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1×2 microstrip patch antennas array for mm-waves 5G application

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ABSTRACT

In this paper we present the design of an antenna array for 5G applications. The proposed prototype of the antenna array is design to function at both 24 GHz and 27 GHz frequencies, utilizing Rogers RT5880 with a permittivity equal to 2.2 and a loss tangent of 0.0009. The CST Studio Suite software is employed for simulating the suggested. The primary goals of this research encompass achieving a notable return loss, increased gain, minimized voltage standing wave ratio (VSWR), enhanced directivity, and an overall improvement in operational efficiency. The results of the simulation showcase encouraging performance metrics, including a return loss of -68.70 dB, a bandwidth larger 7.369 GHz (ranging from 22.191 GHz to 29.56 GHz), a gain of 10.52 dB. Furthermore, the microstrip patch antennas (MPA) array system showcases an impressive efficiency rating of 95.63%.

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1. INTRODUCTION

In the present era, there has been significant progress in communication system, who to evolve a lot important studies in the field of antennas whose various depending of the application [1]. Antennas are devices used to radiate the electromagnetic field into space or to capture it [2]. Several types of antennas exist including aperture antennas, wire antennas, microstrip antennas, array antennas [3], lens antennas, and reflector antennas [2]. The patch antenna is the type who utilize for more application like us radars [4], wireless communication, because of its small size [5], low cost and low weight [6], [7]. The patch antenna can be affixed to the surface of high-performance platforms such as aircraft, spacecraft, satellites, automobiles, and handheld mobile telephones [8]. Microstrip patch antennas (MPA) come in a variety of shapes, encompassing square, circular, rectangular, triangular, elliptical, and dipole configurations [9]. The rectangular MPA is usually used among all types of micro band antennas [10]. The rectangular MPA is composed of a rectangular metallic radiation patch integrated on one side of a dielectric substrate. The substrate possesses a relative permittivity of εr and a thickness of h, while the opposite side features a metallic ground plane [11]. The materiel of substrate and her thickness measure has effects change values of the gain, the directivity [12].

The selection of frequencies 24 GHz and 27 GHz, which fall within the millimeter-wave spectrum [13], [14], presents notable advantages for 5G applications [15], including elevated data rates, reduced latency, and expanded network capacity. Moreover, selecting these frequencies aligns with worldwide initiatives aimed at allocating spectrum for the deployment of 5G technology. The antenna array is utilized for increasing gain, directivity, and enlarging bandwidth and also for resonant for more one frequency. This type of antenna who we propose the prototype can be function at 24 GHz. It's consist of a metallic patch on a grounded substrate, this proposed topology antenna array 1×2 has just two rectangular patch antenna placed above same substrate and ground.

The importance of MPA has been amplified in the progress of contemporary wireless communication networks, spurred by a getting bigger enthusiasm for a wide range of wireless applications [16], [17]. The design process depending, throughout. The focus is on the electrical properties of these MPAs, like as center frequency (f_0), S-parameters, gain, and directivity [18]. These factors are essential for attaining capabilities in rapid data transfer.

In the first we design and optimize of a rectangular MPA operating at 24 GHz [19], after we add another rectangular patch antenna placed above same substrate and ground (antenna array) operating at 24 GHz and 26.9 GHz frequencies custom-made for 5G applications [20], and also can be utilize for automotive radars [21] for distinguish and detecting the speed and scope of targets that is near the vehicle [22]. The goal of designing the array antenna [23] is to improve S-parameters and increase a gain. Additionally, the aim is to enhance both gain and directivity while expanding the bandwidth [24] to ensure effective utilization in 5G wireless systems [25]. This paper presents design of antenna array 1×2, the simulation was performed by CST Studio Suite software, who permit for an accurate results of the array antenna's design, CST Studio Suite was chosen for various reasons, chiefly its extensive adoption and esteemed standing within the realm of electromagnetic simulation for antenna development. With its array of sophisticated tools, it furnishes advanced simulation functionalities, facilitating precise forecasts of antenna performance metrics and refinement of design parameters to attain optimal outcomes. The array antenna proposed serve application in 5G wire-less communication [26], the results obtained is very important for 5G application [27].

2. DESIGN PARAMETERS FOR RECTANGULAR MICROSTRIP PATCH ANTENNAS

Prior to designing the antenna array, it is imperative to first devise a single antenna. The creation of a MPA encompasses three crucial parameters,elucidated as follows [28]:
- Frequency of operation (f_0).
- Height of the substrate (h_s).
- Permittivity of the substrate (ε_r).

In this investigation, a rectangular patch shape has been chosen for its simplicity in design illustrated in Figure 1.

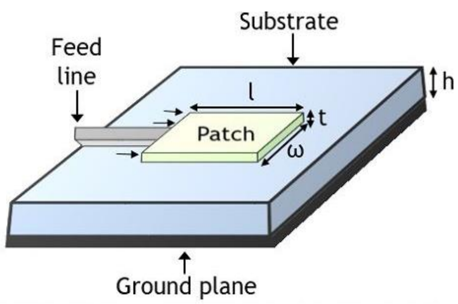


Figure 1. MPA

The selected substrate material is Rogers RT5880, it is Renowned for its outstanding electrical characteris-tics, and also high-frequency laminate material is esteemed for its superior performance. Opting for Rogers RT5880 provides numerous benefits, including minimal signal attenuation, robust power handling capabilities, and dependable performance across diverse temperature and environmental settings. The assessment of the antenna's performance implies multiple metrics, including bandwidth, gain, S-parameters, and directivity.
In (1)-(4) employed for sizing the microstrip antenna align with those outlined in the literature [29]-[31]:

$$W=\frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

$$L=\frac{c}{2f\sqrt{\mathcal{E}_{reff}}}-2\Delta l \tag{2}$$

$$\mathcal{E}_{eff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{3}$$

$$\frac{\Delta l}{h}=0.412\,\frac{(\mathcal{E}_{reff+0.3})(\frac{W}{h}+0.264)}{(\mathcal{E}_{reff}+0.258)(\frac{W}{h}+0.8)} \tag{4}$$

The W is the width, ΔL represents fringe length, L denotes the actual length, $\mathcal{E}_{reff}$ stands for the dielectric constant, and L_{eff} indicate the effective length. The dimensions of the MPA array design employed in this study are presented in Table 1 (Figure 2). The Figure 2 showcases the geometry of the MPA array.

Table 1. Dimensions of MPA array design

Parameters	Values
Wg-Ws	20
Lg-Ls	14
Wp	4.3
Lp	2.3
Wf	1
Lf1-Lf2	2.75
Lf	3.25
Hs	1.575
Ht	0.035

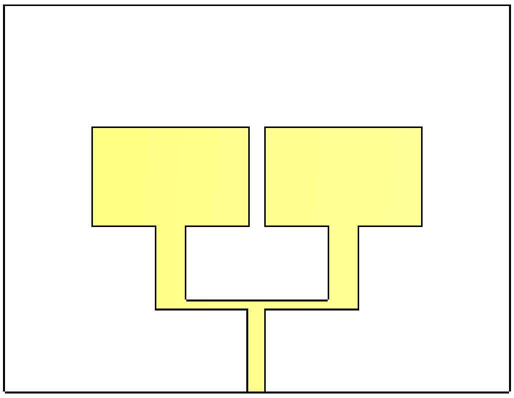


Figure 2. Geometry of MPA array

3. RESULTS AND DISCUSSION

The MPA array undergoes detailed design and simulation using CST. Which a robust software, this flexible application finds extensive application in designing various antennas tailored to specific applications and resonance frequencies. It facilitates accurate computations and graphical representations of essential parameters such as S-Parameters, gain, and directivity.

3.1. Return loss

In the case of the single antenna, the S11 parameter registered a value of -31.54 dB at a frequency of 24.02 GHz. However, with the antenna array, the S-parameters doubled compared to the single antenna, as depicted in Figure 3, showcasing an impressive value of -68.70 dB at the frequency 24.02 GHz, which is exceptionally favorable. Where the bandwidth of the antenna, measured at -10 dB, is determined to be 7.369 GHz in the proposed design, owing to the utilization of a 1×2 antenna array. This represents a notable expansion from the original bandwidth of 2.8046 GHz observed with a single antenna.

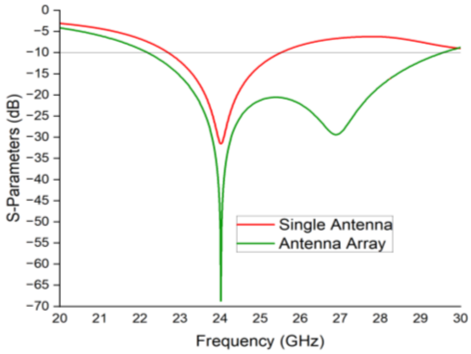


Figure 3. S-parameters of MPA array

3.2. 3D radiation pattern for gain

The assessment of an antenna's performance is greatly influenced by its gain, which indicate how much stronger the signal is in a specific direction compared to an isotropic radiator when transmitting, or how much better it can receive signals from a particular direction compared to an isotropic radiator when receiving. Gain is typically expressed in decibels (dB) and is a crucial parameter in determining the performance and effectiveness of an antenna. Within the context of this investigation, the gain of the proposed MPA array is accurately measured at 24 GHz, yielding a value of 10.52 dB, as shown in Figures 4 and 5, in comparison, the single antenna had a gain value of 8.093 dB. Based on Figure 6(a), it is evident that employing an antenna array eliminates secondary lobes while simultaneously increasing gain. In Figure 6(b), a notable and substantial gain enhancement is clearly demonstrated, with a gain value of 10.52 dB and a -3 dB angular beamwidth of 62.4° in the xy-plane at 24 GHz.

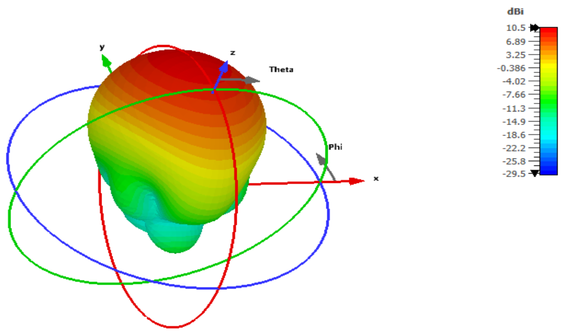


Figure 4. Radiation pattern Gain of MPA array

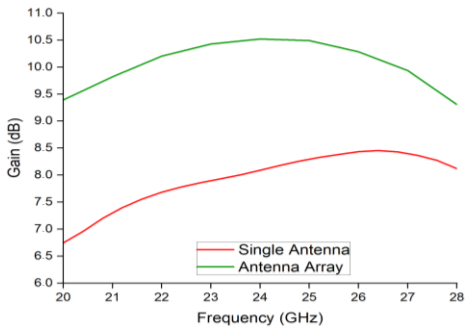
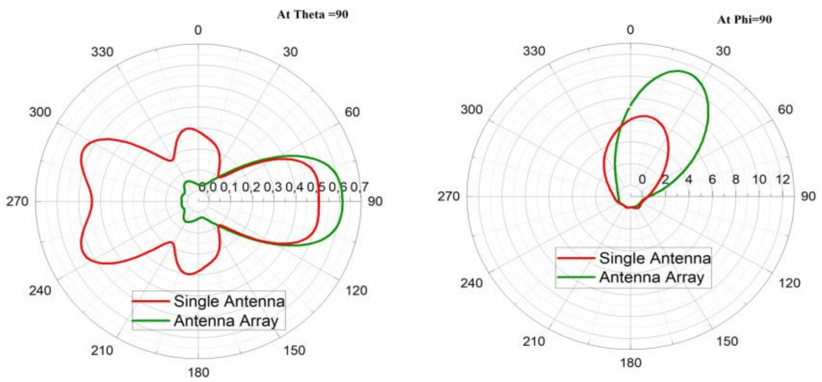


Figure 5. Gain curve for single antenna and antenna array



(a) (b)

Figure 6. Radiation pattern in linear scale of single antenna and antenna array: (a) xy plane (θ=90) and (b) yz plane (π=90)

3.3. Efficiency

Antenna efficiency refers to the ratio of power radiated by an antenna to the input power supplied to it. Essentially, it measures how efficiently an antenna transforms electrical power into radiated electromagnetic energy. The graph depicted in Figure 7 showcases the radiation efficiency. The array antenna attains a peak efficiency of 95.63%. Table 2 illustrates the outcomes of a single antenna in comparison to a array antenna 1×2 configuration, indicating that incorporating an additional antenna on the same ground and substrate resulted in enhancements the S-parameters, gain, and directivity.

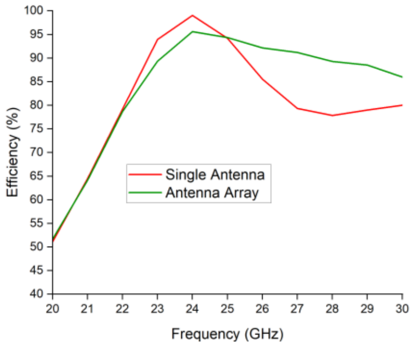


Figure 7. Radiation efficiency

Table 2. Comparison the antenna array with single antenna

Prototype	S-parameters (dB)	VSWR	Gain (dB)	Directivity (dBi)	Efficiency (%)
Single antenna [19]	-31.54	1.05	8.093	8.127	99.58
Antenna array	-68.70	1.0007	10.52	11	95.63

Table 3 compares the current antenna array with various designs documented in existing literature [13], [22], [32], [33]. Any modification about antenna array induces a change in his performance. In the end, achieving convergence in gain and directivity values, along with expanding bandwidth, is crucial for enhancing antenna efficiency. This providing a comparative analysis of the efficiency of our antenna array with similar configurations would enhance the robustness and relevance of our findings. Furthermore, we recognize the significance of elucidating the potential real-world implications of achieving high efficiency in antenna design such as its impact on signal coverage, data throughput, energy consumption, and overall system performance in various deployment scenarios.

Table 3. Comparing the suggested antenna with other works

References	Dimension	Resonnance frequency (GHz)	Substrate material	S-parameters (dB)	VSWR	Gain (dB)	Directivity (dBi)	Efficiency (%)
[22]	30×60	24	FR4 expoxy	-23.80	1.38	9.74	-	-
[32]	20×22	28	Rogers RT5880	-	-	10.2	-	90
[33]	26.7×20.4	24	Rogers RO3003	-	-	9.2	9.2	100
[13]	40×30	25.69	Rogers RT5880	-42.134	1.0158	8.104	8.615	89.77
This work	20×14	24.02	Rogers RT5880	-68.68	1.0007	10.52	11	95.63

4. CONCLUSION

In this paper, we developed and simulate of an MPA array tailored for 5G applications. The MPA array functions at a frequencies of 24 GHz and 26.9 GHz. The results include analysis critical parameters such as bandwith, gain, and S-parameters. The suggested antenna array has an important bandwidth of 7.369 GHz. Additionally, the MPA array appears a gain of 10.52 dB at the 24 GHz frequency. These results offer important insights into the Effectiveness, and significance of the array antenna for 5G applications. Nevertheless, there are several pivotal domains warranting further exploration and enhancement. These include but are not limited to beamforming techniques, frequency bandwidth enhancement, compact and low-profile designs, as well as integration with emerging technologies.

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