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A novel beamforming antenna array for 5G and beyond applications

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***Abstract*—5G is supposed to be the solution of issues the current cellular network is facing like low data speed and higher latency, as the number of users comes online 4G and LTE gets unable to handle users. To enable a 5G compact size microstrip patch antenna plays an important role. A microstrip patch antenna array is being proposed in this paper which consists of six radiating patches and is fed using a microstrip line feeding technique. ROGER 3003 is employed as a dielectric material because of its advance and environment-friendly features which makes it suitable for the application of 5G and B5G.The designed antenna is evaluated based on its resonating frequency at 28.8GHz with a -10 dB impedance bandwidth of 1GHz. The antenna if offering a high gain of 9.19dBi. impedance and radiation coverage with a compact antenna array having low cost makes it to be a suitable candidate for 5G and beyond communication applications.**

Keywords— microstrip, antenna array, beamforming, millimeter-wave

I. Introduction

In the last two decades, wireless communication has revealed a magnificent growth in the development of modern communication, this was accomplished because of the expansion in antenna designing. The researcher believes microstrip patch antennas and millimeter waves are appropriate candidates to fulfill the requirements of future 5G, IoT, air traffic, earth detection, space exploration, remote sensing mapping, driverless, and biomedicine [1]. The upcoming 5G needs five essential technologies to empower the approaching fifth generation which are small cells, full-duplex, beamforming, MIMO, and mm-Wave. Turning into this research antenna arrays have attracted emerging attention in many applications related to wireless communications, designing array antenna technology a cornerstone of electrical engineering. The rapid expansion of technology in modern radio systems, such as those meant for the upcoming deployment of 5G networks operating at sub-centimeter and millimeter-wave frequencies, antenna arrays are compulsory to meet progressively more stringent specifications in terms of architecture complexity, as well as broadband behavior, high-gain multi-beam characteristics, and low scan losses [2]. In literature, many techniques have been utilized to accomplish beamforming [3] [4] [5] [6]. The simpler and widely used technique is to be extending the element pattern of the array can improve the coverage [3]. 16x16 array technique is applied in [4] using metal walls. Furthermore, the pattern-reconfigurable method is an efficient computing technique for phased arrays with significant scanning coverage expansion [5] [6]. In addition, shared coupling among the radiating elements in an array is accountable for accomplishing large-angle beamforming in linear and phased arrays [7] [8]. On the other hand, some previously applied methods involve adding dielectric sheet above the array [9], using multilayers as a ground plane [10] similarly combing or mixing different techniques also included some mechanical and electrical combinations to improve beamforming [11]. In Wideband antenna applications, beamforming is accomplished using tightly coupled techniques [12] [13] but for future 5G and B5G tightly coupled method is not as suitable as for wideband antenna applications, this is because of the strong coupling between the elements of the array. Although the above-mentioned methods can observe beamforming but have some limitations such as complex structure, scanning accuracy of the beam, efficiency, gain fluctuation should be solved.

In this paper, an efficient approach is introduced to enhance the beamforming coverage with low gain reduction. The designed antenna is lightweight and can be easily fabricated in bulks. The designed antenna is suitable for future 5G. Stepping forward, this paper comprises three sections. the design and development of the proposed antenna are discussed in Section II. Furthermore, the performance of the designed antenna is expressed in section III and section IV takes up to the conclusions.

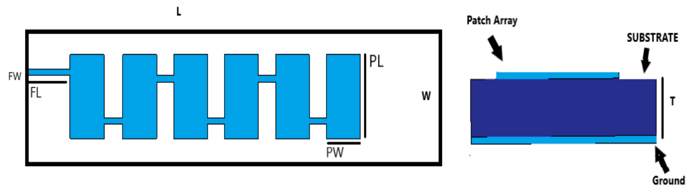

Figure 1 Antenna geometry a) front view b) side view

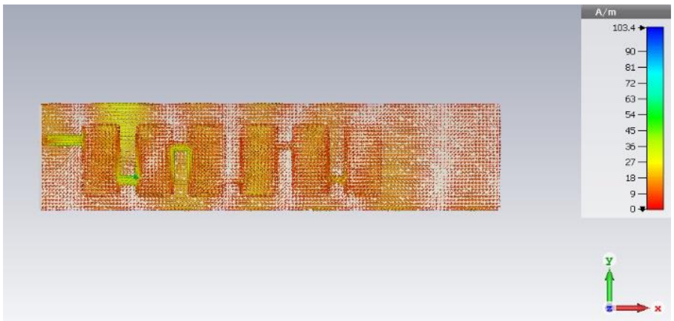

Figure 2 Current distribution of the designed antenna array

II. ANTENNA DESIGN AND DEVELOPMENT

The suggested antenna geometry comprises of a 26 mm x 6 mm rectangular sheet of dielectric material (dielectric constant = 3, loss tangent 0.0009, thickness 1.574 mm) that is backed by a conducting ground plane and topped with 6 radiating patch elements. The antenna is feed using a microstrip line feeding technique. This feeding method was employed because the microstrip line feeding technique enhances the bandwidth whereas the fabrication is easier as compared to the other feeding techniques [14]. On the other hand, the Roger RO3003 has magnificent features like easy accessibility, low cost and remains stable in different environments, it is better known for cores with better high-frequency properties and is less lossy at high-frequency applications [15][16]. The composition of the designed antenna is exhibited in figure 1 and the physical measurements are illustrated in table 1. The excited elements are rectangular which are placed above the substrate and are linked via a thin transmission line, although every single section of the feed line connecting the five radiating elements and the leading supplier has a length of 2600 µm and width of 300 µm. The ground plan place under the substrate, it has a length and width comprises of 26x6 mm. The feed point for each antenna is balanced from the center of the patch in the horizontal direction as this was found to be the location of the best return loss results. The antenna design and important simulated results were extracted using CST Microwave Studio® because of its user-friendly interface and Finite Integration Technique (FIT) for the computation of Maxwell's equations [17].

III. ANTENNA PERFORMANCE AND EVALUATION

The antenna performance is assessed based on free space parameters like matching of transmission line, S- parameters or return loss which indicates the resonant frequency, current distribution, the far-field pattern of E-plane H-plane, and Gain.

A. Current distribution

Current distribution of the antenna is evident from the figure 2 that a traveling wave pattern is being formed where the primary contributor is the middle section of the designed antenna, and the radiation is approaching from the microstrip line feeding port. The current distribution along the radiating patches of the designed antenna is also presented in figure 2.

B. Reflection coefficient

In figure 3 work band is being reported that starts from 28.2GHz to 29.2GHz. The figure also illustrates that the designed antenna is radiating at 28.8GHz. Similarly, it also illustrates that the proposed antenna not only expands the bandwidth but also sufficiently supports the communication operations in the Ka-band of the mm-wave frequency range for 5G and B5G. The simulated results shown in figure 3 confirm that antenna is resonating at 28.8GHz with a -10 dB impedance bandwidth of 1GHz and the return loss lesser than -10 verifies that the designed antenna is resonating at 28.8GHz within the ka-band.

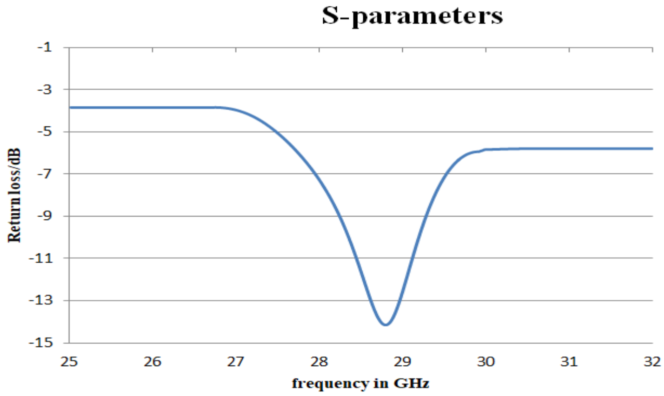

Figure 3 Reflection coefficient response of antenna

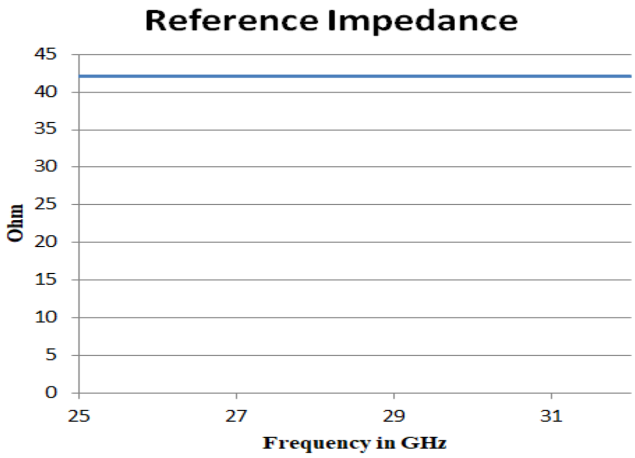

Figure 4 Reference Impedance

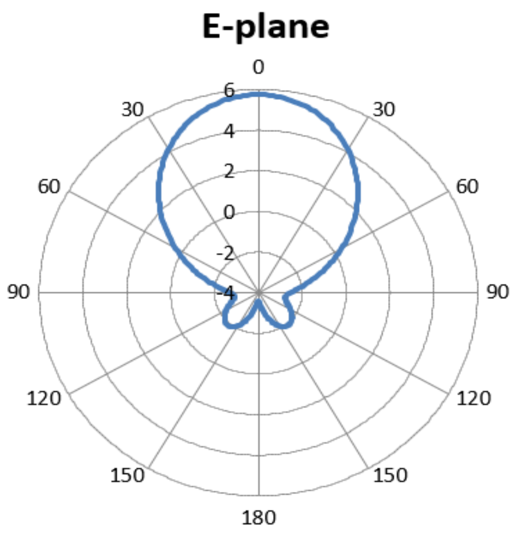

Figure 5 2-D E-plane pattern of radiations

C. Impedacne matching

Figure 4 exemplifies the perfect matching of the transmission line at 42.5 Ω with negligible reactance. The simulated results indicates that the designed antenna is properly matched. Maximum power is being delivered to the radiating patches with minimal losses.

D. Radiation pattern

Figure 5 and figure 6 shows the radiation pattern of 2-D far-field of the antenna in ϕ = 0° and ϕ = 90° planes whereas the 3D radiation pattern of the antenna is displayed in figure 7. The simulated results of 2D and 3D radiation pattern proves that antenna has good radiation coverage in both planes. The magnitude of the main lobe is 5.75 dBi, whereas the angular width (3dB) is 84.6°. The main lobe is forming a beam shaped as shown in the polar plot.

E. Gain and efficiency

The designed antenna carries a magnificent Gain profile at the resonant frequency with a value of 9.19 dBi, efficiency of this antenna is above the acceptance level with a value of 65% at the resonating frequency.

The simulated result of the designed antenna reported in this paper evaluates that the antenna is offering profound performance within the Ka-band with an excellent impedance bandwidth and radiation coverage. Similarly Gain of the presented antenna is excellent 9.19dBi which is higher as compared to the design present in literature, the comparison of the designed antenna is shown in table II, similarly the antenna efficiency is above the acceptance level. The accomplishment of the presented antenna makes it a suitable contender for communication under the concept of 5G and beyond applications. Steering the beam using an amended transmission line would be the next step in this research work.

IV. Conclusion

A design of Roger-based six patch antenna array is designed for mobile communication of next generation 5G networks. Dielectric material ROGER 3003 is employed as a substrate material to fulfill the requirements of the 5G mobile communication. The designed antenna is feed using a microstrip line feeding method and it consists of six radiating patches, each patch is connected using a transmission line and the primary is connected to the port. The antenna occupies a complete size of 26x6x1.574mm. The performance of the antenna design presented in this paper is evaluated in terms of -10 reflection coefficient, impedance matching, current distribution, and radiation pattern of E-plane and H-plane. The simulated results shown in this article illustrate that the antenna is offering a -10 dB impedance bandwidth of 1GHz on the frequency starts from 28.3GHz to 29.3GHz in Ka-band. Moreover, the antenna Gain is noticed to be 9.19dBi which falls in the bracket of high gain in the case of beamforming. The proposed model is lightweight, low cost, and can easily be fabricated in bulk for applications, it also has a modest feeding formation. The size of the antenna is compact which makes it an appropriate for future communication.

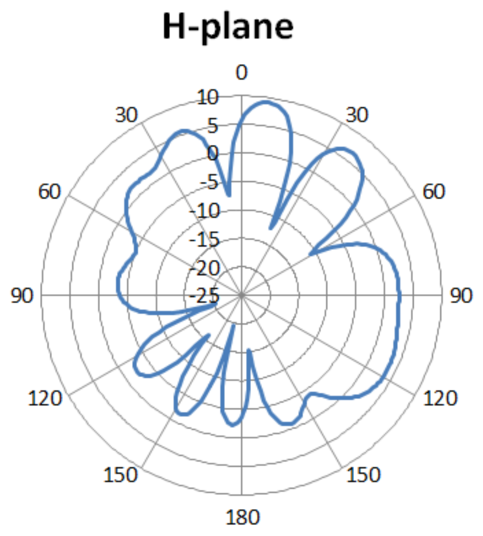

Figure 6 2-D H-plane pattern of radiations

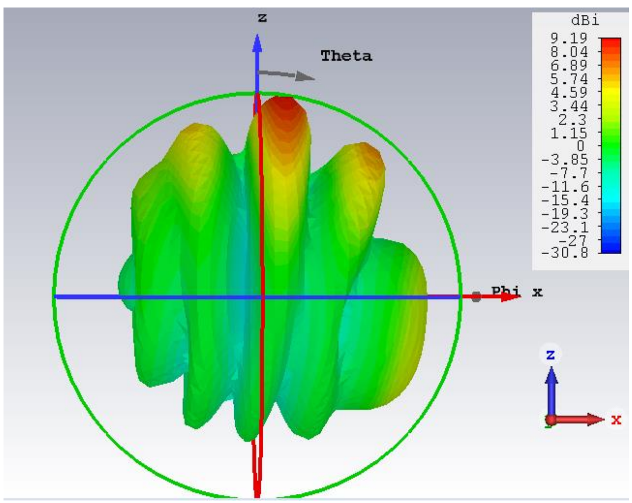

Figure 7 pattern of radiations at resonant frequency of 28.8GHz

TABLE I. DESIGNED ANTENNA DIMENSIONS

Antenna elements	***Parameters***	***Dimensions mm***
Substrate	Length (L)	26
	Width (W)	6
	Thickness (T)	1.574
	Permittivity (ε)	3
Feedline	Length (FL)	2.6
	Width (FW)	0.3
Ground	Length (GL)	26
	Width (GW)	6
Patch	Length (PL)	2
	Width (PW)	4

TABLE II. COMPARISON OF THE DESIGNED ANTENNA WITH PREVIOUSLY COMPLETED WORK

Ref	**Size (mm)**	**Resonant frequency (GHz)**	**Bandwidth (GHz)**	**Gain (dBi)**
[9]	42.5x42.5	28	6	5
[17]	102x86	28	1.5	1.51
[10]	2.5x0.53	52	1.35	3.5
[18]	37x37	28	2.4	9
Proposed work	26x6	28.8	1	9.91

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