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Design and Simulation of Microstrip Patch Antenna Array for 5G Applications at 25GHz

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Abstract :

In the research, a model of a microstrip antenna array 1x2 is designed to be suitable for 5G applications and operate at a 25 GHz frequency. The antenna array's overall size is (19 x 9.2 x 1.6)mm^3. The array was fed using strip line technology. Was used in the epoxy(FR-4) insulating material with a dielectric constant of 4.3. The finding showed that the return loss at 25GHz is -35.86dB, and the gain is 3.33dB, the directivity is 6.58dBi, and the VSWR is 1.03 at 25GHz. The fractional bandwidth is 24.64% at 25GHz. An antenna array was designed and simulated, and the results were displayed using CST$_{2019}$(Computer Simulation Tool) software.

Keywords: Microstrip Patch Antenna Array, 5G, CST, FR-4 .

تصميم ومحاكاة مصفوفة هوائيات الشريحة الرقيقة لتطبيقات الجيل الخامس عند التردد 25GHz

منى رشيد طلب ، فارس صالح عطاالله
جامعة تكريت/ كلية العلوم / قسم الفيزياء

مستخلص:

في هذا البحث تم تصميم نموذج لمصفوفة هوائيات الشريحة الرقيقة 1x2 مناسب لتطبيقات الجيل الخامس ويعمل عند التردد 25GHz، الحجم الكلي لمصفوفة الهوائيات (19 x9.2 x 1.6) mm^3 ز, تم تغذية المصفوفة بتقنية الخط الشريطي، كما تم استعمال المادة العازلة من الايبوكسي (FR-4) لها ثابت عزل 4.3 . كانت النتائج ان خسارة العودة عند التردد 25GHz تساوي 35.86- dB, وبكسب 3.33dB وباتجاهية 6.58dBi, ونسبة الموجة الواقفة للفولطية (VSWR) 1.03 2 عند التردد 25GHz. عرض الحزمة الترددية الكسرية هي 24.64 ٪ عند نفس تردد العمل. تم تصميم ومحاكاة وعرض نتائج مصفوفة الهوائيات باستعمال برنامج CST$_{2019}$.

الكلمات المفتاحية: مصفوفة هوائيات الشريحة الرقيقة ، الجيل الخامس ، CST ، الايبوكسي

1. Introduction

Wireless communication technology has witnessed many developments in recent in recent times in of device size, of operating systems, as well as wireless system performance and enhancement techniques. The demand has increased widely with the emergence of new wireless systems that are not only compressed but also multi-functional[1]. One of the fundamental components if wireless devices is the antenna. The miniaturization of mobile devices has led to the requirement for compact and lightweight antennas that can be easily integrated into wireless frequency bands. For antennas that cover different wireless communication ranges[2]. There was a lot of interest in microstrip antennas, particularly in the 1970s, and because of their inexpensive cost, small size, lightweight, easy manufacturing, and integration with solid-state devices, became mostly utilized in wireless applications [3]. These antennas are fully compatible with portable wireless devices such as cell phones, spacecraft, wireless computer networks in military aircraft and missiles, and also in remote-controlled devices [4]. Broadband can be used for low-power signal transmission, high-data- rate transmission, and radar imaging [5].

Nowadays, microstrip antennas are widely employed in many communication systems and are crucial to wireless communication systems. They have been employed to transfer electromagnetic energy between the antenna and the transmission source [6].

Array antennas represent designs that contain a group of antennas arranged in a geometric manner that works as a single antenna, through which good radiation properties of the antenna are obtained. To produce radiation of a particular shape, the antenna array is regularly connected between identical antennas, and when the number of radiating elements doubles, increasing the radiated power [7], each antenna in it is called an array element, and the array elements do not have to be of a specific type, rather, they may be single-or dipole-type antennas or microstrip patch antennas [8].

4G technology has reached an advanced stage after its deployment around 2010. The network architecture has not undergone any significant modifications despite the growing mobile industry. 4G technology cannot meet current requirements such as spectrum congestion or reduced power consumption. For this reason, 5G technology is being world-facused [9]. In the field of communications technology, work is underway on the infrastructure of the 5G cellular network to meet the demand for wireless communications, the 5G technology will add more sustainable features such as the transmission time, and more reliable communication, to facilitate the above-mentioned features, many previous researchers have designed antennas for both the base station and the cellular phone [10].

A. Yadav et al. [11] simulated a microstrip antenna array 1x2 for 5G applications, the array properties were improved by creating a U-shaped slot in the radiating layer an antenna operates in the frequency range (3.4-3.8) GHz, the research shows the analysis results: such as efficiency, return loss and radiation pattern. J. Colaco & R. Lohani [12] designed a microstrip antenna that works within 5G applications at 26GHz, the researcher used patch a rectangular shape, the researcher obtained the results; the loss coefficient was -33.4 dB, a bandwidth of 3.56GHz, and an efficiency of 99.5%. The design that has been suggested is helpful during ongoing shutdowns worldwide . S. Didi et al. [13] designed a rectangular microstrip antenna array operating at 27.5 GHz for 5G applications, the aims of the research is to improve antenna performance in terms of efficiency, bandwidth, gain, return loss, and directivity.

2. Antenna Array Design

A set of mathematical formulas was used to design the microstrip patch antenna array to determine the radiating patch's dimensions thickness of 1.6 mm and dielectric constant of 3.4, the design was made at a frequency of 15 GHz, which operates within the 5G applications, the dimensions of the patch are calculated from the relationship [14].

$$W_p = \frac{C}{2f_o}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad \text{.........} \ (1)$$

Where: W_p is the radiant patch width, C is speed of light, f_o is work frequency, , ε_r is insulation constant.

The effective insulation constant (ε_{reff}) is calculated from the relationship [15].

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 2\frac{h}{W_p}\right]^{\frac{1}{2}} \quad \text{.......... (2)}$$

Where: h is insulating substrate thickness.

The effective length of the radiated patch (L_{eff}) is calculated from the relation [16].

$$L_{eff} = \frac{C}{2f_o\sqrt{\varepsilon_{reff}}} \quad \text{........... (3)}$$

The difference between the electrical and physical lengths (ΔL) is from the relation [17][18].

$$\Delta L = 0.412\,h\left[\frac{\varepsilon_{reff} + 0.3}{\varepsilon_{reff} - 0.258}\right]\left[\frac{\frac{W_p}{h} + 0.264}{\frac{W_p}{h} + 0.8}\right] \quad \text{.................. (4)}$$

The radiating patch's length (L_P) is calculated using the relationship [19].

$$L_P = \frac{C}{2f_o\sqrt{\varepsilon_{reff}}} - \Delta L \quad \text{................ (5)}$$

The fractional bandwidth (FBW) is calculated from the relation [20].

$$FBW = \left[\frac{F_H - F_L}{F_C}\right] x\,100\% \quad \text{........... (6)}$$

Where: F_C is central frequency, F_L is low frequency, F_H is highest frequency.

3. CST Simulation Program.

To obtain a suitable and timely design for electromagnetic devices, in addition to their analysis. Several electromagnetic simulation programs are used, as these programs help reduce design repetition and allow systems and their capabilities to be analyzed and improved from the early stage, which makes the design process faster and at a lower cost. One of these programs is the Computer Simulation Tool (CST) program, which is an advanced 3D simulation program used in the design and analysis of electromagnetic devices. It is characterized by an easy-to–use interface and extensive optimization capabilities, making it an ideal tool for electronics and communications engineers [21], as in fig.(1).

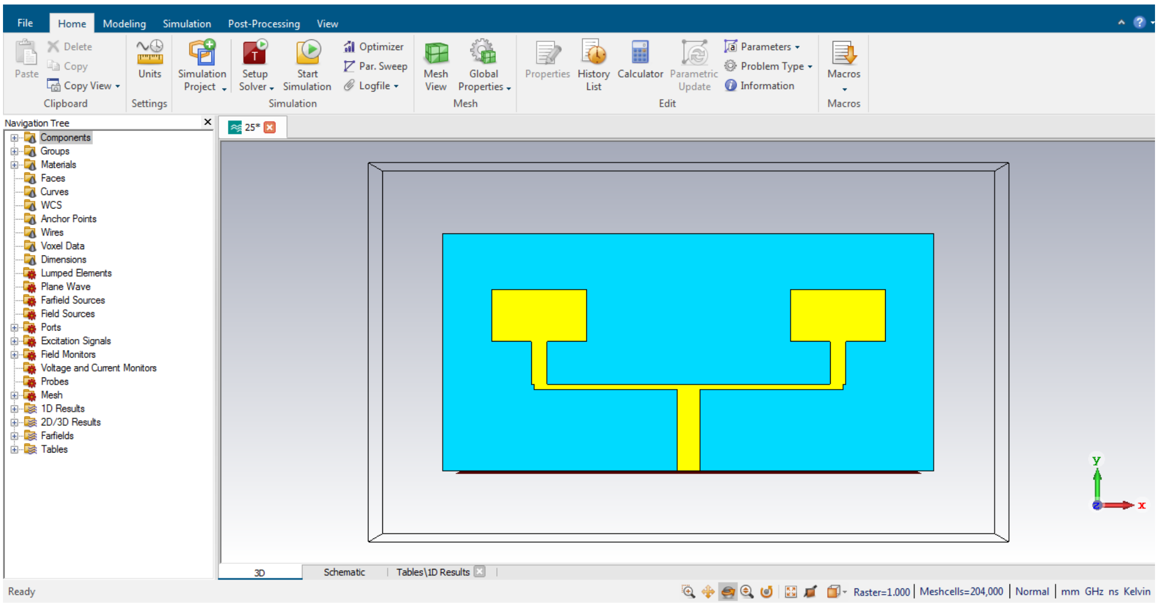

Fig.1 CST program main interface.

Fig.2 Shows the design of the suggested microstrip antenna array in current work, with the primary dimensions fixed on it and consisting of the following parts: the ground plane made of copper, the insulating material made of epoxy (FR-4) with an insulation constant of 4.3, the microstrip line-type feed line and the made copper radiating patch.

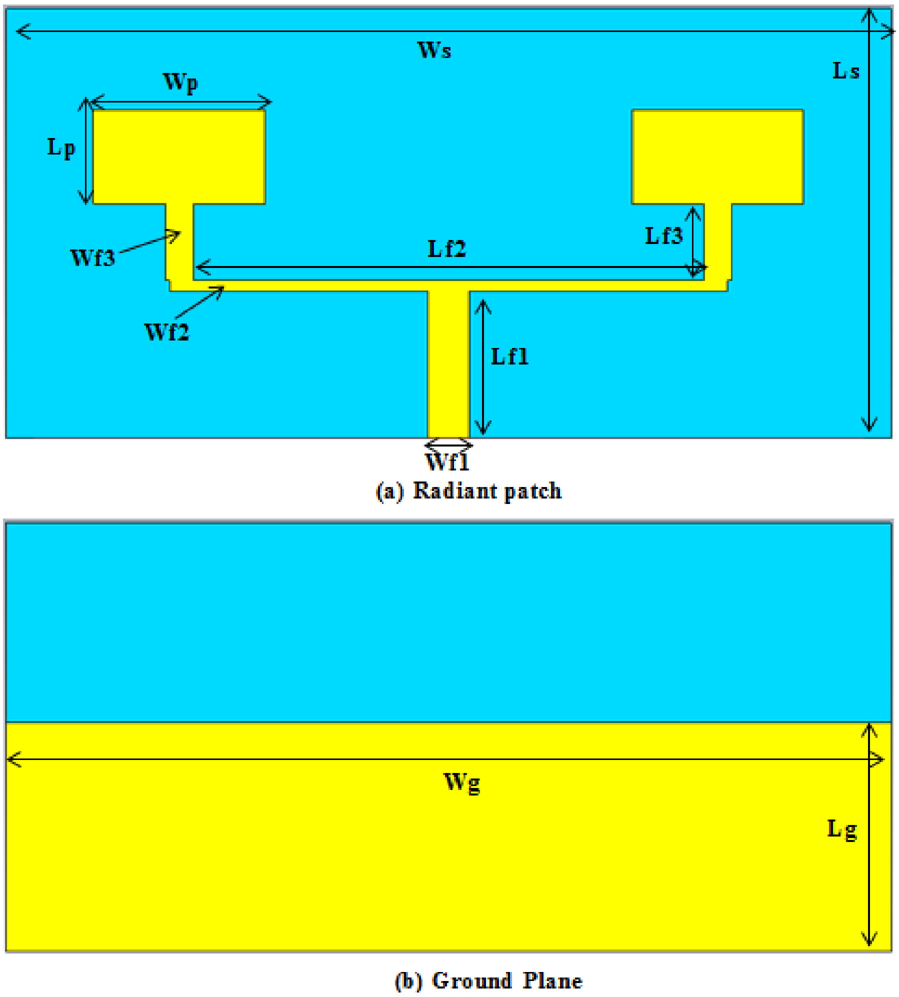

Fig.2 Antenna array proposed in the present work.

Table 1 Displays the microstrip antenna array 's primary dimensions, all expressed in unit mm.

dimensions	Ls	Ws	Lp	Wp	Lg	Wg	Wf1
Value	9.2	19	2	3.68	4.9	19	0.88
dimensions	Wf2	Wf3	Lf1	Lf2	Lf3	h	
Value	0.22	0.6	3.15	5.44	1.65	1.6	

4. RESULTS AND DISCUSSION.

4.1 RETURN OF LOSS

Fig. 4 Displays the return loss plot, through which the operational frequency of the microstrip antenna array was determined , at a frequency of 25GHz, the return loss was -35.837dB, which is less than -10dB, which is a reference.

Also, the bandwidth was calculated at 25GHz and its value was 6.1626GHz, which starts from 22.636GHz and end at 28.798GHz. Also, the fractional bandwidth was calculated using Eq.(6) and its value was 24.64%.

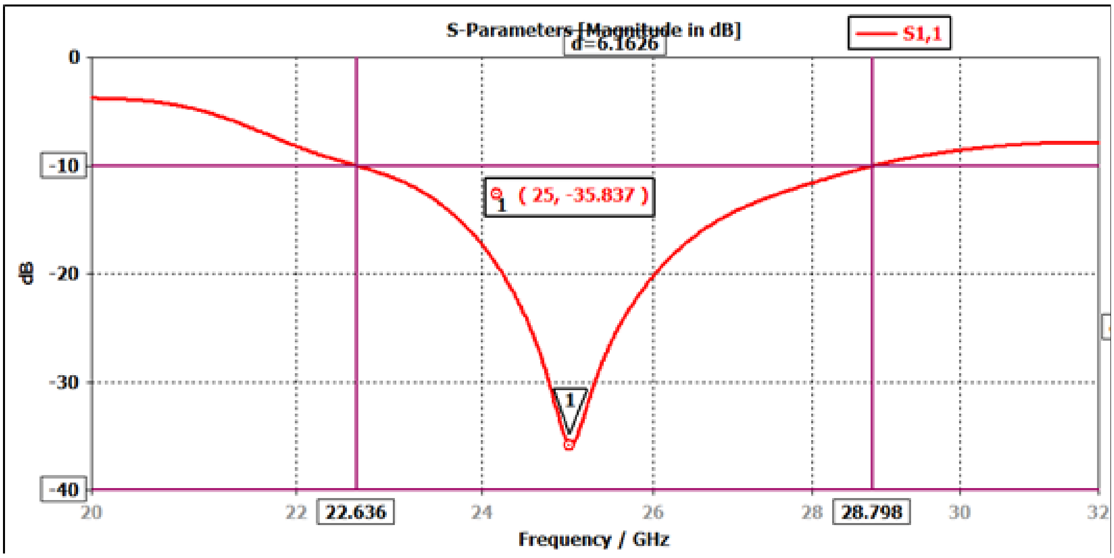

Fig.4 Return loss.

4.2 VOLTAGE STANDING WAVE RATIO (VSWR).

Fig.5 Shows the value VSWR that is equal to 1.0328 at the working frequency of 25GHz. It is near one, which is an ideal value because the range is 2≥VSWR≥1. The source and the transmission line are therefore well matched, and thus the reflected signal to the source is small.

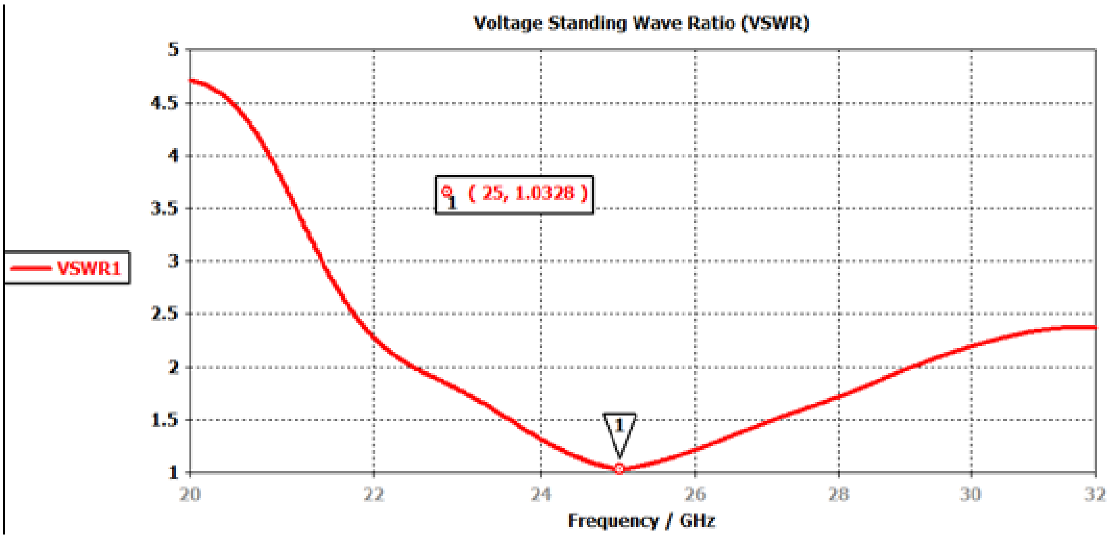

Fig.5 Change in VSWR as a function of frequency.

4.3 SMITH CHART

Fig.6 Displays the Smith chart, showing the real and imaginary parts of the microstrip antenna array's impedance. It was also noted that the antenna array has matching at the operating frequency of 25GHz, as the impedance of the real part approaches 50Ω and equals 51.63Ω, and its imaginary part approaches 0Ω and equals 0.138Ω. This indicates that the antenna array radiates most of the supplied energy into the vacuum.

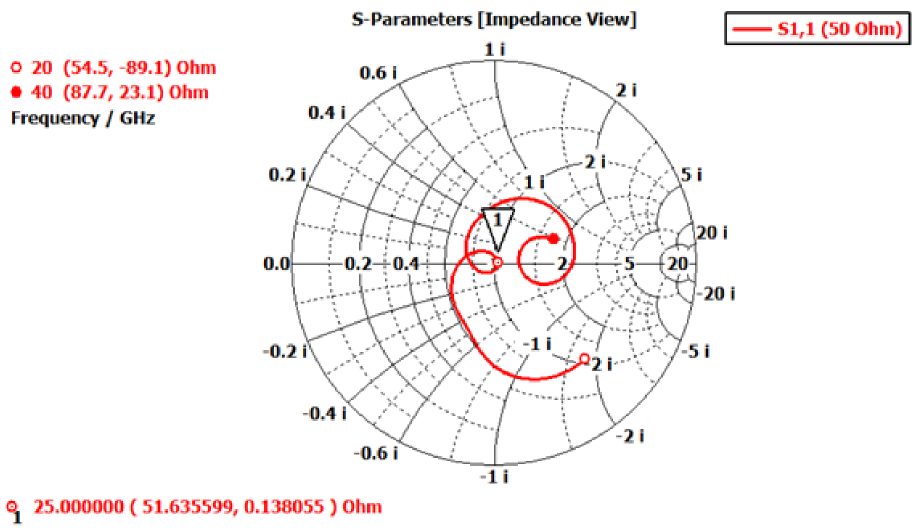

Fig.6 Smith chart

4.4 IMPEDANCE OF MICROSTRIP PATCH ANTENNA ARRAY.

Fig.7 Shows the antenna array impedance diagram with its real imaginary parts. It was also noted that the antenna array has a high matching for both its imaginary and real parts at the operating frequency of 25GHz.

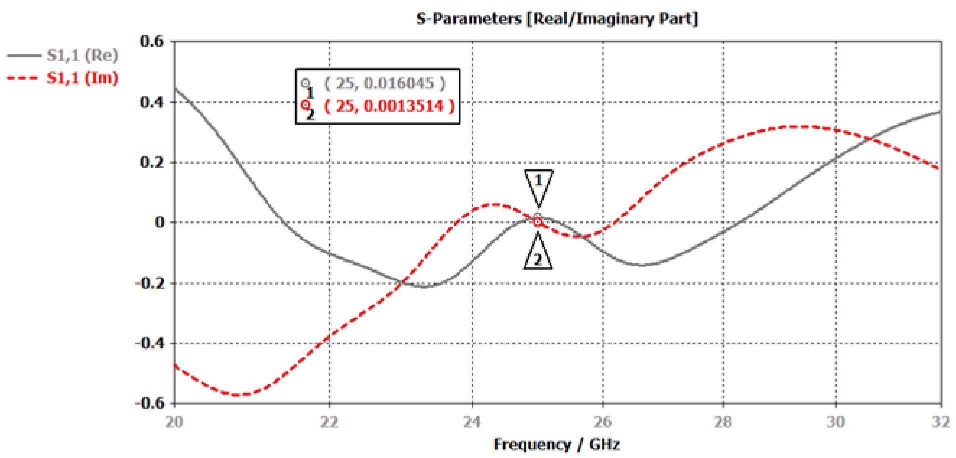

Fig.7 Impedance of antenna array.

4.5 GAIN

Fig.8 Shows the gain of the microstrip antenna array 's gain changes with frequency, and it was noted that the gain value is greater than zero at the operating frequency of 25GHz, which is equal to 3.332dB.

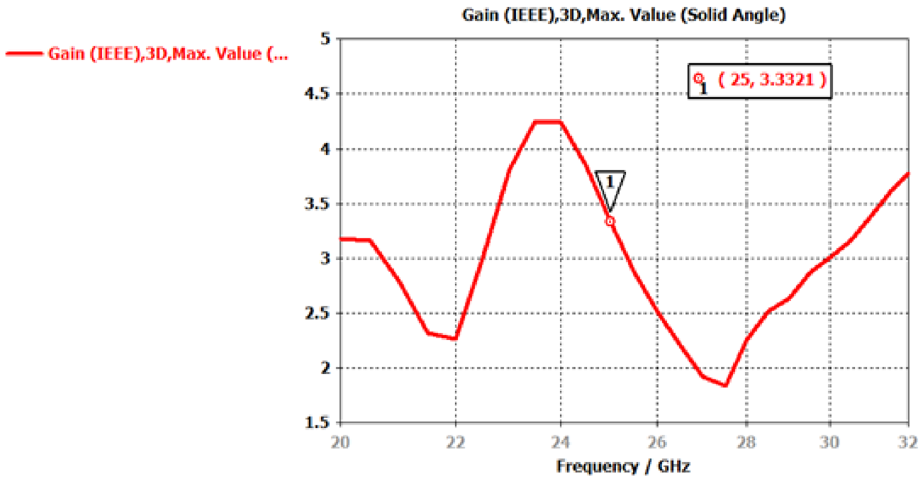

Fig.8 Antenna array gain.

4.6 DIRECTIVITY

Fig.9 Displays the microstrip patch antenna array's directivity as a function of frequency. It was noted that its value is greater than zero at the operating frequency and was 6.579dBi, at the frequency of 25GHz, one of the benefits of the antenna array is that its directivity value increases, as the number of array elements increases.

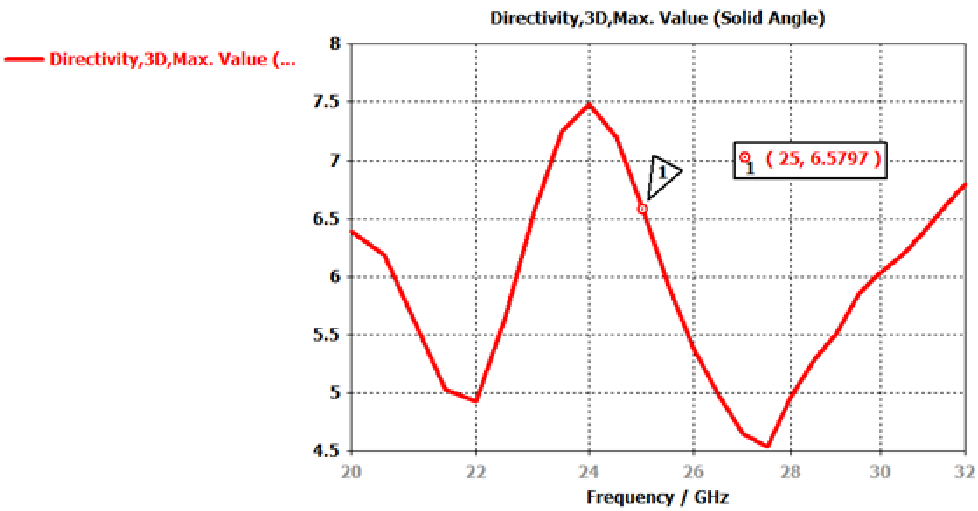

Fig.9 Directivity of an antenna array.

4.7 CURRENT DISTRIBUTION

Fig.10 Displays the current distribution of the antenna array at the operating frequency of 25GHz. The current distribution is very important and can be used to determine the area that can be improve, and through it, some improvements can be made to the array to change the path of the current through the radiated patch and the ground level. It was noted that the red area is responsible for the antenna operating frequency and the current is at its maximum.

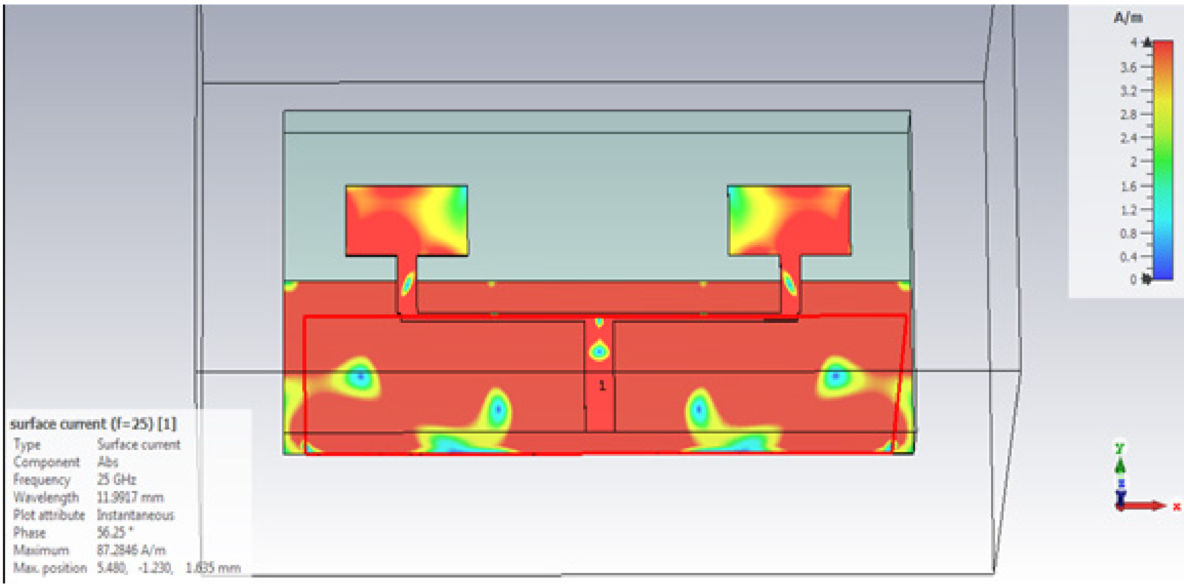

Fig.10 The antenna array 's current distribution.

4.8 RADIATION PATTERN

Fig.11 Displays the radiation pattern of the antenna array at the operating frequency of 25 GHz for both the electric field plane (E-Plane) and the magnetic field plane (H-plane), and the Y-Z plane represents the magnetic field plane when the angle Phi = 90^0 and the X-Z plane represents the electric field plane and the smith plane when the angle Phi = 0^0 .

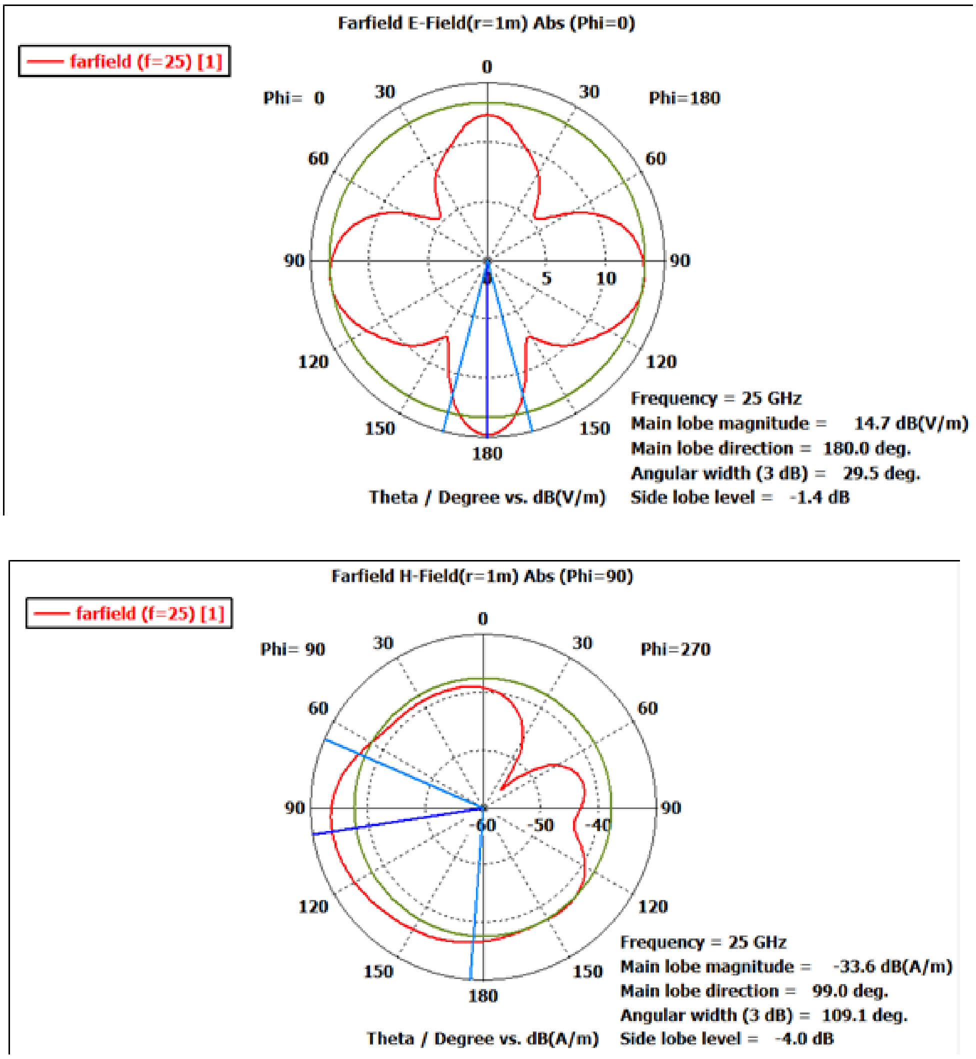

Fig.10 The antenna array 's radiation pattern for the magnetic and electric planes.

5. CONCLUSION

This research includes the design, simulation, and presentation of the results of microstrip patch antenna array for 5G applications that operate at 25GHz. The study showed that all the properties of the antenna array obtained are good. The study also showed that the impedance has good matching in both its real and imaginary parts and that the directivity increases with the increase in the number of array elements. The current distribution of the antenna array is also important, through which the area that can be improved is determined. In future work, we propose to design and simulate MIMO antenna arrays for 5G applications.

The authors declare that they have no known competing financial interests or personal relationships that could have reported to influence the work reported in this paper.

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