

A High Gain Patch Antenna Array for 5G Communication

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Abstract—This research proposed a 1X4 patch antenna array for 5G Communication. The proposed antenna was designed to resonate at 28GHz frequency band. CST Microwave studio was used for the simulation of the antenna by employing Roger RT 5880 LZ with thickness and permittivity 0.762mm and 1.96 respectively as the substrate. The antenna was fed using a quarter-wave transformer to match its impedance to 50 ohms. The single patch resonates at 27.9GHz frequency with; a bandwidth of 1.87GHz, and a gain of 7.79dB. The addition of another element brought about an increment in the above-mentioned values. Furthermore, the implementation of the four element array configuration brought about the significant enhancement of values for bandwidth and antenna gain with maximum achievable gain of 13.5 dB. The design procedure, structure and simulation of the antenna are discussed in this paper.

Keywords—Array, 5G communication, microstrip patch antenna, quarter-wave transformer

I. INTRODUCTION

In recent years, the new generation of devices (smartphones, tablets), are preinstalled with data hungry and high bandwidth demanding applications which results in an exponential proliferation of wireless data traffic. Owing to the rapid growth of the wireless system, the cellular network is migrating from the conventional voice centric to a data network. It is expected that by the end of the year 2020, the amount of connected devices that will use the cellular network will be above 50 billion [1]. The 5G network is the potential candidate to satisfy the modern day data traffic requirement. The 5G wireless communication network is generally characterized by three distinct features: (i) connectivity is ever present (ii) Low latency (iii) High speed of data transfer [2]. The 5G cellular system utilizes the higher frequency in the millimeter wave which can provide wider bandwidth when compared with the 3G or 4G bands. Among the existing millimeter wave spectrum, 28- GHz is broadly underlined for 5G as a result of lesser atmospheric absorptions and relatively lower

attenuations. [3,4]. To fully utilize the 5G communication technology, antenna design is one of the essential issues to consider as the antenna plays a vital role in any wireless communication. The benefit offered by microstrip patch antennae which includes; lightweight, less expensive and ease of incorporating with circuitry devices brands them an appropriate option for the current generation wireless communication device requirements [5, 6]. However, the conventional patch antenna is characterized with low gain and a small bandwidth. The patch antenna performance can, however, be improved by configuring the antenna in an array fashion. Hence this work proposes a 1X4 patch antenna array for 5G communication.

Recently, the 28 GHz has been receiving a lot of attention as several researchers are focusing on developing array antenna for 5G applications. A dual feed mesh type antenna was proposed to operate at 28 GHz [7]. However, the antenna bandwidth is too small. A steerable millimeter wave antenna array was designed for 5G smartphone application [9]. This antenna works within the 26-32 GHz frequency range and has a bandwidth of 6GHz and achieves a maximum directivity of 13dBi. A compact notch antenna which is based on aperture couple slot and microstrip feeding was designed in [10]. Though the antenna was compact, the achieved bandwidth is low. A compact dual-band antenna resonating at 28 GHz for 5G operation was designed in [11]. The antenna has narrow bandwidth and low gain with a maximum achievable gain of 6.6 dB. In [14], an EBG (Electromagnetic Band Gap) supersubstrate, 2 element array was design for future 5G. The antenna resonates at three frequency bands (25 GHz, 28 GHz and 38 GHz) with a maximum achievable gain of 12.5 dB and a bandwidth of 1.02 GHz. A 2 dimensional compact slotted antenna consisting of 8 elements array was proposed for 5G applications. The antenna has a maximum achievable gain of 9 dB and a bandwidth of 1.38 GHz [15]. An elliptical shape slotted circular patch

antenna array resonating at dual frequency band was proposed in [16]. The antenna has a bandwidth of 1.2 GHz and achieves highest gain of 13.5 dB. A millimeter wave slotted antenna array working at 28GHz was proposed for 5G applications [8]. The element array achieves a highest bandwidth of 1.38 GHz and maximum gain of 9 dB. In [12], a 1X2 rectangular patch antenna operating at 28GHz was designed for 5G application. The antenna attains a maximum achievable gain of 10.7dB. The performance of this antenna can, however, be improved by adding more elements to the array configuration as presented in this paper. Hence, the objective of this paper is to improve the work of [12] in terms of achievable gain appropriate for 5G communication.

In this work, a 1X4 microstrip patch antenna operating at 28 GHz is proposed. The four elements array gain is increased as compared to one and two elements with a maximum gain of 13.5 dB. The remaining part of the document is arranged accordingly: in section II, the design and analysis of the proposed antenna is discussed, the simulated result of the one element, two elements and four elements arrays are discussed in section III while section IV concludes the paper.

II. ANTENNA DESIGN

In the design of a patch antenna, it is essential to first select the substrate to be used since its parameters such as the thickness and dielectric constant have a great influence on the antenna characteristics. This design employed roger RT 5880LZ with $h = 0.762\text{mm}$ thickness and a relative dielectric constant $\epsilon_r = 1.96$. Copper material is used as the patch conductor and ground plane. Popular models such as transmission line model, cavity model, and the full wave model are employed in analysing microstrip patch antenna [5, 13]. Among the above-mentioned models, it is said that the transmission line model is the easiest [13]. The dimensions of single patch element are calculated using transmission line model accordingly:

$$w_p = \frac{c}{2f_o} \sqrt{\frac{2}{\epsilon_{rl} + 1}} \quad (1)$$

The patch width is w_p , ϵ_{rl} is the relative dielectric constant and f_o represents the frequency at which the antenna resonates.

The effective dielectric constant is expressed as:

$$\epsilon_{reff} = \frac{\epsilon_{rl} + 1}{2} + \frac{\epsilon_{rl} - 1}{2} \left(1 + \frac{12h_s}{w_p}\right)^{-\frac{1}{2}} \quad (2)$$

As a result of fringing, the length of the patch is extended by a distance equal to:

$$\Delta L_p = 0.412h_s \frac{(\epsilon_{reff} + 0.3)(w_p/h_s + 0.264)}{(\epsilon_{reff} - 0.258)(w_p/h_s + 0.8)} \quad (3)$$

h_s is the substrate height.

The length is determined by:

$$L_p = L_{eff} - 2\Delta L_p \quad (4)$$

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{reff}}} \quad (5)$$

$$\text{The edge impedance } Z_{in} = 90 \frac{\epsilon_{rl}^2}{\epsilon_{rl} - 1} \left(\frac{L_p}{w_p}\right)^2 \quad (6)$$

The line impedance of the quarter wave is given by:

$$Z_T = \sqrt{Z_0 Z_{in}} \quad (7)$$

The length (L_p) and width (w_p) of the radiating patch for the design was calculated to be 3.2 mm and 4.4 mm using the mathematical equations described above. The load impedance at the edge of the patch is calculated to be approximately 190.5 ohms using Eq. (6). A simulation model for the single element antenna implemented in CST-MWS is shown in Fig. 1(a).

The 1 X 2 array arrangement is obtained by replicating the structure of the single element patch in order to have an antenna with two patches joined together by a 100 ohms line. This arrangement enables to improve the antenna performance. The spacing between each element is 0.63λ [12]. A simulation model for the two elements antenna implemented in CST-MWS is shown in Fig 1(b).

For further enhancement of antenna performance, an arrangement of four elements array is implemented. The 1 X 4 array arrangement is obtained by following the same procedure used in the design of the 1 X 2 with the same spacing between each element. A simulation model for the four elements arrays implemented in CST-MWS is shown in Fig. 1(c).

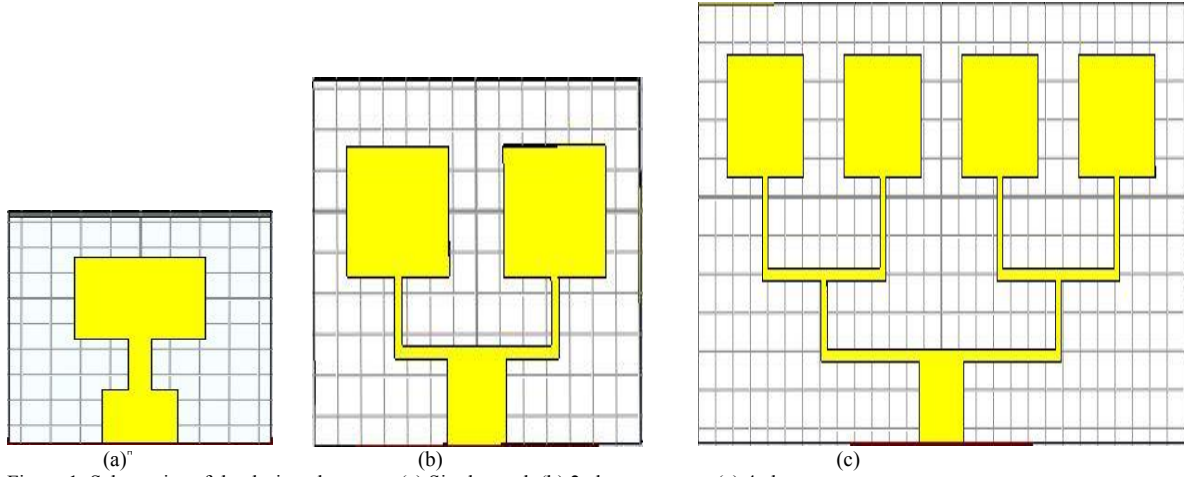


Figure 1: Schematics of the designed antenna (a) Single patch (b) 2 elements array (c) 4 elements array

III. SIMULATION RESULT AND DISCUSSIONS

The antenna proposed was simulated using CST Microwave Studio. The result of the simulated coefficient of reflection for the single element patch is shown in Fig. 2(a). The antenna resonates with a return loss of approximately -23dB with a bandwidth of 1.787GHz at 27.9GHz . It has been noted from the radiation pattern plot in Fig. 2(b), that the antenna has an achievable gain of 7.9 dB which can be increased by configuring the antenna in an array fashion. Fig. 3(a), shows the return loss plot of the two element arrays. It was noted that the antenna resonates at 2 frequencies (28GHz and 32GHz) with an estimated bandwidth of 8.2GHz within the 26.5GHz - 34.7GHz frequency range. The gain of the antenna was found to be 10.8 dB as observed from the radiation pattern chart shown in Fig. 3(a), which is greater than the gain of a single element patch. The result of the simulated coefficient of reflection for the four elements patch is shown in Fig. 4(a). It was noted that the antenna resonates at 3 frequencies (28GHz , 32GHz and 34GHz) with a maximum

bandwidth of 5.2 GHz in the range of 27 GHz - 32.2 GHz . The radiation pattern plot is shown in Fig. 4(b), which indicates that the realized gain has increased to 13.5 dB which is suitable for the 5G application [16].

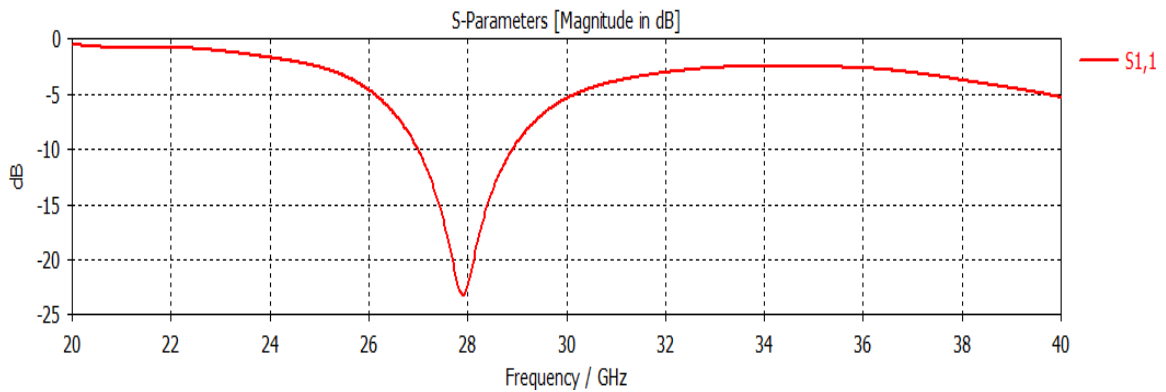


Fig. 2(a): Return loss plot of a single element patch antenna

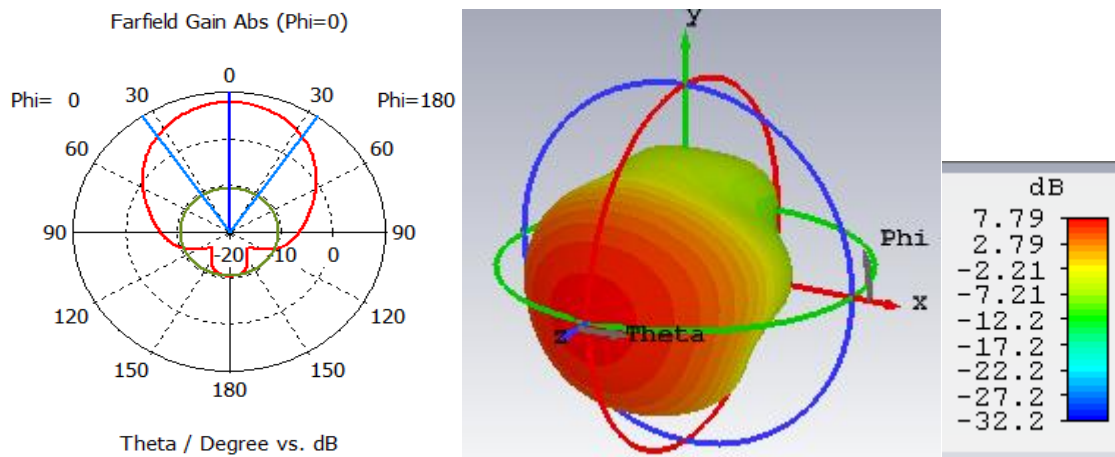


Fig. 2(b): Radiation pattern plot of a single element patch antenna

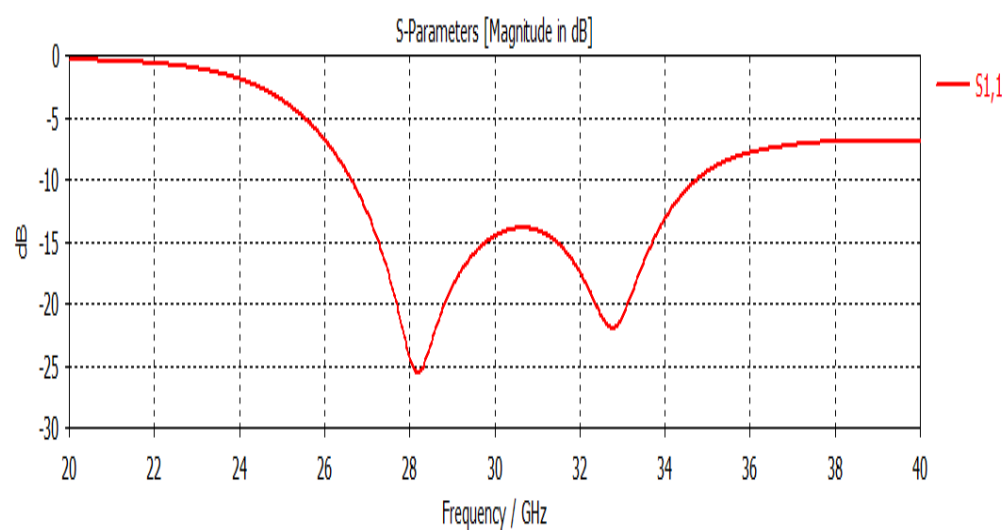


Fig. 3(a): Return loss plot of 2 element patch antenna array

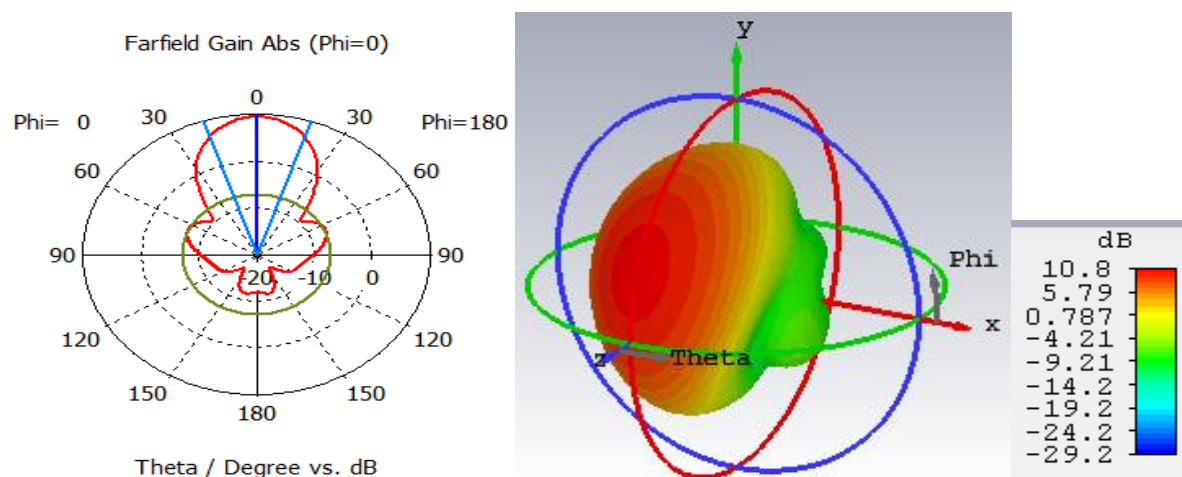


Fig. 3(b): Radiation pattern plot of 2 element patch antenna array

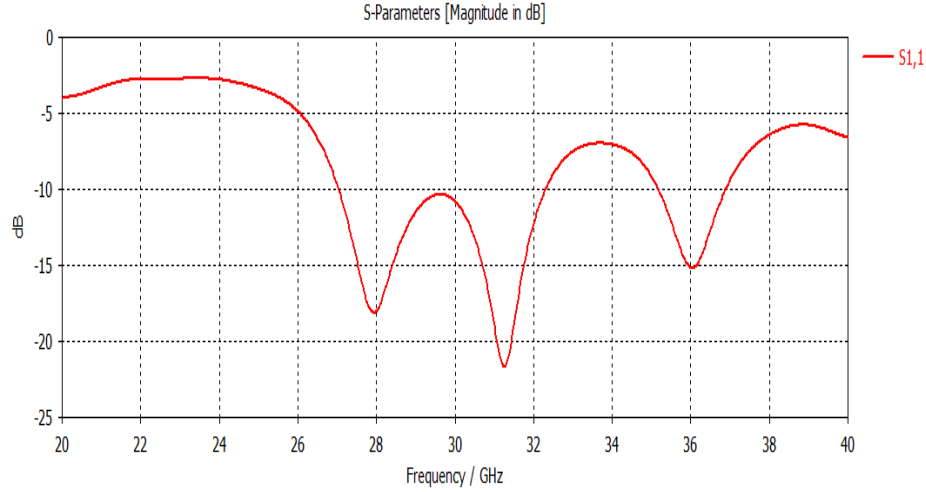


Fig. 4(a): Return loss plot of 4 element patch antenna array

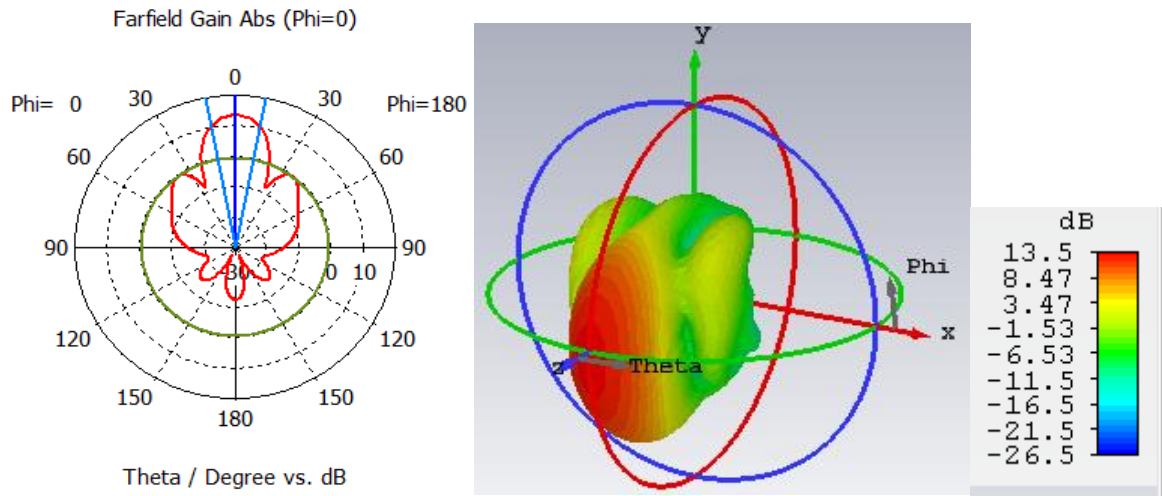


Fig. 4(b): Radiation pattern plot 4 element patch antenna array

TABLE I: COMPARISON BETWEEN THE PROPOSED DESIGN AND OTHER REPORTED ANTENNAS

Antennas	Number of array elements	Antenna array size (mm)	Bandwidth (GHz)	Gain (dB)
Proposed design	4	28×11×0.762	5.2	13.5
Reference [12]	2	----	8.9	10.7
Reference [14]	2	25×27×0.508	1.02	12.5
Reference [15]	8	29.9×28.7×0.13	1.38	9
Reference [16]	4	31×7×0.578	1.2	13.5

Table I summarize the comparison between the proposed design and other reported 5G array antennas. From the table, the proposed 5G antenna array antenna is found to perform better than the majority of the counterparts in the aspect of size, bandwidth and gain.

IV. CONCLUSION

Microstrip patch antenna has been designed for 5G application in mobile communication. The antenna was designed to resonate at 28GHz. The single element patch antenna has a bandwidth and gain of 1.87GHz and 7.9dB which is not sufficient for the future 5G communication requirements. The antenna was configured in an array fashion to improve the gain and bandwidth suitable for the

5G communication. With the implementation of two elements array, antenna performance was improved as the gain increased to 10.8 dB while the bandwidth increased to 8.2 GHz. These values are seen to be better, compared to those obtained when a single element was used. In order to further improve the antenna gain, a configuration for the arrangement of four elements was implemented. This yielded improved values for gain with an achievable gain of 13.5 dB.

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