

# Design of Microstrip Antenna Array for 5G Communication Systems

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**Abstract**—For the time being, the fifth generation (5G) communication system has been realized in many countries and the number of 5G subscribers is very large. Unlike previous generations that only focused on improving network capacity, the 5G communication systems extends telecommunication services from humans to objects (things), and also from consumers to industries. This enables a wide range of services from conventional mobile broadband to industry 4.0, virtual reality (VR), Internet of Things (IoT), and automatic driving. The values of 5G services and applications greatly support the mobility and flexibility of today's customers such as remote surgery in hospitals, online education, driverless vehicles, unmanned delivery, robots, smart healthcare, industrial automation. This study presents the design and realization of a 4×4 rectangular microstrip antenna array. This antenna can be applied to support 5G communication. The antenna array configuration is arranged uniformly. For antenna excitation, an inset feed transmission line is employed to each antenna element. The antenna array has been validated and works at a frequency of 2.3 GHz, with an HPBW of 30° in the E-plane. Meanwhile, based on measurements, the gain and bandwidth values are 13.51 dBi and 100 MHz respectively.

**Keywords**—Microstrip Antenna; Antenna Array; Inset feed; 5G

## I. Introduction

The mobile communication industry comes from the first generation of the analog cellular systems such as AMPS and Nordic Mobile Telephone. For the time being, wireless communication systems grow fastly, especially in cellular communication system referred to Long Term Evolution (LTE). In 2009, commercial LTE networks were released in Sweden and Norway [1]. LTE is created to send multimedia services. LTE operates Internet Protocol on basis with high throughput. It is of 300-Mbps data rate peak for downlink and 75 Mbps for uplink [2]. Currently, 5G has been becoming one of attractive issue. Unlike 4G which is of focus on improvement of network capacities, 5G is going to range mobile communication services from human to things.

One of the most important devices in a wireless communication system is an antenna. The type of antenna that is currently developing is the microstrip patch antenna. A microstrip patch antenna is an antenna that is composed of a thin layer of metal conductor on a substrate that can travel electromagnetic waves, while on the other

side it is coated with a conductor as a grounding plane. The microstrip patch antenna designed has dimensions in the form of a radiating rectangular section of 16 elements arranged in an array with a symmetry parallel feed network configuration. For the array technique, it is intended to obtain greater antenna gain than a microstrip antenna that only has one element. On the other hand, symmetry parallel feed network configuration is able to produce wider bandwidth [3].

The development of microstrip antennas for 5G communication systems is presented in [4]. The research proposed by [5] has succeeded in designing a circular single element microstrip antenna at a frequency of 3.5 GHz with a gain of 5.15 dBi. One of methods for increasing antenna gain is to apply parasitic element, as described in [6]. However, this technique does not yield a gain increase significantly.

In order to achieve a very directional beam, hence high antenna gain, in this paper, design of antenna patch array by  $4 \times 4$  for 5G applications with the center frequency of 2.3 GHz is presented. The array method is employed in order to obtain high antenna gain. For the purpose of impedance matching, inset feed technique will be applied to maximum power transfer between antenna patch and transmission line.

## II. Research Methodology

### A. Antenna Array Simulation

In this section, design process involves patch antenna array and feeding network designs. The initial stage of this research is to calculate the dimensions of the single-element antenna patch according to the specifications of 2.3-GHz center frequency as well as better than 10-dB reflection coefficient, and its associated inset feed with an impedance of 50 ohms.. Meanwhile, feeding network utilizes T-junction power divider on basis for excitation of two antenna patch elements and quarter wavelength transformer as well for matching purposes of impedance.

Furthermore, the single and two element antennas and the associated inset feed are simulated using HFSS Ansys with the criteria of reflection coefficient value  $\leq -10$  dB at the center frequency of 2.3 GHz. After that, the whole antenna was developed by using the  $4 \times 4$  element array in manner. The array method aims to increase the antenna gain by arranging the antenna elements in parallel which are connected to each microstrip feeder channel and separated by a distance  $(1/2 \lambda)$ . To produce optimal gain, an iteration process is carried out by modifying some parameters of the antenna element dimensions as well as the space between two elements. This research is conducted at Laboratory of Telecommunication for simulation purpose and Laboratory of High Frequency and Transmission for the fabrication one, State Polytechnic of Ujung Pandang. Array antenna design is going to be implemented on the substrate of FR-4 Epoxy PCB. The PCB specifications is presented in Table 1. In addition, design flowchart is presented in Figure 1.

Table 1. Substrate specifications of FR4 Epoxy

Parameter	Value
Dielectric constant ( $\epsilon_r$ )	4.4
Substrate thickness ( $h$ )	1.6 mm
Loss tangent ( $\delta$ )	0.019
Conductor (copper) thickness ( $t$ )	0.035 mm

**B. Fabrication of Antenna Array**

Fabrication process includes measurement of antenna prototype. The measurement set of VSWR and bandwidth as well as far-field radiation pattern is demonstrated in Figure 2 and Figure 3, respectively.

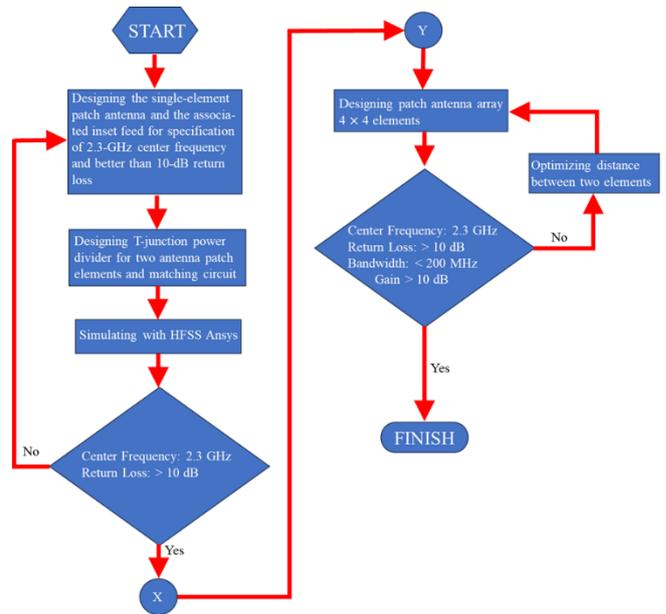


Figure 1. Design flowchart

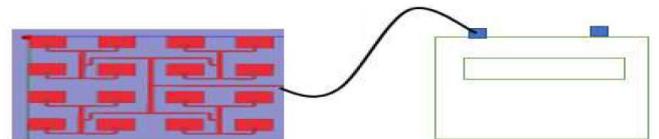


Figure 2. VSWR and bandwidth measurement set of antenna array

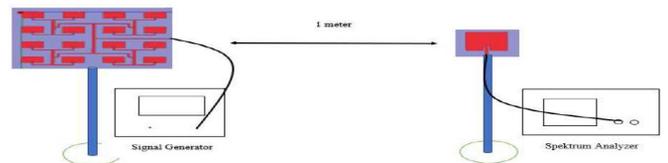


Figure 3. Measurement set of far-field radiation pattern

**III. Results and Discussion**

The initial stage of this research is to calculate the dimensions of the single-element antenna patch as follow [7]:

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \tag{1}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2\sqrt{1 + \frac{12d}{W}}} \tag{2}$$

$$\Delta L = \frac{0,412d(\epsilon_{reff} + 0,3) \left(\frac{W}{d} + 0,264\right)}{(\epsilon_{reff} - 0,258) \left(\frac{W}{d} + 0,8\right)} \tag{3}$$

$$L = \frac{c}{2f_r \sqrt{\epsilon_{reff}}} - 2\Delta L \tag{4}$$

The input impedance of a single patch microstrip antenna can be approximated by [7]

$$Z_A \approx 90 \frac{\epsilon_r^2}{\epsilon_r - 1} - \left(\frac{L}{W}\right)^2 \Omega \tag{5}$$

For an impedance matching purpose, the impedance of the quarter-wavelength transformer can be utilized by means of calculating

$$Z_{\frac{1}{4}\lambda} = \sqrt{Z_{in}Z_A} \Omega \tag{6}$$

However, the quarter-wavelength transformer can be replaced by an inset feed transmission line manner as shown in Figure 4 for the impedance matching. It can be designed by using the following equation with input impedance  $R_{in}(x = 0) \Omega$ .

$$R_{in}(x = x_0) = R_{in}(x = 0) \cos^2\left(\frac{\pi}{L}x_0\right) \Omega \tag{7}$$

In this case,  $R_{in}(x = 0) = Z_{\frac{1}{4}\lambda}$ . Therefore, Eq. (7) can be reduced to

$$R_{in}(x = x_0) = Z_{\frac{1}{4}\lambda} \cos^2\left(\frac{\pi}{L}x_0\right) \Omega \tag{8}$$

or

$$R_{in}(x = x_0) = \sqrt{Z_{in}Z_A} \cos^2\left(\frac{\pi}{L}x_0\right) \Omega \tag{9}$$

$R_{in}(x = x_0)$  usually take into account of  $50 \Omega$  as well as  $Z_{in}$ . Hence,  $R_{in}(x = x_0) = Z_{in}$  which means impedance matching.

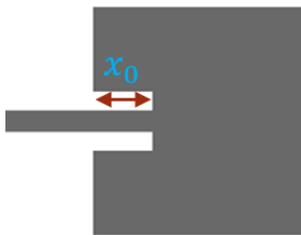


Figure 4. Inset feed technigue

From the results of the calculations that have been carried out, the array structure and dimensions are obtained which can be seen in Figure 5 and Table 2. T-junction for two elements and T-junction for four elements is exhibited in Figure 6 and Figure 7, respectively.

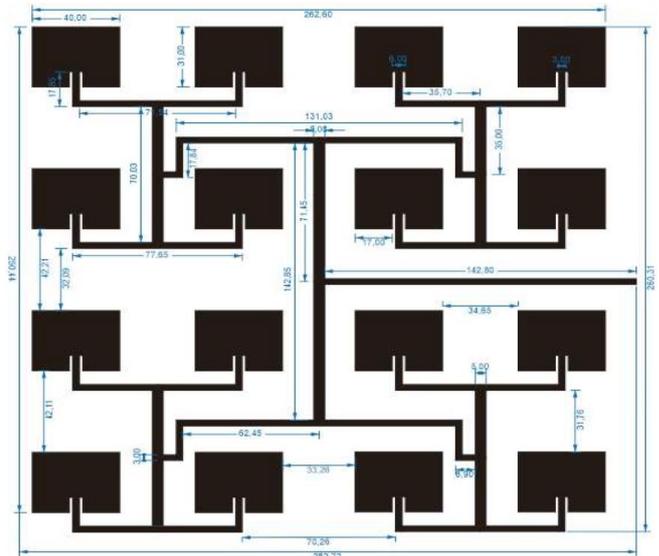


Figure 5. Dimension calculation result

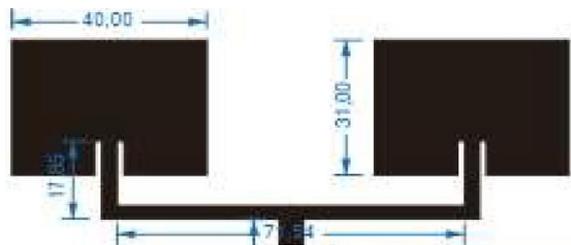


Figure 6. T-junction for two elements

Table 2. Dimension of the parameters from calculation

Parameter	Dimension (mm)
Length of antenna element	39.69
Width of antenna element	30.74
Length of inset feed slot	7.88
Width of inset feed slot	1.53
Length of element feed line	17.86
Width of element feed line	3.06
Distance between element	34.55
Length of T-junction for two elements	71.54
Width of T-junction for two elements	3.06
Length of T-junction for four elements	70
Width of T-junction for four elements	5

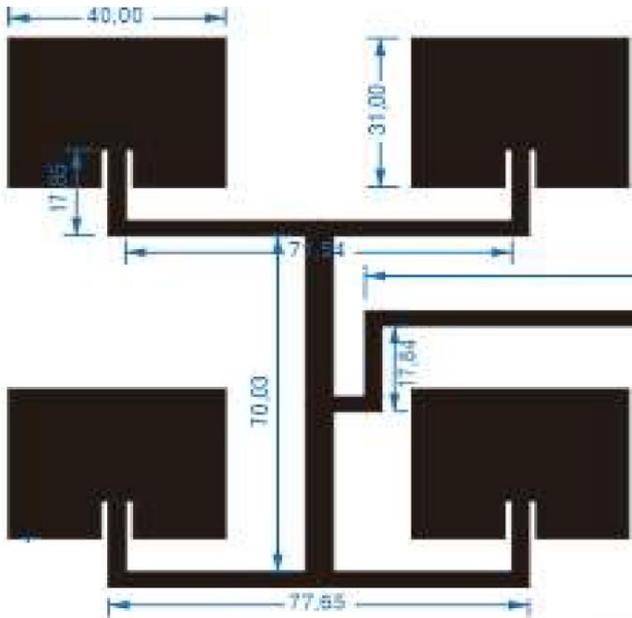


Figure 7. T-junction for four elements

The simulated result for the return loss of the  $4 \times 4$ -element array antenna is shown in Figure 8. From the simulation, the return loss of better than 10 dB can be achieved within bandwidth of 40 MHz at the center frequency of 2.32 GHz. Such results have satisfied the defined specification. On the other hand, Figure 9 and Figure 10 point out far-field radiation pattern in 2D and 3D, respectively. From the simulation result, it exhibits that antenna array can achieve gain of 10.62 dB.

Meanwhile, the measurement result for the return loss of the  $4 \times 4$ - element array antenna is shown in Figure 11. From the simulation, the return loss of better than 10 dB can be achieved within bandwidth around 80 MHz at the center frequency of 2.32 GHz. On the other hand,

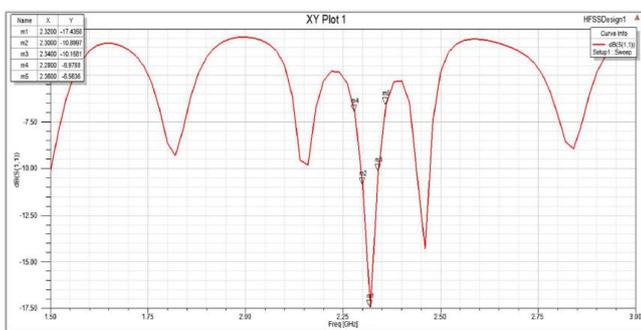


Figure 8. Simulated return loss

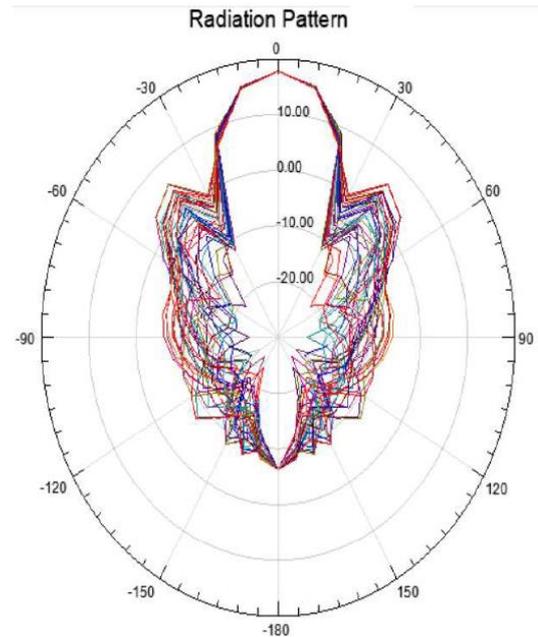


Figure 9. Simulated 2D far-field radiation pattern

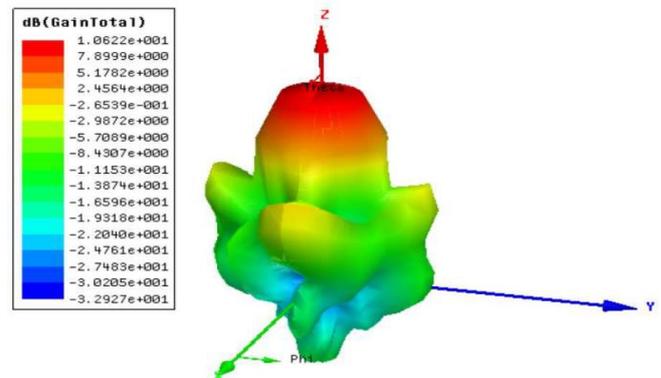


Figure 10. Simulated 3D far-field radiation pattern

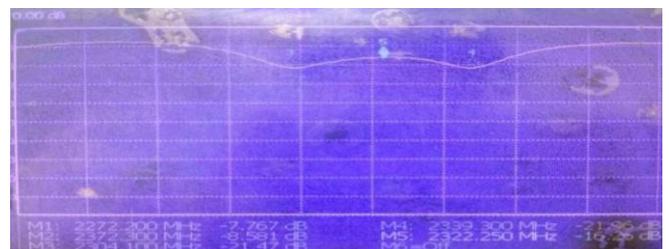


Figure 11. Measurement result of return loss

Figure 12 shows the measurement result of the far-field radiation pattern. It exhibits that the received power level of a 16-element antenna array is  $-43.1$  dBm. Meanwhile, the received power level of a single element is  $-53.6$  dBm. Thereby, gain of a 16-element antenna array against a 1-element microstrip antenna is 10.5 dB. It is known that the gain of a conventional microstrip antenna is 3 dBi.

Therefore, gain of a 16-element antenna array is  $10,5 \text{ dB} + 3 \text{ dBi} = 13.5 \text{ dBi}$ . Fabrication result of the antenna array is presented in Figure 13.

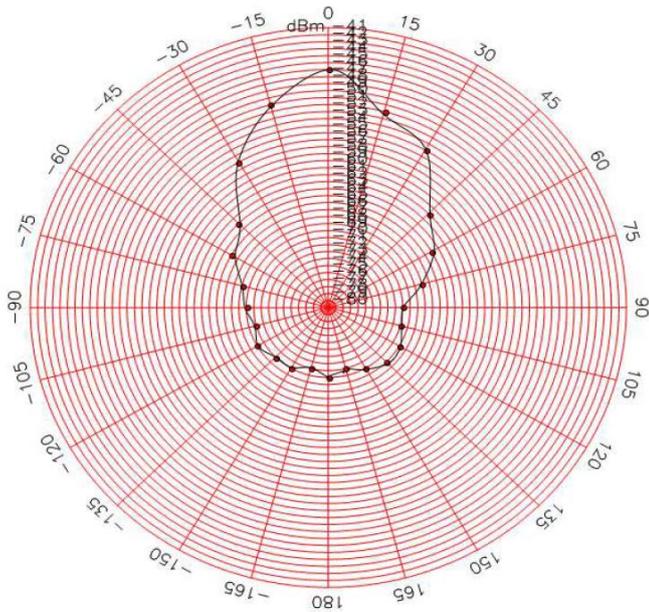


Figure 12. Measurement result of the far-field radiation pattern

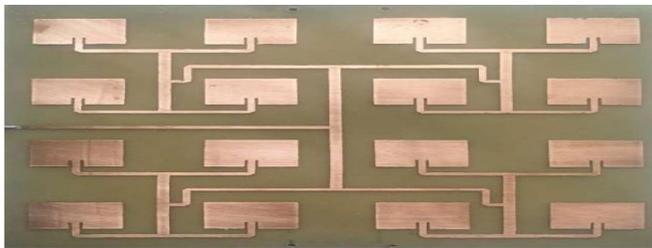


Figure 13. Fabrication result of the antenna array

#### IV. Conclusion

In this study, the design for developing a  $4 \times 4$ -element microstrip array antenna that works at a frequency of 2.3 GHz for the Fifth Generation (5G) communication system has been exhibited. In general, the design steps procedur consist of the patch element design and the feeding network design. Initially, the performance of a single patch element is designed and observed. Principally, the

basic design comes from the design of a  $2 \times 1$ -element patch array which has satisfied the interested spesifications of the 2.3-GHz center frequency and the better than 10-dB return loss. The feeding network consists of T-junction power divider and quarter wavelength transformer as well as inset feed technique. Furthermore, a  $4 \times 4$ -element microstrip array antenna has been realized and measured. In general, the designed antenna array demonstrates that the prototype measured and HFSS simulated results are in agreement. The performance of this antenna array can be envisaged and validated for 5G communication systems at 2.3 GHz.

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