A 4-Element Corporate Series Feed Millimeter-Wave Microstrip Antenna Array for 5G Applications

G. Viswanadh Raviteja

***Abstract*—**In this paper, a microstrip antenna array is designed for 5G applications. A corporate series feed is considered to operate with a center frequency between 27 to 28 GHz to be able to cover the 5G frequency bands 24.25-27.5 GHz, 26.5-29.5 GHz and 27.5-28.35 GHz. The substrate is taken to be Rogers RT/Duroid 6002. The corporate series 5G antenna array is designed stage by stage by taking into consideration a conventional antenna designed at 28 GHz, thereby constructing the 2X1 antenna array before arriving at the final design structure of 4-element corporate series feed antenna array. The discussions concerning S11 parameter, gain and voltage standing wave ratio (VSWR) for the design structures are considered and all the important findings are tabulated. The proposed antenna array's S11 parameter was found to be -29.00 dB at a frequency of 27.39 GHz with a good directional gain of 12.12 dB.

***Keywords*—**Corporate series feed, millimeter wave antenna array, 5G applications, millimeter-wave (mm-wave) applications.

I. Introduction

RAPID technological advancements took the course over the years since the success of wireless systems. Gigantic technological advancements are seen in the last decade concerning wireless cellular communications [1]. This led to the shortage of global bandwidth which is creating challenges to the service providers. All the wireless applications today are restricted to a frequency range of 700 MHz and 2.6 GHz [2], [3]. Because of the non-availability of the spectrum as it is overcrowded in the lower frequencies, it became necessary to shift to higher frequencies. It is to be noted that to overcome the challenges in accomplishing necessary bandwidth for next-generation wireless systems which is 5G it is necessary to use MMW bands. The region between 24 GHz to 29 GHz is extensively used as there are relatively lower atmospheric absorptions and attenuations rate will be lesser [4]. The available speed of transmission and reception will be over a thousand times faster speed in 5G systems. Since the available frequency spectrum and bandwidth is also mentioned in these MMW bands, the MMW systems are a promising solution for the 5G systems [5]. For high-speed data rates, research is active at 60 GHz in the last few years. But, due to the excessive absorption rate of oxygen, this research at 60 GHz is a limited indoor-to-indoor scenario. As an outcome, the Ka-band which covers the frequency ranges from 26.5 GHz to 40 GHz has been more subject of interest of outdoor communications [6]. One of the problems to discuss is the path loss. Compared to the present lower band of frequencies related to mobile communications, the path loss associated with 5G systems is high. Therefore, the antennas to be used for the 5G systems should of high gain. A tapered slot antenna utilizing substrate integrated waveguide is shown in [7]. A cross-slot millimeter-wave with dual-band characteristics for 5G applications is discussed in [8]. Vivaldi antenna array employing end-fire beam steering for 5G mobile terminals is shown in [9]. Phased array concept for millimeter-wave applications employed in a whole metal covered mobile is discussed in [10].

In this paper, to study the gain and reflection coefficient S11 plots of the millimeter-wave array considered, corporate series feed is employed. Section II deals with the necessary introduction, Section II deals with the antenna structure, Section III introduces a 2X1 antenna array, Section IV deals with proposed 4 element antenna array with corporate series feed and Section V finally concludes the paper.

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II. Conventional Antenna Design

In the initial stage of the design, a conventional antenna is designed to operate within the frequency range of 27 GHz to 28 GHz. The width and length of the ground are taken to be 5.5 mm X 6 mm. The dimensions for the conducting patch are designed to be 3.89 mm X 2.93 mm in terms of width (W) and length (L). The design structure is presented in Fig. 1.

The dimensions are calculated using the general formula for microstrip patch antenna design equations mentioned in [11].

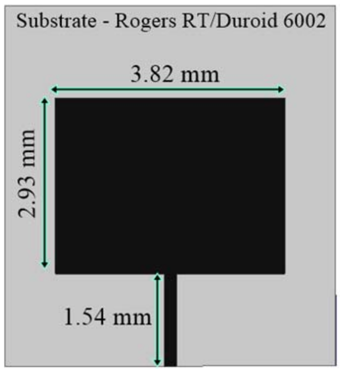

Fig. 1 Conventional Microstrip Antenna

The substrate in this design is considered to be Rogers RT/ duroid 6002 which has a dielectric constant of 2.94 and a loss tangent value of 0.0012. The height of the substrate is optimized to be 0.3 mm. The feeding technique used for this design configuration is strip-line feeding which has a length of

1.54 mm to the center of the conducting patch.

Simulations are carried out using HFSS software. Initially, the reflection coefficient S11 plot is simulated. The S11 value was found to be -34.765 dB for an operating frequency of 27.61 GHz. This is given in Fig. 2.

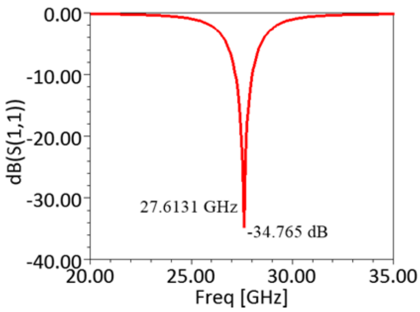

Fig. 2 S11 plot for Conventional Antenna

Once, the S11 value is found out, the VSWR value is calculated. For efficient working of the antenna better matching is to be achieved. The VSWR value should be less than 2 for an optimum working condition of any antenna under consideration. For the conventional antenna, the VSWR is found out to be 1.0372 for the frequency 27.61 GHz. This is given in Fig. 3.

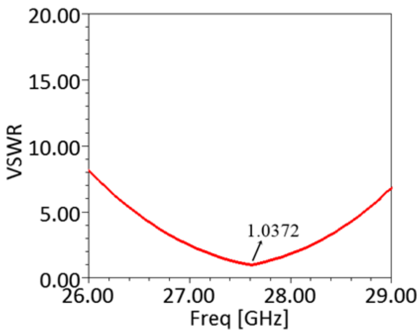

Fig. 3 VSWR plot for Conventional Antenna

Finally, the antenna is simulated for the gain parameter. The gain for the conventional antenna is found to be 7.16 dB for the frequency level 27.61 GHz. This is given in Fig. 4.

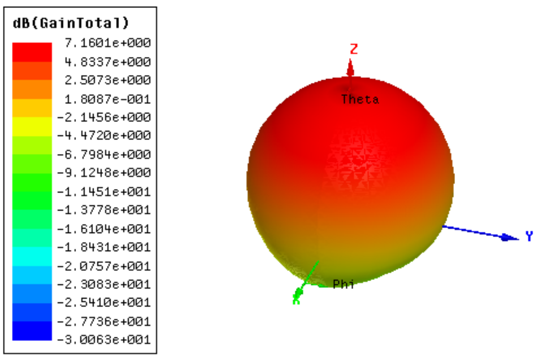

Fig. 4 3D Gain plot for Conventional Antenna

III. 2 X 1 Antenna Array Design

Once, the conventional antenna is designed and simulated, a 2 X 1 antenna array is designed to investigate the working performance of the array at millimeter-wave frequencies. In this case, the array is formed by a similar antenna placed at a particular distance. The distance is optimized to obtain the required results, which is set to be 7 mm. The so formed array is excited using stripline feed similar to conventional structure discussed earlier. The array structure is presented in Fig. 5.

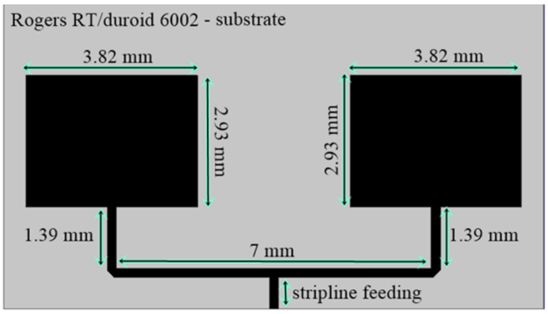

Fig. 5 A 2X1 Microstrip Antenna Array

The designed array is simulated for S11 plot, VSWR and gain plots. The S11 is found to be -28.84 dB at the frequency range of 27.01 GHz. This is shown in Fig. 6. The VSWR, in this case, is found to be 1.0750 for the frequency 27.01 GHz and the gain is calculated to be 9.69 dB. Because of the array configuration, there is an increase in the directive properties of the antenna, which resulted in increased values of gain. The VSWR and gain plots are shown in Figs. 7 and 8.

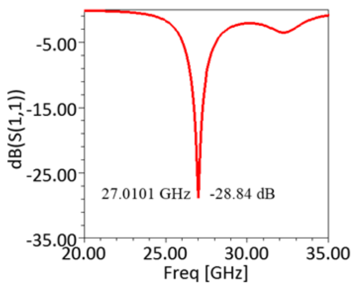

Fig. 6 S11 plot for 2X1 antenna array

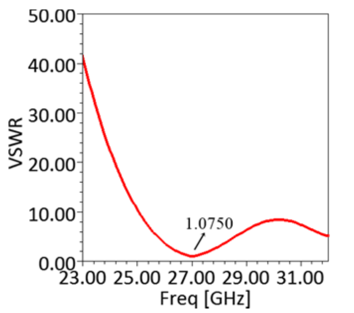

Fig. 7 VSWR plot for 2X1 antenna array

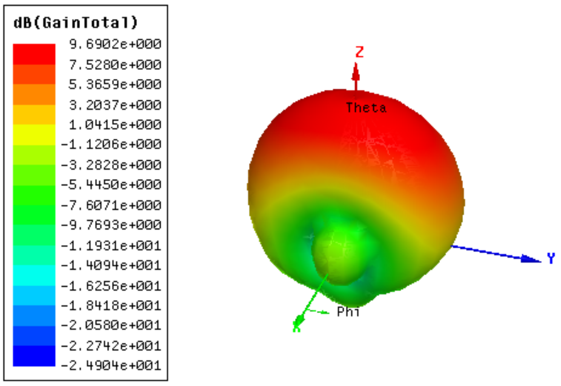

Fig. 8 3D gain plot for 2X1 antenna array

IV. Proposed Corporate Series Fed Antenna Array

As a final stage in the design process, the antenna array in discussed in Section III is modified. Structural modifications are carried implementing the corporate series feed for this case. The antenna array design structure is seen in Fig. 9.

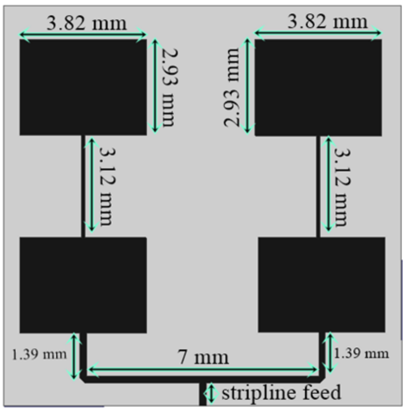

Fig. 9 A 4 – Element Corporate Series Feed Antenna Array

For the 2X1 antenna array discussed in the previous section, two antennas are given a series connection with the length of the series feed being 3.12 mm between the antennas. The distance is optimized for obtaining the required radiation characteristics. The result is a 4-element corporate series feed microstrip antenna array.

The corporate feed, in general, is said to have more control over the feed of every individual antenna. The series feed, on the other hand, is a compact feeding method and the losses associated with this feed is less. The corporate series feed is said to have the combined benefits of the corporate feed and series feed methods. This proves to be advantageous in terms of radiation efficiency. This feed method is responsible for higher directivity and lower beam fluctuations.

The S11 plot for the proposed antenna array is found out to be -29.00 dB at the operating frequency of 27.39 GHz. This is shown in Fig. 10. The VSWR in the case of this proposed antenna array is calculated to be 1.0735 for the operating frequency of 27.39 GHz. The gain is found to be 12.12 dB. These are shown in Figs. 11 and 12.

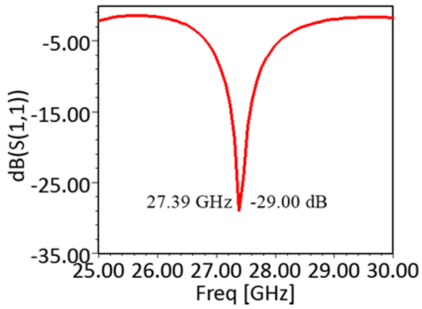

Fig. 10 S11 plot for the 4 – Element Corporate Series Feed Antenna Array

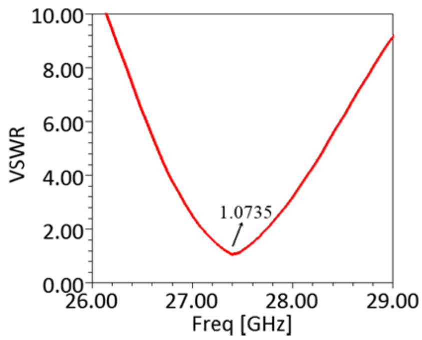

Fig. 11 VSWR plot for the 4 – Element Corporate Series Feed Antenna Array

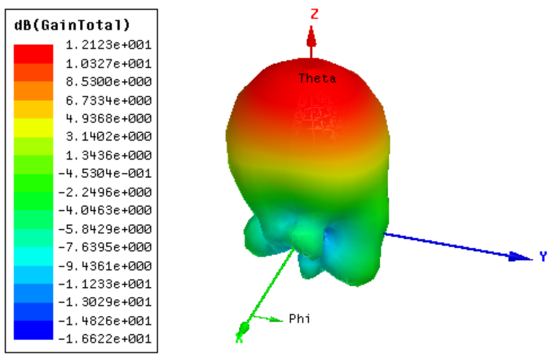

Fig. 12 3D Gain plot for the 4 – Element Corporate Series Feed Antenna Array

TABLE I
ANTENNA PARAMETERS FOR THE DESIGN STRUCTURES

Antenna Configuration	**Operating Frequency (GHz)**	**S11(dB)**	**VSWR**	**Gain (in dB)**
Conventional Antenna	27.61 GHz	-34.765 dB	1.0372	7.16dB
2 X 1 Antenna Array	27.01 GHz	-28.84 dB	1.0750	9.69 dB
4 – Element Corporate Series Feed Antenna Array	27.39 GHz	-29.00 dB	1.0735	12.12dB

V. Conclusion

A high directive, high gain corporate series feed microstrip antenna array for millimeter-wave applications is discussed in this paper. The antenna array is designed to operate in millimeter-wave frequency range 27 to 28 GHz. The designed antenna's performance is compared to the previous modifications in the design structure. The proposed antenna array exhibited a peak gain of 12.12 dB which is relatively more when compared to the 2X1 antenna array which exhibited 9.69 dB and the conventional antenna whose gain is calculated to be 7.16 dB. The S11 value of the proposed antenna is -29.00 dB at 27.39 GHz frequency with VSWR being 1.0735. On an overall note, the proposed corporate series feed 4-element antenna array is good in terms of the antenna parameters computed and can be extensively used of millimeter-wave communications.

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