A 2x2 Millimeter-Wave Microstrip Antenna Array for 5G Applications

G. Viswanadh Raviteja

***Abstract*—In this paper, microstrip antenna array is designed and simulated for 5G applications. The array was designed with the intent to cover the millimeter-wave spectrum at 27GHz frequency. The substrate used in this antenna construction is Rogers RT Duroid 6002 with a loss tangent of 0.0012 and dielectric constant 2.94. The idea behind this research is to design antenna array for 5G systems able to operate in the frequency band of 24.25 – 27.5 GHz. Initially, a conventional antenna is designed. Thereby 2X1 microstrip antenna is designed and finally, a 2X2 antenna array is designed. In each stage, the antenna parameters such as S11 parameter, gain, and VSWR are calculated. Comparisons are also drawn concerning the directivity of the three antenna configurations discussed. For the end design which involves a 2X2 microstrip antenna array, the S11 is calculated to be -31.94 dB at the frequency of 26.78 GHz. The gain achieved was 11.02 dB and the directivity is found to be 11.12 dB. All the important findings from the simulations performed are tabulated.**

***Index Terms*—Antenna array, 5G Applications, Millimeter-Wave, Rogers RT Duroid 6002, MMW Applications.**

I. Introduction

Wireless mobile communication success led to rapid development in technology. From 2G cellular communications in 1991 to 3G communication systems launched in 2001, there is a huge transformation in the way information is transmitted and received. Rich multimedia content was possible with 3G systems [1]. The progression of 3G to fourth-generation systems followed which included HSPA and advanced LTE systems. Various other wireless application services also came into existence such as WIFI (2.4 GHz and 5.2 GHz), Bluetooth and ultra-wideband systems. The operating range of these services ranges from a few kilohertz to gigahertz range [2]. With the development and rapid change in wireless technologies, the data traffic for mobile had a drastic increase over the years. To meet the specific needs of mobile data, millimeter-wave communication received increased attention in the wireless industry [3]. When compared to the 4G systems, the major difference adopted in 5G systems is the migration to higher frequencies is seen where available spectrum and bandwidth is available [4]. It is also discussed that the bandwidth offered by the millimeter-wave systems is broader than previous-generation wireless systems. On the other hand, mm-wave systems often need antennas which offer high gain because of the problem associated with propagation losses which are high in mm-wave systems compared to previous generation communication systems [5]. Therefore, at these mm-wave frequencies, it is necessary to operate antennas having high directivity and be able to steer properly in novel ways because of the extremely small wavelengths [6-7]. With 5G communications higher data rates requirements can be handled and also be able to meet the future wireless applications such as massive machine-type communications. With this new technology, it is also possible to build highly reliable networks [8].

In the present work, a conventional microstrip antenna is designed and studied. The second stage includes designing a 2X1 antenna array and in the final stage, proposed 2X2 microstrip millimeter antenna array is designed

II. Antenna Design Structure

The millimeter-wave antenna array design is started with the design of a basic conventional antenna. The ground plane with dimensions 5.5 X 6 (in mm) in terms of width and length is considered. With a height of 0.5 mm, the dielectric substrate is placed on the proposed ground plane. The substrate used in this case is Rogers RT/ duroid 6002 with dielectric constant ‘2.94’ and loss tangent of ‘0.0012’. The design is shown in Fig. 1.

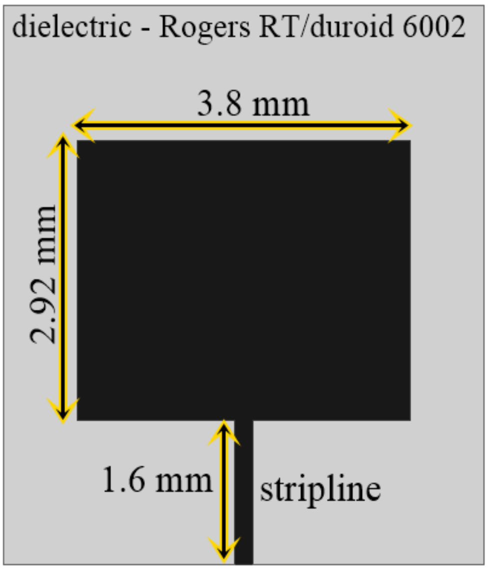

Fig. 1. Conventional Antenna

The width and length of the patch placed on the dielectric substrate are taken to be 3.8 X 2.92 (in mm). Strip-line feeding is employed for this design configuration. The antenna is designed to cover the 5G frequency band 24.25 to

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27.5 GHz. The dimensions for the design are calculated from the microstrip antenna design equations mentioned in [9]. Once the design is completed, simulations were carried out using HFSS software. The antenna parameters S11 plot, VSWR and gain are calculated. The S11 and corresponding VSWR are found out to be -38.10 dB and 1.161 for the operating frequency of 26.81 GHz. These are given in Figs. 2 and 3.

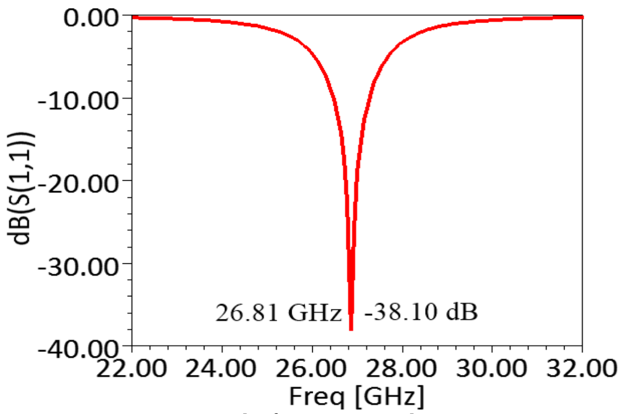

Fig. 2. S11 plot for Conventional Antenna

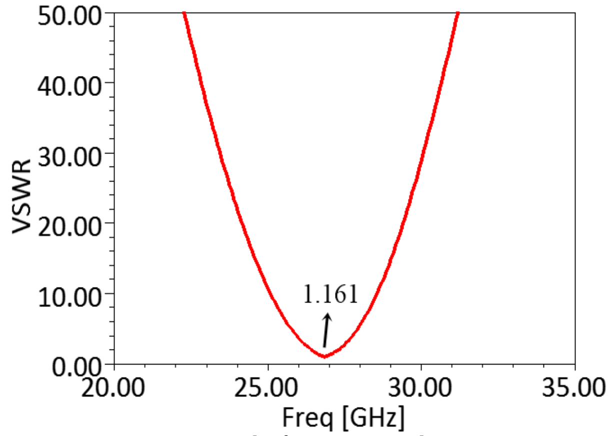

Fig. 3. VSWR plot for Conventional Antenna

The gain for the conventional antenna is calculated using the far-field measurement setup specifying the 'phi' and 'theta' values. At the operating frequency 26.81 GHz, the gain of the antenna is calculated and is found to be 7.12 dB. Fig. 4. shows the 3D gain plot.

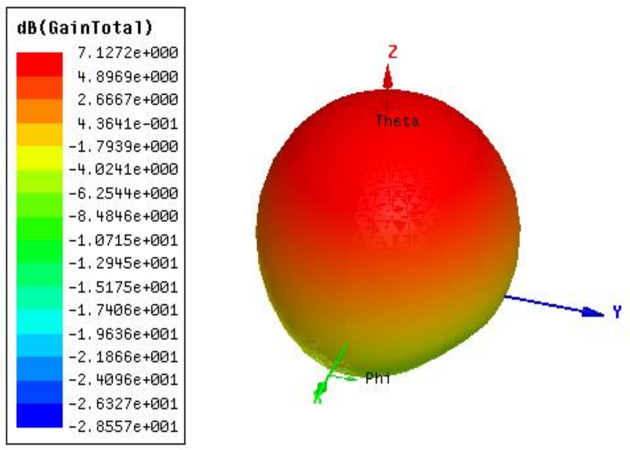

Fig. 4. 3D gain plot Conventional Antenna

III. The 2X1 Millimeter-wave Antenna Array

In the second stage of the design process, the concept of conventional antenna is extended to form an array. Initially, a 2X1 antenna array is designed. The separation between the individual antenna elements is taken to be 7.5 mm for the center of the excitation feed between the two antenna elements. The separation distance considered is the optimized value taken to obtain necessary radiation characteristics. The structure is shown in Fig. 5.

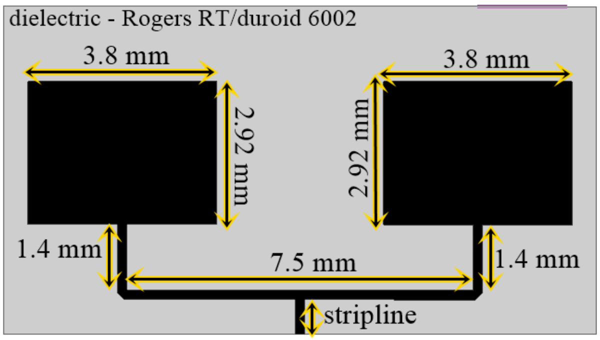

Fig. 5. A 2X1 Millimeter Wave Antenna Array

The simulations performed, found S11 value to be -35.11 dB with a center frequency of 26.71 GHz. The VSWR, in this case, is 1.035. These are shown in Figs. 6 and 7.

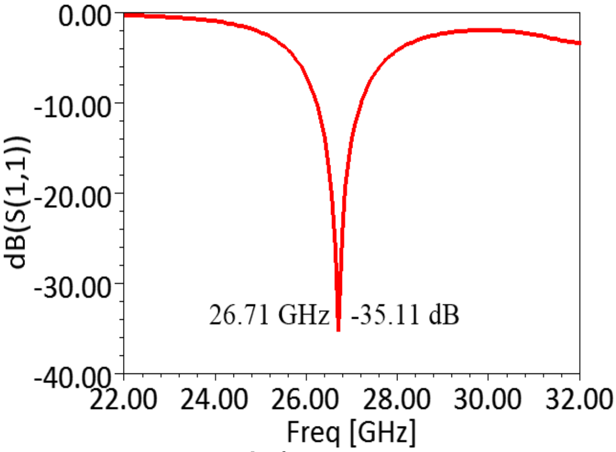

Fig. 6. S11 plot for 2X1 Antenna Array

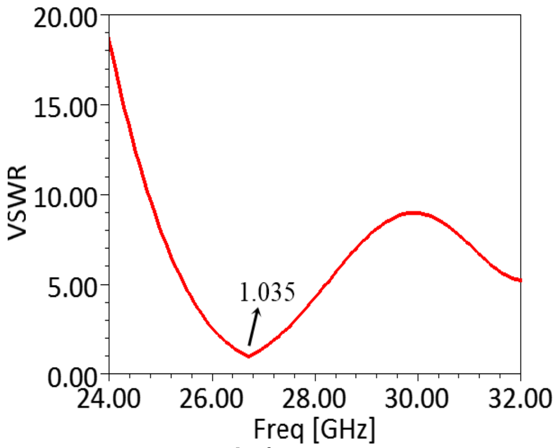

Fig. 7. VSWR plot for 2X1 Antenna Array

The gain for the 2X1 antenna array is simulated and calculated to be 9.695 dB for the frequency 26.71 GHz. From the plot shown in Fig. 8, it can be seen that the gain of

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the antenna array is increased greatly thereby also enhancing the directional properties.

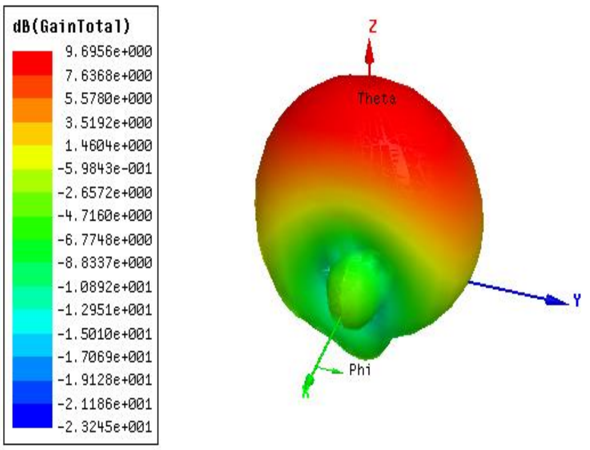

Fig. 8. 3D Gain plot for 2X1 Antenna Array

IV. Proposed 2X2 Millimeter-Wave Antenna Array

As a final step in the design, the 2X1 antenna array is extended to 2X2 antenna array. 4 elements forming the 2X2 array configuration with the use of corporate feed is proposed. The feed system, feed length and the distance between individual antenna elements are optimized to obtain the desired radiation properties. The structure is shown in Fig. 9.

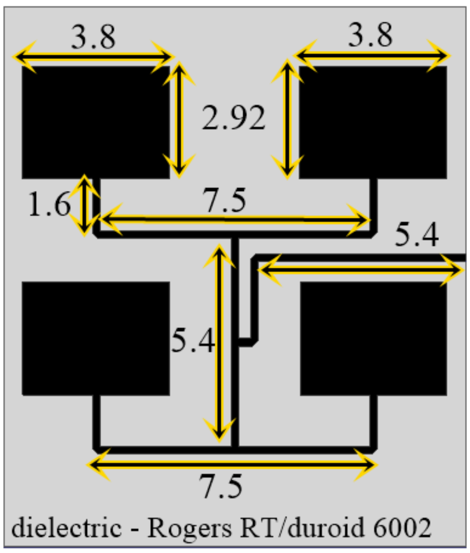

Fig. 9. Proposed 2X2 Millimeter-Wave Antenna Array

Simulations in the case of the proposed millimeter-wave antenna array showed an S11 value of -31.94 dB with the operation frequency at 26.78 GHz. The VSWR is found out to be 1.0519. These are given in Fig. 10 and 11.

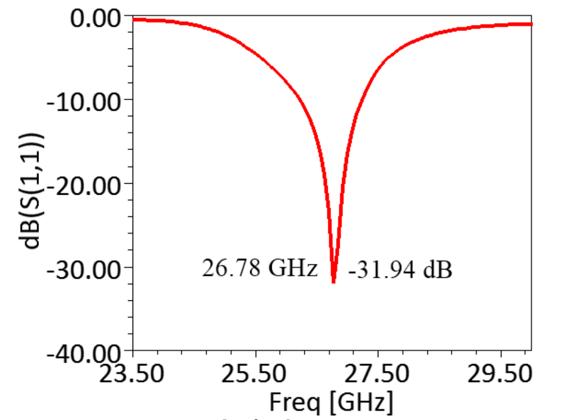

Fig. 10. S11 plot for the 2X2 Antenna Array

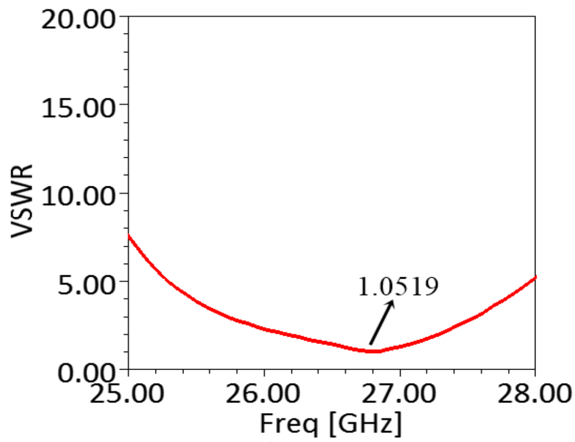

Fig. 11. VSWR plot for the 2X2 Antenna Array

The gain is calculated for the final stage antenna array configuration is found to be 11.02 dB. This directional property of the array is greatly increased compared to the previous antenna configurations. The gain plot is shown in Fig. 12.

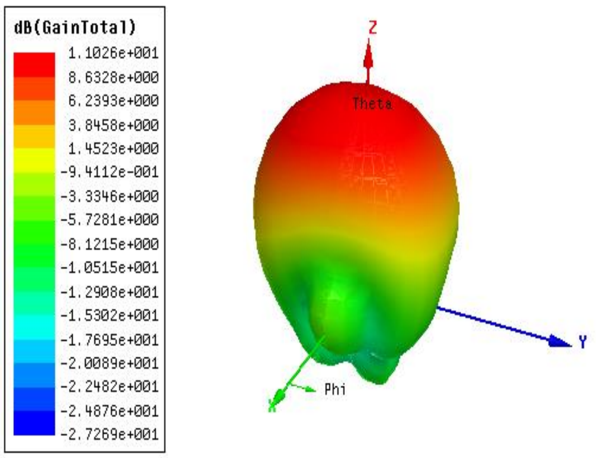

Fig. 12. 3D Gain plot for the proposed 2X2 Antenna Array.

TABLE I: Antenna Parameters Comparison Table

Antenna Configuration	Operating Frequency (GHz)	S11(dB)	VSWR	Gain (in dB)
Conventional Antenna	28.61 GHz	-38.10	1.161	7.12dB
2 X 1 Antenna Array	26.71 GHz	-35.11	1.035	9.695 dB
2X2 Antenna Array	26.78 GHz	-31.94	1.051	11.02 dB

V. CONCLUSION

A 2X2 antenna array employing the corporate feeding technique is proposed. The antenna array's S11 value is -31.94 dB at 26.78 GHz frequency. The final design structure is an end result of stage by stage modifications to a conventional antenna. All the three antenna configurations showed good reflection coefficient values, -38.10 dB, -35.11 dB and -31.94 dB in the operating frequency. The gain values also showed considerable improvement at each design stage of the antenna configurations, 7.12 dB, 9.695 dB and 11.02 dB. Therefore, the proposed antenna can be considerably used for millimeter wave applications covering the frequency ranges 24.25 – 27.5 GHz proposed for the 5G systems.

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