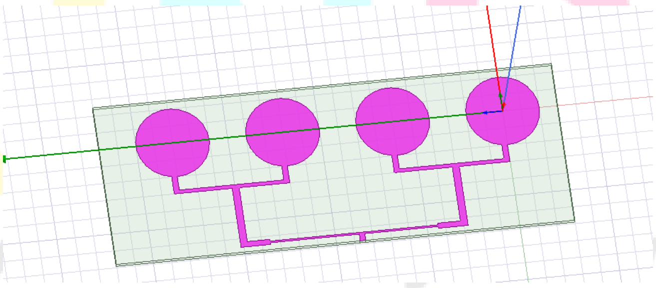
The formula for determining the characteristic impedance (Z0) of a Quarter Wave Transformer is as follows: $Z0 = \sqrt{(ZL * Zin)}$, where Z0 represents the characteristic impedance in ohms, ZL denotes the load impedance in ohms, and Zin represents the input impedance.

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:

1×4 array antenna

Fig 3:1×4 array antenna



The array comprises four elements and has an overall size of 9 mm × 25 mm × 1.27 mm (L2 × W2 × h) The antenna design is specifically tailored for one of the frequency bands that may be utilized in future 5G mobile communication.

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, a single patch antenna, 1×2 and a 1x4 array of antennas are simulated to assess their respective performances and make comparisons.

Performance of the single patch antenna:

The S11 plot in Figure 4 demonstrates a return loss value of -21.93 dB at 28 GHz, while Figure 5 depicts the VSWR plot of the designed single patch antenna, which exhibits a value of 1.17 at the same frequency of 28 GHz.

The 3D radiation pattern of the single patch antenna is visualized in Figure 6 demonstrating a single balloon shape with the main-lobe peak aligned along the Z-axis. At 28 GHz, the antenna exhibits a gain of 9 dB. To optimize the design and improve the gain, minimize return loss, and ensure proper impedance matching, an array configuration is implemented.

Fig 4: S_{11} plot of the single antenna

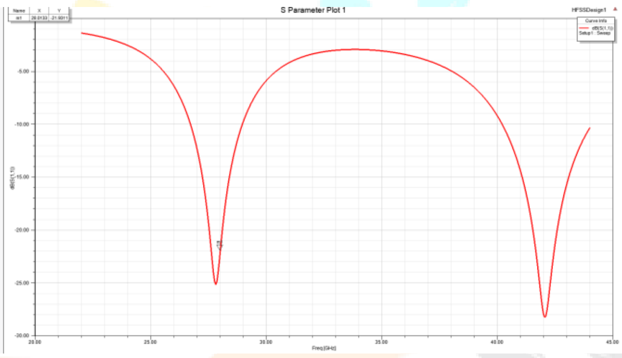


Fig 5: VSWR Plot of the single antenna

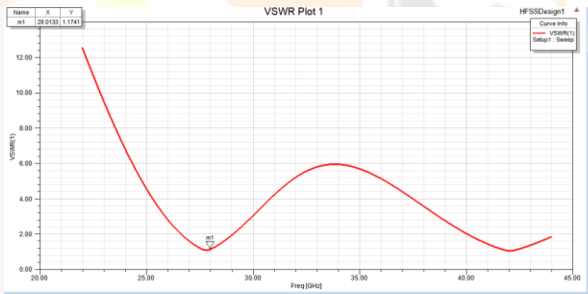
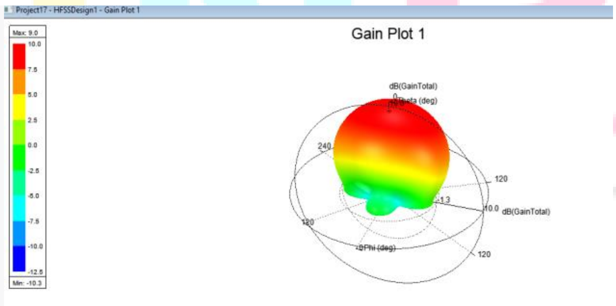


Fig: 6 radiation pattern of single antenna



Performance of the 1×2 array antenna:

Figure 7 presents the S11 (return loss) versus frequency plot for the 1x2 array antenna, revealing a resonant frequency of 28 GHz with a value of -14.49 dB. Figure 8 complements this by showing the VSWR versus frequency plot, indicating a value of 1.15 at 28 GHz. This VSWR value is within the desired range of being less than 2, signifying the antenna's optimal performance.

Figure 9 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 28 GHz frequency, the antenna achieves a gain of 11 dB.

Fig 7: S_{11} plot of the 1*2 array antenna

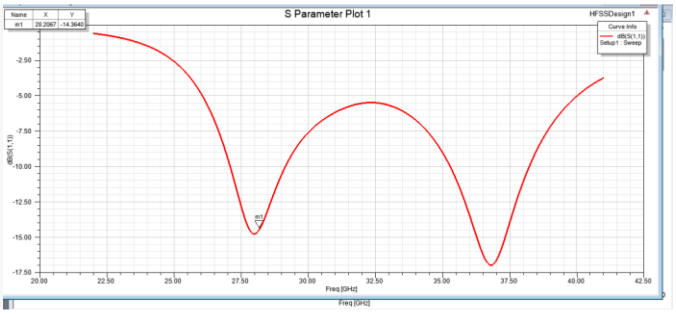


Fig 8:VSWR Plot of 1*2 array antenna

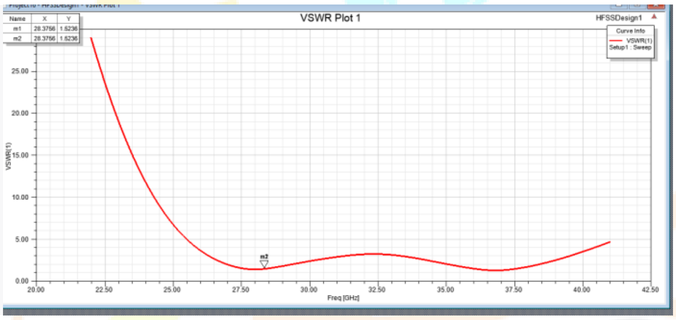
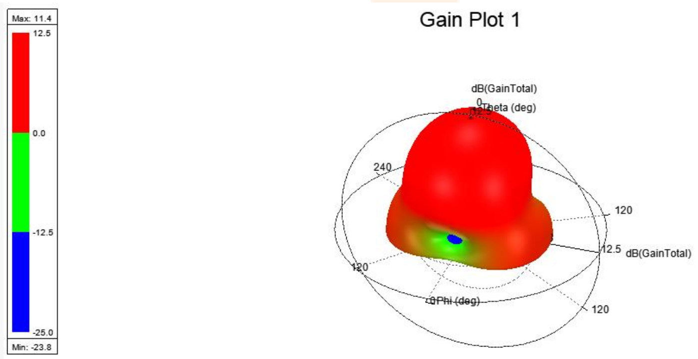


Fig 9: Gain plot of 1*2 array antenna



:

Performance of the 1×4 array antenna :

Figure 10 displays the S11 (return loss) versus frequency plot of the 1x4 array antenna, indicating a value of -20.49 dB at the resonant frequency of 28 GHz. Furthermore, Figure 11 illustrates the VSWR versus frequency plot of the antenna, with a value of 1.19 at 28 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 12, demonstrating a single balloon shape with the main-lobe peak aligned along the Z-axis. At 28 GHz, the antenna exhibits a gain of 13dB.

Fig 10: S_{11} plot of the array antenna

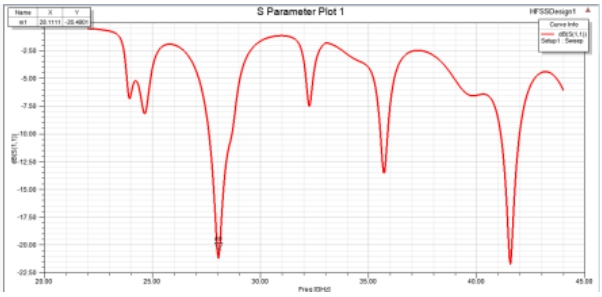


Fig10: VSWR plot

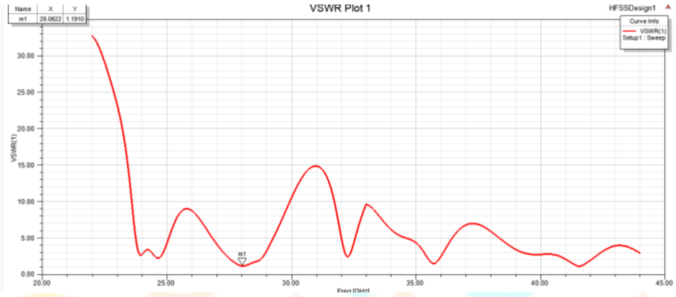
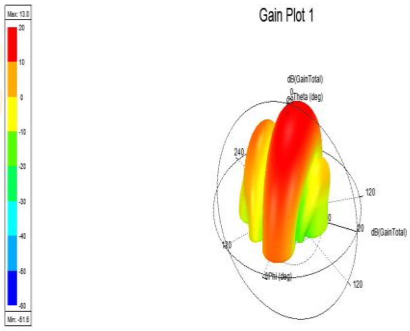


Fig11: radiation pattern



Comparison of the result parameters:

A comparison of the result parameters between the single patch antenna, 1×2 and 1×4 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 frequency of 28 GHz when compared to the single patch antenna.

Table: comparison of the results

S.N	parameters	Single antenna	1×2 antenna array	1×4 antenna array
1	S11	-20.49dB	-14.49	-21.49dB
2	VSWR	1.17	1.15	1.19
3	gain	9dB	11dB	13dB

CONCLUSION:

A proposed circular patch antenna design, operating at 28 GHz, incorporates a single 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 -20.49 dB and a gain of 9 dB. Furthermore, a compact linear array antenna is constructed by combining two and four of these single 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 11 and 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.

.REFERENCE

1.Djellid, Asma, et al. "Novel high-gain and compact UWB microstrip antenna for WIFi, WIMAX, WLAN, X band and 5G applications." Optical and Quantum Electronics 54.7 (2022).

2. Jadhav, Ashish, et al. "Multiband, Circular Microstrip Patch Antenna for Wireless Applications." Wireless Personal Communications (2022)

3. Arockia Michael Mercy, P., and K. S. Joseph Wilson. "A novel design of triple-band cross slotted antenna for WLAN and WiMAX applications." Microsystem Technologies 28.5 (2022.

4. Kishore, Siddharth, and AR Abdul Rajak. "Microstrip Patch Antenna with C Slot for 5G Communication at 30 GHz." Emerging Science Journal 6.6 (2022).

5. Chen, Jiangcheng, et al. "Broadband Cross-Slotted Patch Antenna for 5G Millimeter-Wave Applications Based on Characteristic Mode Analysis." IEEE Transactions on Antennas and Propagation 70.12 (2022): 11277-11292.

6. Nagurvali, Sk, et al. "Design and Simulation of Srichakra Shape Microstrip Tri-Band Patch Antenna." International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075.

7. Joshi, J. G., Shyam S. Pattnaik, and S. Devi. "Metamaterial loaded square slotted dual band microstrip patch antenna." 2011 IEEE Applied Electromagnetics Conference (AEMC). IEEE, 2011.

8. Colaco, John, and R. B. Lohani. "Metamaterial based multiband microstrip patch antenna for 5G wireless technologyenabled IoT devices and its applications." Journal of Physics: Conference Series. Vol. 2070. No. 1. IOP Publishing, 2021.