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Design of A Dual-Band Microstrip Antenna for 5G Communication

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Abstract

The necessity for mobile communication devices is increased rapidly. Users expect to get very fast information access and data access without delay. The fifth-generation (5G) development in wireless mobile telecommunication technology promises capacity enhancement, ease connectivity, high efficiency, and high data rate transmission. The appropriate device should support this improvement of the technology. The antenna is one of the main devices to support the high data rate transmission. This paper proposed designing a dual-band rectangular patch antenna in 29 GHz and 38 GHz that supports 5G technology. This microstrip antenna is composed of 4 patch array elements to obtain higher gain. The material used for this microstrip antenna is RT Duroid 5880 with a dielectric constant of 2.2 and a thickness of 1.575 mm. Both measurement and simulation are confirmed that the 2×2 array microstrip antenna in 29 GHz and 38 GHz frequency have a return loss value of -12.5 dB and -16 dB, respectively. The bandwidth for both frequencies has a value of 4.5 GHz and 3.75 GHz.

Keywords:
5G;
Antenna;
Array;
Dual Band;
Microstrip;

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INTRODUCTION

In many recent years, wireless mobile communication technology develops faster than ever. A new wide range of new standards of mobile communication also appears to achieve sophisticated wireless systems. The situation happens because humankind has become a wireless society where their behavior was shifted for both pleasures and work from static to mobile behavior [1].

Wireless communication is dominated by digital transmission [2], not only for human interaction but also for data transmission that needs a huge amount of data [3, 4, 5]. 5G wireless mobile communications that define in IMT-2020 and ITU-R M.208 [6] promise high-speed data transmission from 1 GBps until 20 GBps Those data rates can be achieved by several techniques, such as modulation technique or wide bandwidth [7][8]. To achieve a wide bandwidth, implementing carrier aggregation [9] on modulation or to use a higher frequency [3][4] can be a solution. A higher frequency band for 5G wireless mobile communication was described in ITU-R M.2376-0 [10]. The 5G application was proposed to be implemented in a spectrum band above 6 GHz, such as 10 GHz, 20 GHz, 38 GHz, and 60 GHz [10]. More researchers have presented their papers at popular mm-wave bands such as 28 GHz and 38 GHz because of its more achievable [11][12].

One of the most important things in the wireless mobile communication system would be an antenna system [13]. Antenna systems act as a transducer. Its function converts electrical energy to become electromagnetic wave energy [14]. Therefore, the antenna system needs to be presented with the best design, lightweight, and compact antenna to build the best performance of wireless mobile communication [15]. One of the lightest and compact antennas would be a microstrip antenna design [16].

Microstrip antenna design is an antenna that has been fabricated using strip, line, or patch techniques on a copper layer of the printed circuit board on one side. This strip, line, or patch acts as a radiator to radiate electromagnetic wave energy into the free space. Meanwhile, on the other side of the PCB, we have a full copper layer or varieties of the design that act as a ground. As a result, a lot of microstrip designs emerge not just for antenna [17][18] but also as a filter [19], a waveguide [20], transmission line [21], and others [22].

This paper proposed a lightweight and compact microstrip antenna to enhance bandwidth by implementing a proximity coupling technique. The proposed antenna is working on 29 GHz and 38 GHz [23]. The condition happens because feasibility and efficiency in mm-wave communications propose for 5G cellular communication has been proved has 20 times higher than 4G (LTE) cellular communication. From the need for 5G technology, it can be concluded that an antenna that has a wide bandwidth and high gain is needed. Previous research was carried out by [24]. Based on the simulation, the designed antenna has a thickness of 1.575 mm, with Duroid 5880 Rogers Substrate material with a dielectric constant εr = 2.2 and a tangent loss (*tan δ*) of 0,0009. The antenna consists of a triangular patch with a proximity coupled technique. With the number of elements 6, the highest gain is obtained, with a maximum gain of 7.47 dBi with a Return Loss of -30.70 dB at 28 GHz and 12.1 dBi with a Return Loss of -34.5 dB at 38 GHz is obtained. The microstrip antenna design is described in section 2, followed by explaining the feeding line design and radiator array design.

METHOD

This paper proposed the rectangular patch and array technique for microstrip antenna that works on 29 GHz and 38 GHz frequency because the array technique can increase the gain of the microstrip antenna, and the patch technique combined with the proximity couple can increase the bandwidth. First, the size for the patch antenna is computed using the transmission-line model [17] that described as follows.

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon r + 1}{2}}} \tag{1}$$

$$\varepsilon_{\mathrm{reff}} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(\frac{1}{\sqrt{1+12h/W}}\right) \tag{2}$$

$$\Delta L = \left|0.412h\,\frac{(\varepsilon reff + 0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff - 0.258)(\frac{W}{h}+0.8)}\right| h \tag{3}$$

$$L = \frac{C}{2f\sqrt{\varepsilon reff}} - 2\Delta L \tag{4}$$

$$d = \frac{c}{2\mathrm{x}fr} = \frac{3\mathrm{x}10\hat{}8}{2\mathrm{x}\,fc\ \mathrm{x}\ 10\hat{}9} \tag{5}$$

Where *f* denotes the frequency used of the antenna and *c* denotes the speed of light. *L* and *W* are corresponding to the geometrical length and geometrical width of the patch, respectively. *Leff* is the effective length of the antenna, *reff* is the effective dielectric constant, and Δ*L* is the additional length of the patch due to the fringing field at the end of the structure.

We design simulations on software HFSS and fabrication to confirm the simulation result. The material used in this paper was RT Duroid 5880 with a dielectric constant of 2.2 and had a thickness of 1.575 mm. we presented two sub-layer designs, Proximity couple on layer one, which is feedline array design, and layer two design patch array.

Feeding Line Design

That for each radiating element, Figure 1 shows for feeding line design. We propose a four-element antenna array. The implementation of the array technique in this design was to increase gain. In contrast to the six-element array base on simulation, here we proposed a simulation and fabrication antenna. And the proximity feed lines are branched used to enhance the bandwidth of antenna structures [25].

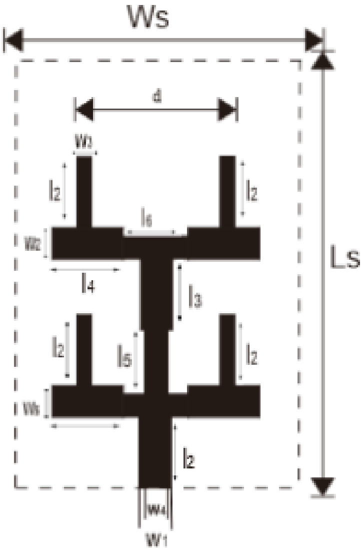

Figure 1. Feeding Line Antenna Design

Radiator Array Design

To increase gain, one of the techniques was to implement an antenna array design [20]. In this paper, an antenna array radiator with four patch elements with 2x2 is implementing, as shown in Figure 2.

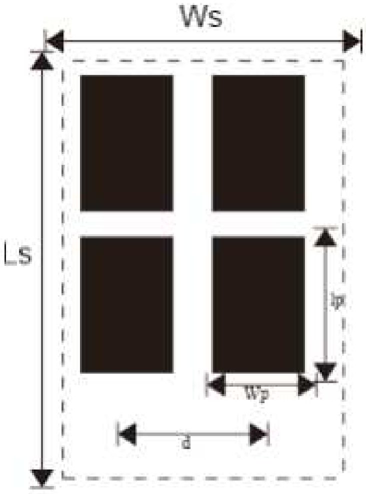

Figure 2. Antenna array radiator 2x2

RESULTS AND DISCUSSION

In this section, Figure 3 gives the fabrication design of the designed antenna system, using RT Duroid 5880 material, with the patch arrangement being in the second layer and feeding on one layer. Finally, we show the final design of the antenna. The complete antenna system comprises two layers: the radiator layer and the feeding layer. On the radiator layer (top layer), the radiating elements structures are multiple rectangular patch antennas design with four radiators 2x2 array configurations. These elements are located in the top layer. On the feeding layer (bottom layer). For the matching parallel branches, we use a λ/4-transformer and λ/2-transformer feeding technique. The feeding line dimensions structure is shown in Table 1.

Table 1. Antenna array radiator and feeding line Dimension

Symbol	**Dimension (mm)**
Wp	6.5
Lp	9.7
w1=w2	2.22
w3	1
l1=l2=l3=l4	5
w4=w5	1.58
l5=l6	4.6
Ws	20
Ls	25
d	6.95

Using Ansys HFSS version 16, the antenna design is simulated for the reflection factor parameter and gain parameter. Also, to validate the design, we measure with VNA RS ZVA 67 GHz for the reflection factor parameter. Figure 4 show a simulation using reflection factor parameter with one element and four elements. It can be seen different results for one element. The result is only one work frequency.

In contrast, it can produce two work frequencies for those using four elements, and from the results, the bandwidth of one element is smaller than that for those using four elements. It can be seen that the different results of the gain between one element and the two elements of Figure 5 look bigger when using four elements. The gain value is compared to those using two elements at a frequency of 29 GHz. Figure 6 shows a simulation utilising a gain parameter in 38 GHz. From this figure, the difference between one element and four elements that determine the antenna gain value, using array techniques increases the gain by about 10%. Figure 7 shows the comparison between simulation and measurement. Table 2 shows a comparison between reflection factor and bandwidth parameter using simulation and measurement.

Figure 3 shows the design of the antenna fabrication. Figure 3(a) image of the fabrication of the antenna array radiator using a rectangular patch design. Figure 3(b) is feeding the antenna using the 1/4 λ and 1/2 λ transformer method on the feedline. Figure 3(c) is the ground of the antenna.

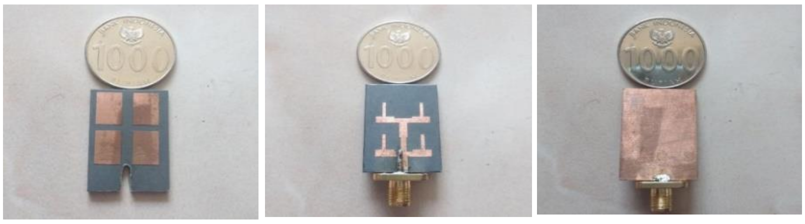

Figure 3. (a) Fabrication Antenna array radiator 2x2, (b) Fabrication Feeding Line Antenna, (c) Fabrication Ground Antenna

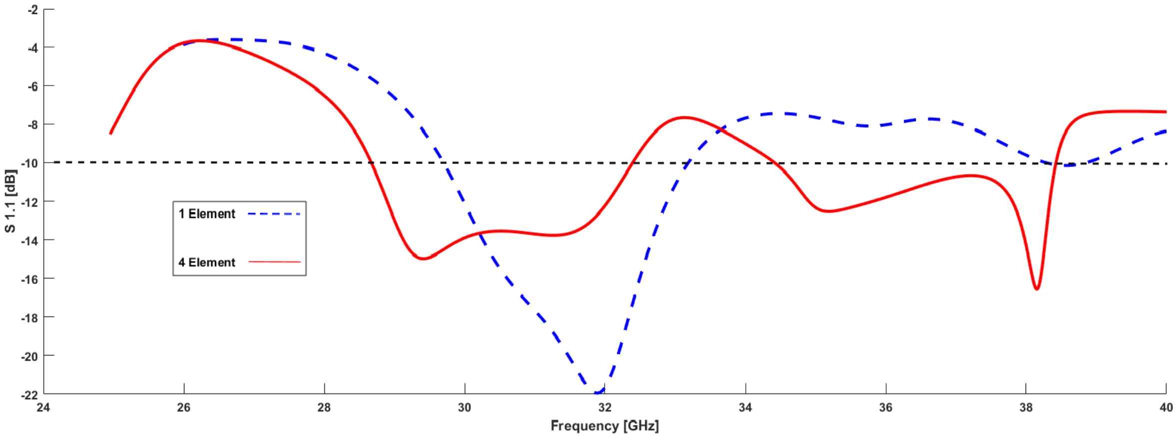

Figure 4. reflection factor simulation with one element (dashed line), and simulation with four elements (solid line)

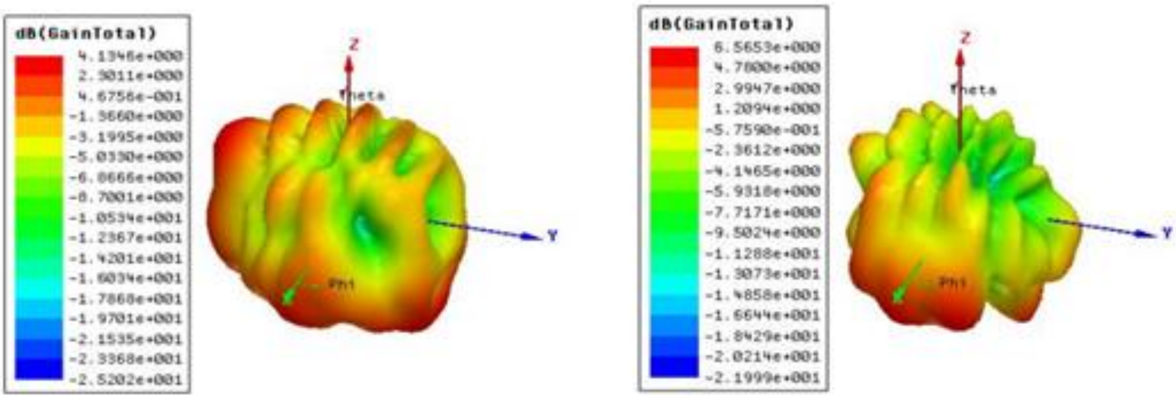

Figure 5. Gain parameter simulation with one element (left), simulation with four elements (Right) in 29 GHz

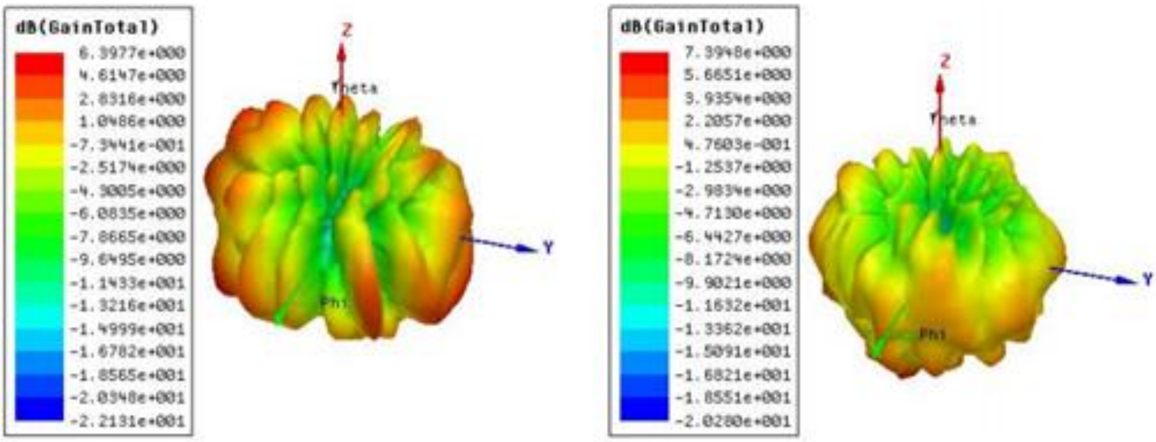

Figure 6. Gain parameter simulation with one element (left), simulation with four elements (Right) in 38 GHz

Figure 5 and Figure 6 show the gain simulation at the two frequencies above between a single element antenna and four element array antennas. It shows that at a frequency of 29 GHz with a single element antenna, the gain is 4.13 dB, while for a four element array antenna, it is 6.56 dB for the 38 GHz frequency. The gain for a single element antenna is 6.39 dB, while for a four element array antenna, it is 7.39 dB. From the above results, there is an increase in gain caused by the many elements that are designed.

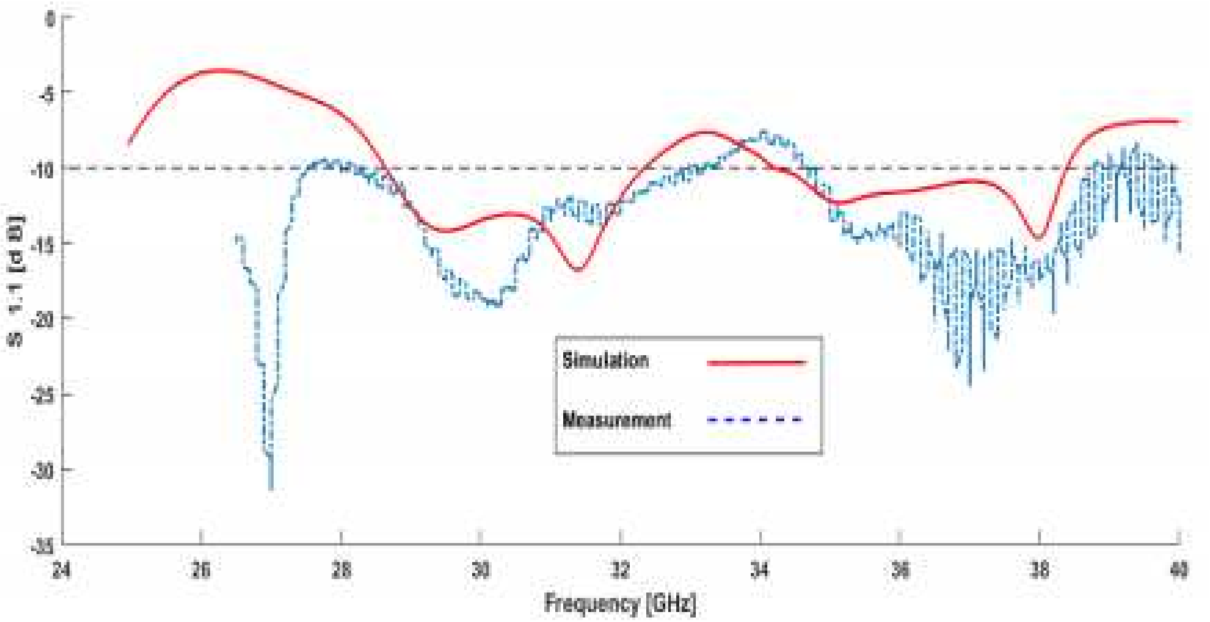

Figure 7. reflection factor simulation versus real-time measurement

Figure 7 shows the reflection factor comparison between measurement results using Rohde Schwarz ZVA 67 (solid line) and simulation (dashed line). Reflection factor around dual-band 29 GHz and 38 GHz. From the above results, it can be seen that there is no shift in frequency for simulation and measurement. Only a small difference in return loss occurs between simulation and measurement. From the results obtained in Figure 7, it can be concluded that between simulation and measurement, the antenna works successfully at two frequencies, 29 GHz and 38 GHz, it can be seen in Table 2.

Table 2. A comparison between reflection factor and bandwidth parameter using simulation and measurement

Result Antenna	Range Frequency [GHz]	Reflection Factor [dB]	Bandwidth [GHz]
Simulation	29	-13	3.7
	38	-14.6	4.15
Measurement	29	-12.5	4.5
	38	-16	3.75

CONCLUSION

The four element array antenna can work at frequencies of 29 GHz and 38 GHz with VSWR below 2 and Return Loss below -10 dB. The resulting bandwidth reaches ≥ 600MHz, where the simulation frequency of 29 GHz is 3.7 GHz, and at 38 GHz the bandwidth obtained is 4.15 GHz and when the measurement of the bandwidth obtained at the 29 GHz frequency is 4.5 GHz, and the frequency 38 is 3, 75 GHz. This antenna is designed using the feed designed using the $\lambda/2$ and $\lambda/4$ transformer variation technique to get the appropriate impedance. The proximity coupled combine technique array on feeding and patch to achieving the required bandwidths at respected frequency. Using array technique gain is increase 10%. The reflection factor measurement has verified the simulation results, and so it can be implemented for 5G applications.

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