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# DIRECTIVE HIGH GAIN MICROSTRIP PATCH ARRAY ANTENNA FOR 5G APPLICATION

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## ABSTRACT

With the recent development in wireless communication, low cost, compact, low profile antenna is required for the maintaining of high frequencies performance. Microstrip patch antennas are the fundamental component of every wireless communication system. It has broad practical application in wireless communication because it offers ease, low cost of integration and fabrication with feeding network. Triangular, rectangular and square are the most common shapes of the microstrip antenna which are usually made up of materials of gold or copper. However, the main drawback of microstrip patch antenna is that, it has very narrow bandwidth. This effect can be reduced to the lower level by make use of different feeding method, array configuration, ground plane and dielectric materials. In this research paper a directive high gain microstrip patch array antenna for 5G application is presented. A single antenna element designed based on microstrip technology, which is later be made into a number of arrays to improved gain and bandwidth. Transmission line model method is used to calculate the antenna dimension designed to resonate at 10GHz. To achieved the improve gain; multiple number of array element has to be arranged either in series or in parallel. A microstrip feed line is designed using a 3dB power divider to feed each of the elements of the antenna array. Simulations is carried out using microwave studio (CST) and the antenna performance was studied based on gain, bandwidth and radiation pattern. Fabrication was carried out on readily available FR4 substrate of thickness 1.6mm and dielectric constant 4.6. Measurement and simulation data were taken in to consideration and the result were compared and analyzed. Operation frequency of single-element and dual-element antenna array is 10GHz, while for the fourth and eight-element antenna array resonate at 9.9GHz and 10.7GHz respectively. Approximately 1GHz bandwidth and Directivity of 6.82dBi for achieved for single element. Subsequently, directivity of 7.54dBi for dual, 11.8dBi and 13.2dBi for fourth and eight-elements array antenna respectively. Bandwidth of almost 1GHz is attained for single-element, 1.1GHz for dual-element, 1.2GHz for fourth-element and around 1GHz for eight-element antenna array respectively. Considering the directivity and bandwidth trend obtained it can be observed that the directivity greater than 13dB and a bandwidth greater than 1GHz was achieved, hence the antenna can be a good candidate for 5G application.

**Keywords:** 5G wireless communication, microstrip patch antenna, array element, Directivity and Bandwidth

## INTRODUCTION

Microstrip antenna are the fundamental component of every wireless communication system (Mahabub, et al, 2018). Microstrip patch antenna has broad practical application in wireless communication because it offers ease, low cost of integration and fabrication with feeding network. Microstrip antenna exists in different shape such as triangular, rectangular, squares, which are made of materials of gold or copper. However, the main drawback of microstrip patch antenna is that, it has very narrow bandwidth. This effect can be reduced to the lower level by employing different feeding method, array configuration, ground plane, and dielectric materials (Ershadi, et al, 2017). Series and corporate techniques are the two most commonly used feeding arrangement for microstrip patch antenna element (Errifi, et al, 2015). Array antenna element is a collection of similar radiating element, the word "similar radiators" means the element possess the same element, regular spacing, having the similar feeding arrangement. Performance of the Array antenna can be improved by increasing the quantity array elements. However, size, cost and complexity rise as the number of the element increased. Element complexity results in the mutual coupling that can degrade the performance of the antenna. The main advantage of array antenna compared to the others is its beam ability to be directed electronically through the phase excitation between the elements. Wireless communication network has been evolved from first generation (1G) exploiting an analogue technology. Second generation was come up employing digital technology. Third generation (3G) was also visualized, then later to fourth (4G) is evolved which is known as LTE-A through 3.9G after every ten years.

100Mbps high transmission speed was provided by the LTE-A (Karunkar et al, 2015). The collective demand by the users triggered researchers to come with a great scope to the forthcoming 5G system of mobile communications (Adachi, 2015). 5G is the short term for the fifth generation. This is the mobile broadband technology that is likely to be placed in a couple months from now. The principal objectives of 5G network technologies is to provide data transmission and call volume that have never got in the earlier technology. Two major aspects are involved: Revolutionary and evolutionary. Evolutionary view of 5G network will be able to support www providing an extremely flexible network for example DAWN. While Revolutionary view of 5G system will provide intelligent technology that entire world is capable to be connected without limit (Gupta, 2013). Fifth generation will be a network that can handle more call 10,000 times, data traffic higher than current 4G networks (Huaning et al, 2014).

Furthermore, beyond fourth generation (4G), that is, in the near future, the major demands that need to be provided are improve data rate, increase capacity, decrease latency, and improvement of quality of service. To meet this demands cellular networks architecture need to be extremely improved (Gupta, 2013). Because of the devices to be connected will reached more than hundreds of billions when it comes to realization, hence many application are beyond private communications (Singh, et al, 2012). Thus, with the introduction of 5G, high directive antenna with massive bandwidth is required. Hence, based on these floats, 4G will therefore need to be adjusted to 5G, because it is generally assumed that six challenges will be address by 5G that are not been address by 4G. These are high capacity, end to end latency, higher data rate, massive device to device connection, cost reduction, and providing consistent quality of experience (Gupta, et al, 2015). In recent work, for better directivity, rectangular and circular patch antenna array is proposed for traffic detector application in (Singh, et al, 2015). Though good gain was achieved, but for the rectangular the length of the transmission line is quite long. In (Hassan et al., 2013), E-shape Rectangular antenna array for wireless communication system application is proposed. But narrow bandwidth is attained from the design, hence the antenna cannot be used for 5G application. To achieved more bandwidth and directivity 4-element triangular corporate fed microstrip array antennas is designed for L-band application (Garg et al, 2013). This research work introduced high directive microstrip patch array antenna with operating frequency of 10GHz that can be used for 5G applications and its targeted to achieved at least a gain of 12dBi and Bandwidth of 1GHz. Its highly directivity and enormous bandwidth make the antenna appropriate for 5G wireless communication systems.

**Antenna design**

The proposed directive high gain microstrip patch antenna detailed geometric and information is presented in figure 1 below. Different design can be achieved based on the array antenna arrangement. Such as, microstrip, dipole, log-periodic, each have their own techniques of modelling and performance characteristics evaluation. Rectangular microstrip was adopted in this work, due to its input impedance matching and fabrication conveniences (Bhowmik, et al., 2013). The ground of antenna has been made with copper and thick substrate with lower value of the dielectric constant is desirable for better performance of the antenna (Subhulakshmi et al., 2015). Corporate feed with T-junction power divider is used to fed the array antenna, because it is used to provide split power to $2^n$ (that is n=2;4;8;16 e t c ) ( Zhang ,et al, 2016).

One of the most crucial part in antenna array design is the inter-spacing of the radiating element, the spacing arrangement is set between 0.2λ to λ for proper radiation (Hassan, et al, 2013). FR-4 substrate lossy materials with constant relative permittivity 4.4 and 0.8 thickness was used. This antenna is designed using 2015 microwave studio simulator software. Equations 1-9 in section 2.1 is used to calculate the fed line of the proposed array antenna element. From the equations it can be observed that, the computed length and width of the feeding line was found to be 3.98mm and 2.98mm respectively. Insert-fed cut was attached to the feed line to improve the line impedance of the antenna. (Subhulakshmi, et al, 2015). Such kind of antenna with this modified line feed technique is referred to as inset-fed microstrip patch antenna.

**Microstrip single element design**

Figure 1(a) presents the proposed single element microstrip patch array antenna. The structure composed of radiating element, inset feed line, substrate and ground plane of 30 x 19 mm. Overall dimensions of 8.96mm length, 6.3mm width and 0.003 copper thickness are suitable for mobile communication application. The antenna is energized using 50Ω microstrip feed line of length and width of 3.98mm and 2.98mm respectively. Radiating element is fed using inset feed line techniques to enhance the radiating power and bandwidth. And hence, to reduce the loss to the conductor.

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_{r}+1}{2}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{W}}}\right] \quad (2)$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

$$L = L_{eff} - 2\Delta L \quad (5)$$

$$\lambda_{eff} = \frac{V_O}{F_r}\sqrt{\varepsilon_{eff}}$$

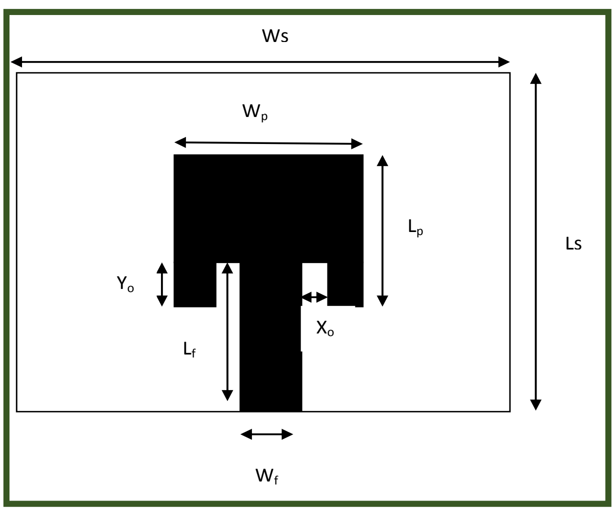
$$L_g \geq \frac{X_{eff}}{4} \times L$$

$$W_g \geq \frac{\lambda_{eff}}{4} \times W$$

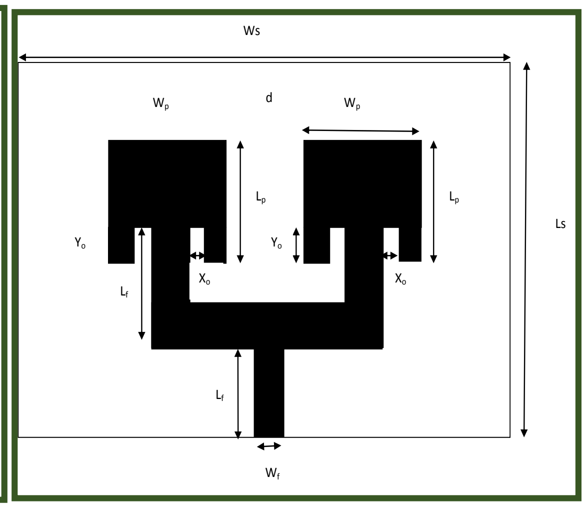
$$Y_o = \frac{L}{\pi} csc^{-1}\sqrt{\frac{Z_o}{Z_{in}}}$$

***Microstrip array antenna design***

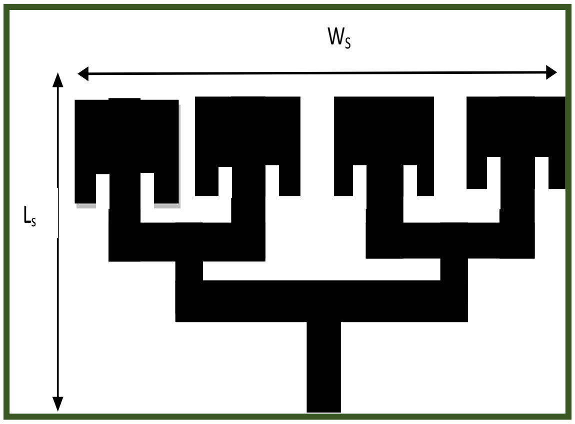
Based on the proposed single element, multiple element is designed as produced in the figure 1 (b, c&d). The spacing of the microstrip patch array antenna is optimized to ensured their mutual coupling is reduced between the elements and greater impedance matching is attained. Figure 1(b) consists of two elements having the same dimension with the single element. The structure is placed on the ground plane of 30 x 19 mm and 0.003mm copper thickness. Corporate feed network is used for the two element network. T-junction power divider is used to match the 50Ω transmission line to the 100Ω lines for wider bandwidth. A corporate feeding configuration is used for dual, fourth and Eight elements with $\frac{\lambda}{2}$ spacing as shown figure 1(b), 1(c) and 1(d) respectively. The corporate feed used facilitates flexible choice of element spacing. Similar connector was used to connect the feeding lines. The proposed feed network contributes to the wide impedance bandwidth and has the highest advantages of optimal space utilization. The antenna array dimensions were optimized using equations 1-9 above. The array antenna design is then fabricated and tested.



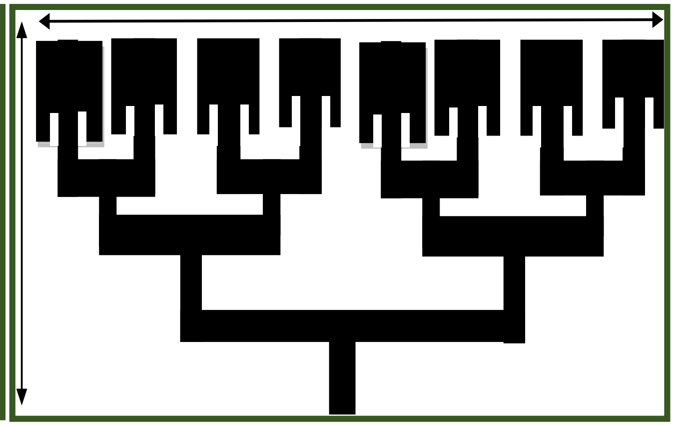

(a)




(b)




(c)



(d)

Fig. 1. Geometry for the array antenna:(a)Single elemant,(a)Two element.

(c) Four element (d) Eight element

**Simulation Result**

Computer Simulation Technology (CST) Microwave Studio 2014 is used to design and simulate the proposed rectangular patch array antenna. The antenna later then fabricated on FR4-substrate of permittivity of 4.6 and high of 1.6mm as showing in the figure 1 (a-d) above.

In addition, the software is used to simulate and find out the performance of the antenna such as return loss, gain, and bandwidth and radiation pattern. The proposed antenna is optimized design values is obtained and fabricated, and comparison were made between the measured and simulated results.

***Radiation patterm***

Polar radiation patterns of the rectangular array antennas is shown in Figure 3. From the figure, it can be clearly observed that single element and 2-elements array antennas has a main lobe that is Omnidirectional radiation directed at $0^0$ with little back lobe. For the 4-element antenna array, the radiation pattern is more directional with a dumb bell shape directed towards the main beam.

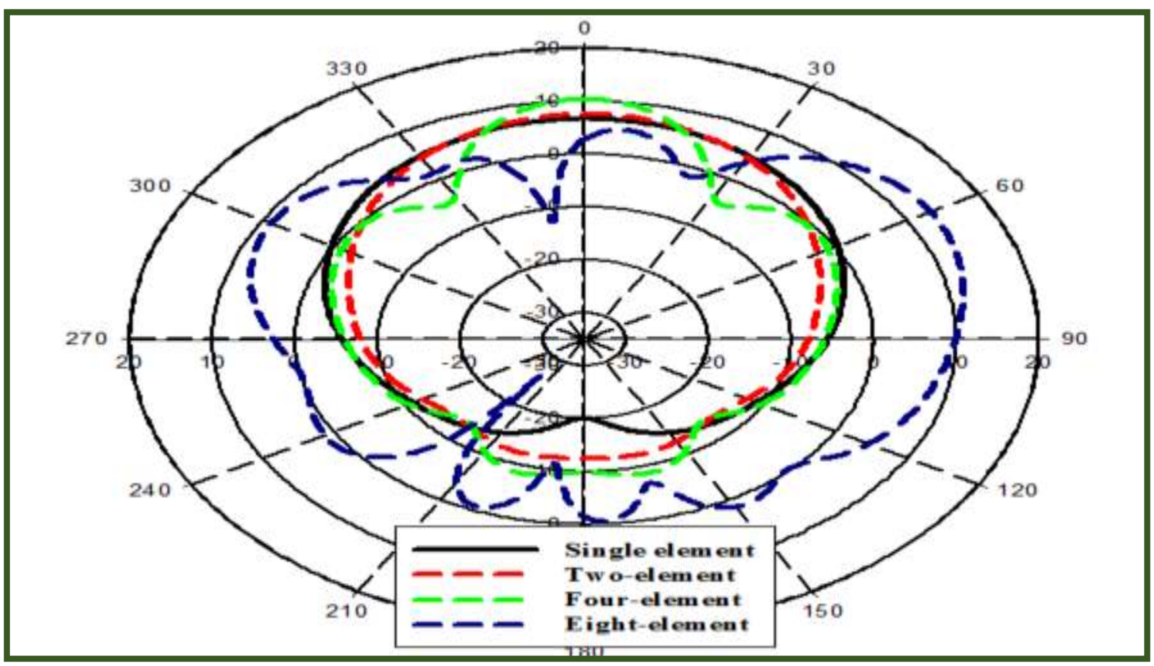



Fig. 3. simulated Radiation Pattern of the antenna array

### *Gain and Directivity*

Table 1 shows the gain and directivity of the rectangular patch array antenna. The directivity achieved for the array antennas are 6.2dB 7.54dB, 11.8dB 13.2dB for the single, 2, 4, and 8-element array antenna respectively. Due to improvement in directivity of the array antenna, it can be ascertained that the directivity and the gain increase as the number of the element increased. Hence good directivity is achieved, and the antenna can be a good candidate for 5G application.

**Table 1: Simulation Result**

| Number of the element | *Resonant Frequency (GHz)* | $S_{11}$ *(dB)* | *Bandwidth (GHz)* | *Gain (dB)* | *Directivity (dBi)* |
|---|---|---|---|---|---|
| Single-element | 10 | -33.1 | 1.00 | 4.25 | 6.28 |
| 2-element | 10 | -54.4 | 1.10 | 5.4 | 7.54 |
| 4-element | 10.7 | -34.0 | 1.20 | 8.3 | 11.8 |
| 8-element | 9.96 | -12.0 | 0.8 | 8.5 | 13.2 |

### Measured Result

The proposed array antenna was fabricated with FR4 substrate using wet etching process. 50Ω SMA-connector is used to connect the transmission of the antenna. Important parameter in testing an antenna is reflection coefficient. Reflection coefficient is referred to as impedance matching to maximum power transfer. Figure 8 shows the measured reflection coefficient of the first, two, four and eight elements respectively. From the figures, it can be seen for the single and dual–element antennas resonate at nearly 10GHz. While for the fourth-element and eight-element array, the antennas resonate at 10.8 and 9.2GHz respectively.

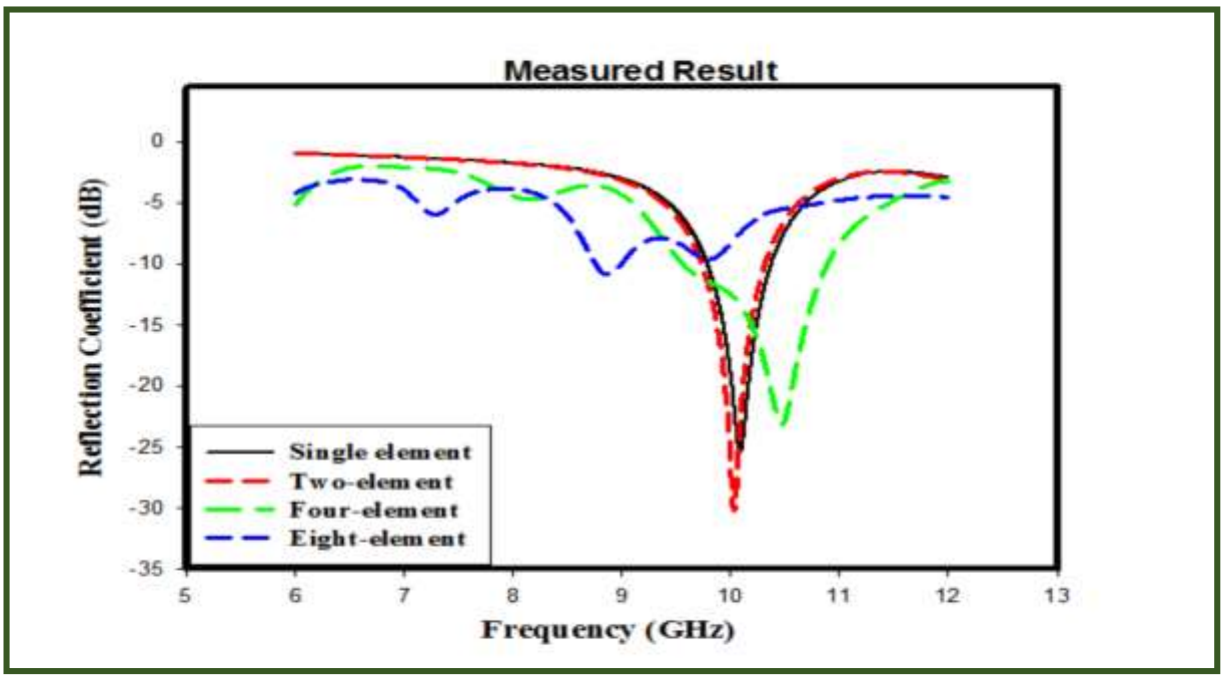
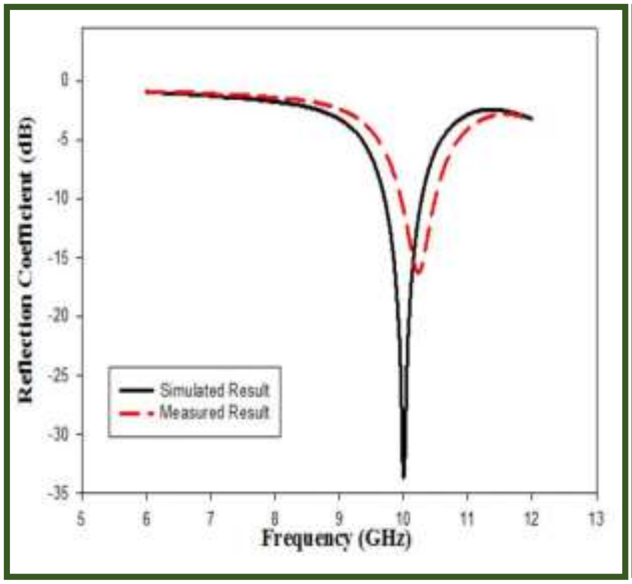



Fig. 4. Measured Reflection Coefficient of the Proposed antenna

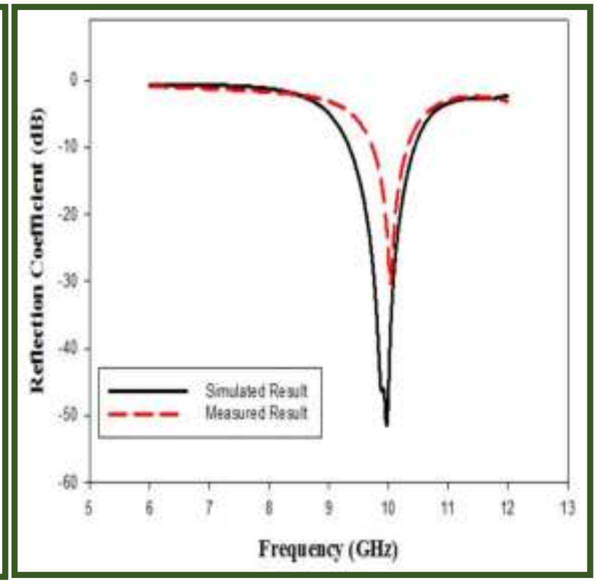
### Comparison Between Simulated and Measured Result

At nearly 10GHz, Simulated and measured reflection coefficient of the array antenna was compared and presented in Figure 5 (a-d). From the figures it can be observed that the simulated and measured return loss synchronized with each other, though some discrepancies exist, which may be cause due to human inefficiency in the fabrication process.

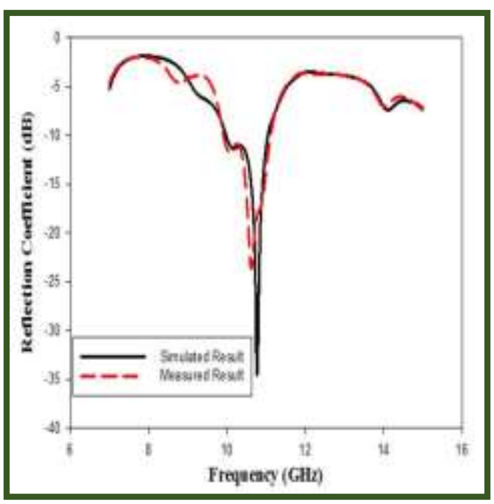
From the analysis of radiation pattern in figure 6 (a-d), single element and dual-elements array antennas has a main lobe that is Omnidirectional radiation directed at 00 with little back lobe. For the 4-element antenna array, the radiation pattern is more directional with a dumbbell shape directed towards the main beam. Eight-element array radiation pattern shifted to the right from centre 00 to 600, this may result because of the possibility to the power division to the radiating element and mutual coupling losses that may arise due to increase of the number of the radiating element. In general, the proposed antenna array is highly directional form both simulated and measured result. This demonstrate the ability of the antenna to be adopt to all 5G wireless communication applications.



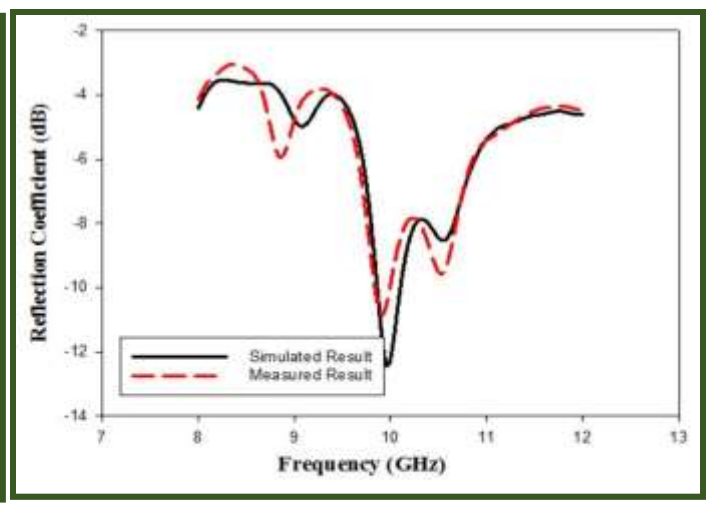

(a)




(b)

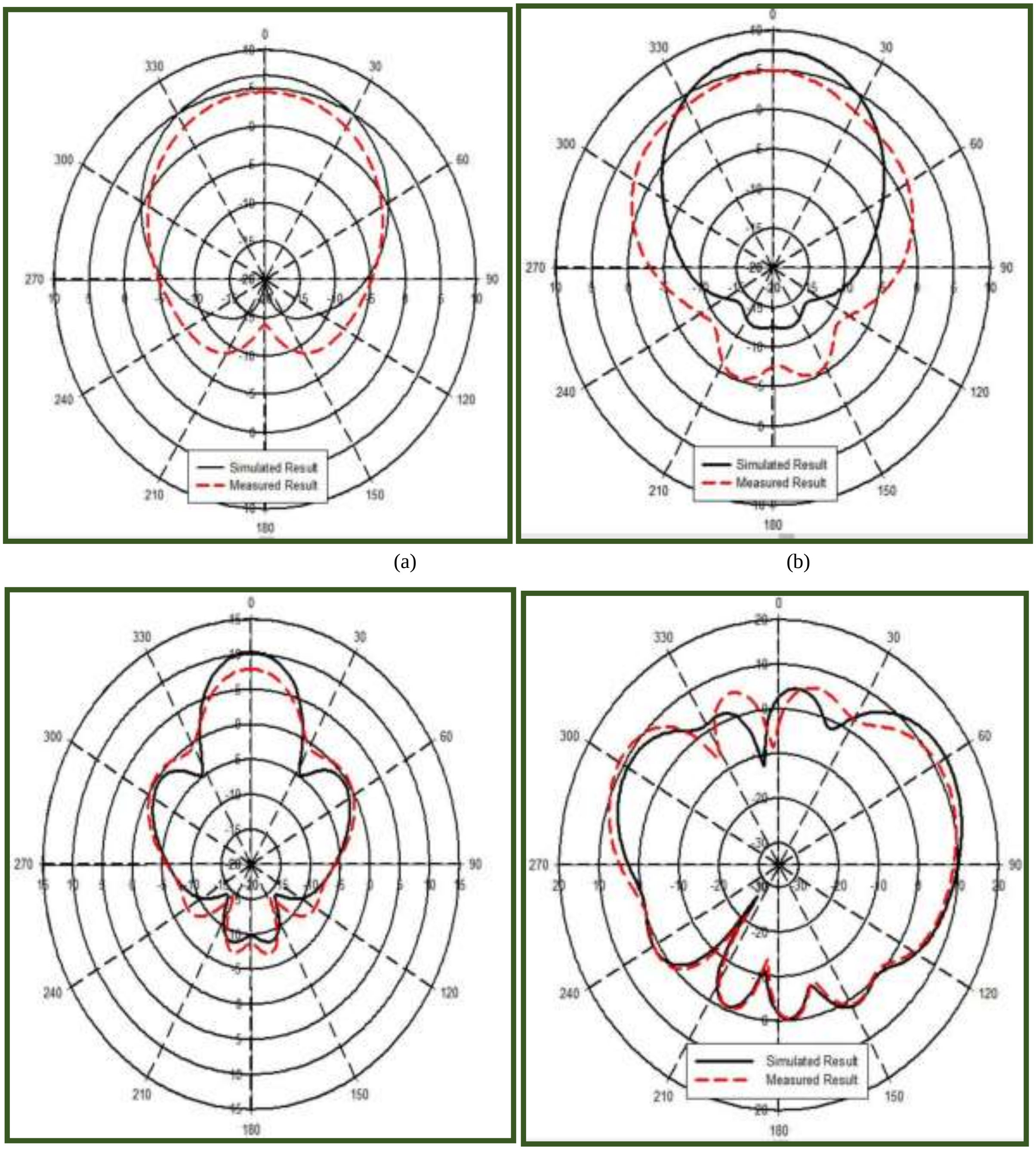



(c)




(d)

Fig. *5*. Simulated and Measured Reflection Coefficient of the antenna array. (a) Single element, (b) Two-element, (c) Four-element, (d) Eight-element




(a) (b)

(c) (d)

Fig. *6.* Simulated and Measured Radiation Pattern of the antenna array. (a) Single element, (b) Two-element,(c) Four-element,(d) Eight-element

**CONCLUSION**

Directive high gain microstrip patch array antenna was designed and implemented. The antenna was fabricated on the FR4 substrate of thickness 1.6mm and dielectric constant of 4.6. The resonant frequency of single-element and 2-element antenna array is 10GHz, and 4-element and 8-element antenna array resonate at 9.9GHz and 10.7GHz respectively. Directivity attained is 6.82dBi, 7.54dBi, 11.8dBi and 13.2dBi for single 2-element, 4-element and 8-element array antenna respectively. Bandwidth of almost I GHz is attained for single-element, 1.1GHz for 2-element, 1.2GHz for 4-element and around 1GHz for 8-element antenna array respectively.
Considering the directivity trend obtained it can be observed that the achieved directivity is greater than 13dB for the 8-element array, hence this antenna can be a potential candidate for future 5G wireless communication applications. However, this antenna design has numerous advantages, it is cost effective. The antennas dimension can be reduced to make the antenna light-weight, more frequency added, and the antenna can be further implemented for high efficiency application such as High-Altitude Platforms (HAPs).

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