Design of Microstrip Array Antenna with Beamforming Capability for 5G Communication

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Abstract

The fifth generation technology (5G) is a wireless network technology that offers access at very high data rates and greater capacity. One important element in realizing 5G technology is the antenna. Antennas with beamforming capabilities are one of the keys to 5G technology. Beamforming itself is an antenna's ability to direct the radiation patterns produced with certain characteristics. Based on previous research, antennas with beamforming capabilities can produce higher gain and wider bandwidth. In that study, antennas with high gain cause the value of SINR to increase, so that the resulting throughput is also higher. One type of antenna that can be used for 5G technology is a microstrip antenna. However, microstrip antennas have several disadvantages, including bandwidth and small gain. At present, the 28 GHz frequency is the most developed 5G frequency candidate. In this research, a microstrip antenna designed with beamforming capability can work at a frequency of 28 GHz. The antenna designed is an 8×8 MIMO array antenna arranged linearly. An array of antennas is carried out in order to increase the antenna gain. The antenna that has been designed is then performed beamforming simulation. The beamforming simulation is done by adjusting the phase difference at each antenna excitation. The desired beam characteristic is that it can point to 60 degrees with a beam width ≤ 30 degrees. The simulation results show that the antenna is able to work in the frequency range of 27.07 GHz - 28.77 GHz at a return loss limit of less than -10 dB with a bandwidth of 1.7 GHz and a gain value of 20.1 dB. Meanwhile, the beamforming simulation results by providing a relative phase difference between excitation of 45 degrees and 90 degrees, resulting in a radiation pattern with a beam characteristic approaching as desired. Setting the phase difference between excitation by 45 degrees produces a beam that leads to 61 degrees, with a beam width of 34.4 degrees. Meanwhile, the phase difference setting between excitation of 90 degrees produces a beam that leads to 64 degrees, with a beam width of 35.8 degrees.

Keywords: 5G Technology, Antenna, Microstrip, Array, Beamforming.

1. Introduction

The fifth-generation technology (5G) is a wireless network technology that offers access at very high data rates and greater capacities (5G Antenna White Paper on New 5G, New Antenna, 2019). The telecommunications industry around the world has done a lot of research to realize 5G technology (Yunfeng, Jiahao, & Xiaohong, 2019). In 2015, World Radio Communication (WRC), the International Telecommunications Union-Radio Communication (ITU-R) Sector officially confirmed that the official name of 5G was International Mobile Communication (IMT) -2020. IMT-2020 itself is a benchmark for the specifications of 5G communication technology. IMT-2020 has several candidate frequencies bands for 5G communication network, including the frequency range of 26.25 - 29.5 GHz, 31.8 - 33.4 GHz, 37 - 43.5 GHz, 45.5 - 50.2 GHz, 50.4 - 52.6 GHz, 66 - 76 GHz, and 81 - 86 GHz (Michael, 2019). The use of this high frequency band provides wider bandwidth for high level data communications over a short range of several hundred meters (Fatimah & Raed, 2016).

Antenna is one important element in realizing 5G technology. Antenna working frequency affects the dimensions of an antenna. The use of high frequencies causes the dimensions of an antenna to become smaller (Balanis, 2005). Based on the frequency range announced by IMT-2020, 5G Technology will use high frequencies. This causes the antenna on the 5G technology will have a small dimension. One type of antenna that can be used for 5G technology is a microstrip antenna. Microstrip antennas are used because they have ease in the design and fabrication process, but microstrip antennas have several disadvantages, including bandwidth and small gain.

Antennas with beamforming capabilities are also one of the key 5G technologies. Beamforming itself is an antenna's ability to direct the radiation patterns produced with certain characteristics. The beamforming capability of the antenna causes the antenna gain to be higher, so the information transmitted to the user has a very low loss value (5G Antenna White Paper on New 5G, New Antenna, 2019). Based on this, we need an antenna design that is suitable for 5G wireless communication in order to achieve greater bandwidth, more directional radiation patterns, and higher antenna gain.

In a previous study, a microstrip antenna design at a working frequency of 28 GHz was carried out with a planar array arrangement using series feed rationing techniques for communication (Varum, Ramos, & Matos, 2018). The results of the study stated that the use of a 4x4 planar array with series fed rationing techniques resulted in a bandwidth of more than 1.5 GHz and a gain value ranging from 18 dBi (Varum, Ramos, & Matos, 2018). The antenna's performance can operate for a 5G communication network, but the design of the antenna has an array of shapes and complex rationing techniques. This research will design an antenna that can operate at a frequency of 5G 28 GHz. The designed antenna will be arranged 8×8 linear array. An array on the antenna is expected to obtain a higher gain value. The feed technique used in antenna design in this study uses the T-shaped microstripe line. The feed technique is chosen so that it can facilitate the unification of the microtrip channel with the antenna array (Rames, Prakash, Inder, & Apispak, 2001). The antenna that has been designed is then performed beamforming simulation. The beamforming simulation is done by adjusting the phase difference at each antenna excitation. The desired beam characteristic is that it can point to 60 degrees with a beam width <30 degrees.

2. Research methodology

2.1 Beamforming

In 5G communication, antenna with beamforming capability is one of the key technologies (Almuthanna, Ahmed, & Abdulhameed, 2015). Antennas with beamforming capabilities usually have the characteristics of a more directional radiation pattern and a higher gain. Beamforming itself is a technique or the ability of an antenna to direct a radiation pattern with certain characteristics (Balanis, 2005). In an antenna array, beamforming can be done by adjusting the phase difference for each element (or supply) (Balanis, 2005). Analysis of the radiation pattern on the antenna array can also be done by reviewing the array factor (AF). An array factor (AF) is defined as the radiation pattern of an array obtained by ignoring the radiation pattern of each element of the array antenna. An array antenna with N elements, where each element is separated by distance and has the same amplitude has a normalized array factor. Normalized element N array elements can be formulated by Equation (1) as follows (Balanis, 2005).

$$AF_n = \frac{1}{N} \times \left(\frac{\sin(\frac{N}{2}\ \psi)}{\sin(\frac{1}{2}\ \psi)} \right). \tag{1}$$

Information:

N = Number of elemen antenna

Ψ = $k.d.\ cos\theta + \beta$.

The constant k is the wave constant while d is the distance between the antenna elements. The angle θ (tetha) is the angle of direction of the signal coming to the antenna element while β is the phase difference given to each antenna element.

2.2 Microstrip Antenna Rectangular Patch

Microstrip antennas generally consist of ground plane layers, substrate, and patch.

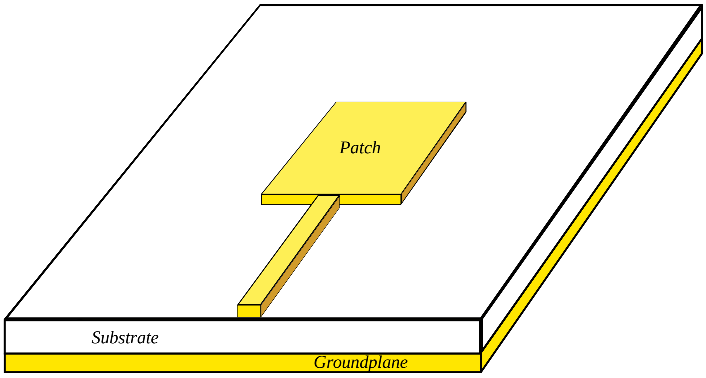

Fig. 1: Structure of microtrip antenna.

Groundplane is the bottom propeller layer on the microstrip antenna. The groundplane is made of conductor material and serves to reflect back unwanted irradiated signals. The substrate is a layer made of dielectric material (does not conduct electricity and serves as a place for rationing the antenna. Patch is the top layer of the microstrip antenna section which is made of conductor material and has the function of radiating electromagnetic waves. Antenna patches have a variety of shapes that can be adjusted for the purpose of the antenna. One form of patch that is most widely developed in wireless communication is rectangular patch (Balanis, 2005).

2.3 Antenna Specification

In this study, antennas that are designed have a working frequency range of 26.5 - 29.5 GHz, which includes the frequency most frequencies licensed by several countries, namely Japan, South Korea, Hong Kong, Uruguay, and America (GSMA Intelligence, 2019) . The antenna specifications are shown in Table 1.

Table 1: Antenna Specification.

Parameter	**Specification**
Work Frequency	28 GHz
Bandiwidth	> 1.2 GHz
VSWR	≤ 1.5
Radiation Pattern	Unidirectional
Directivity	≥ 8 dB
Gain	≥ 8 dB

The characteristic beamforming radiation pattern desired in this study is to be able to direct the beam towards 60 degrees with a beam width of ≤ 35 degrees (Trinh, Ferrero, Lizzim, Staraj, & Ribero, 2016).

The type of substrate used is Rogers RT / Duroid 5880 with a dielectric constant of 2.2 and thickness of the substrate of 0.8 mm. Duroid 5880 substrate was chosen because it can be used to produce shapes of larger dimensions and can work at high frequencies and has a small material permittivity. The material used for groundplane and patches is copper with a thickness of 0.035 mm. Copper is generally used for microstrip antennas because it is very easy to find and has quite good conductivity (Ardianto, Renaldy, Fathir, & Yunita, 2019).

2.4 Design and Simulation

The antenna dimension parameters for the 8×8 array antenna design are as follows.

Table 2: Dimension Parameters of Antena Array 8×8.

Parameter	**Information**	**Dimension (*mm*)**
Ht	Thickness of copper	0.035
Hs	Thickness of substrat	0.8

Wg	Width of groundplane	8.47
Lg	Length groundplane	6.096
Wp	Width of patch	4.235
Lp	Length of patch	3.048
Wf	Width of feed line 50 ohm	2.4852
Lf	Length of feed line 50 ohm	1.1067
Wf2	Width of feed line 100 ohm	0.69987
Lf2	Length of feed line 100 ohm	2.01824
Wf3	Width of feed line 70 ohm	1.405
Lf3	Length of feed line 70 ohm	1.9846
Wjunction	Connection feed	5.355
gf	Width of gap inset feed	1
fi	Length of gap inset feed	1.1067

Based on the antenna dimension parameters in Table 2. An 8×8 array antenna design is obtained as shown in Figure 2. below.

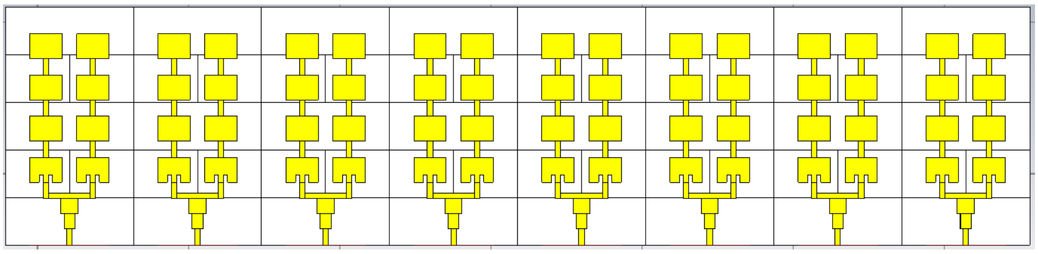

Fig. 2: Preliminary Design of Microstrip Antenna Array 8×8.

3. Results and Analysis

3.1. Result and Analysis on Optimization Design of Antenna Array 8×8

Based on the results of the optimization that has been done on the 8×8 antenna array design, obtained the working characteristics of the antenna shown in Figure 3. and Figure 4.

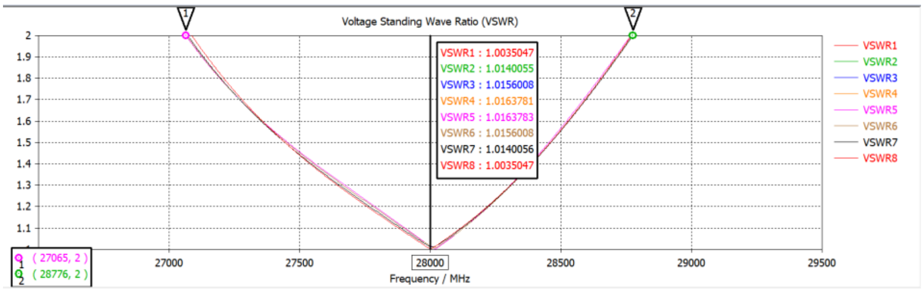

Fig. 3: VSWR of Optimation Result on Antena Array 8×8.

Based on the analysis shown in Figure 3., the average VSWR value for the 8×8 array antenna design is 1,012 with a bandwidth of 1,698 GHz (≈1.7 GHz).

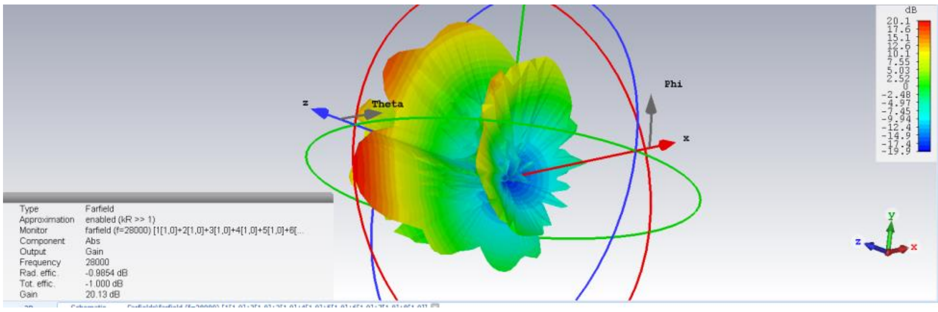

Fig. 4: Gain of Optimation Result on Antena Array 8x8.

The gain obtained is 20.1 dB, the gain value already meets the desired antenna specifications. The resulting directivity value is 21.2 dB and the axial ratio value is 40 dB, where the value indicates that the antenna has a unidirectional radiation pattern.

3.2 Analysis of Beamforming Simulation Results

After the antenna is optimized to get the performance according to the desired work specifications, the antenna is then simulated beamforming by adjusting the phase difference in each array element array. The beamforming simulation results are shown in Figure 5.

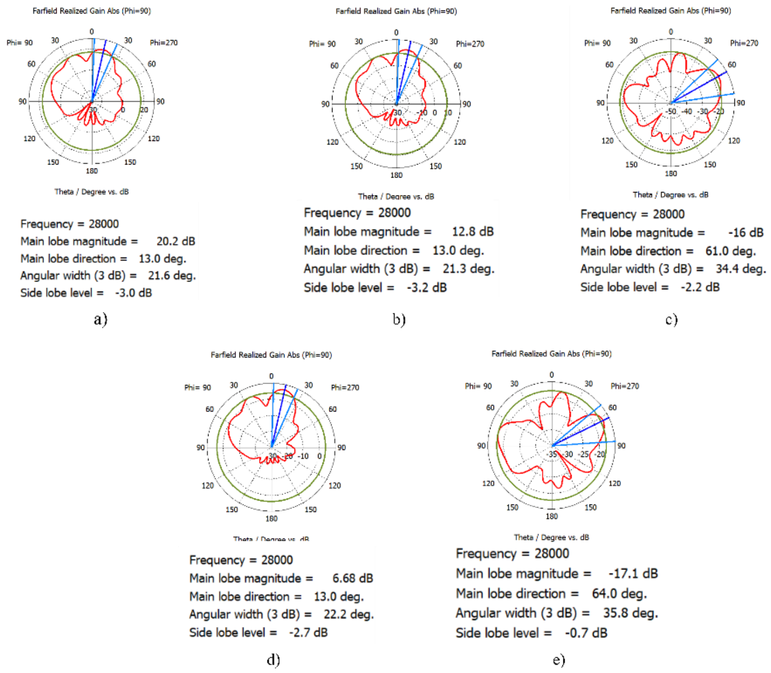

Fig. 5: Beamforming Simulation Result.

Figure 5b) shows simulation result on the first test, the relative phase difference given for each elemental supply is 30 degrees. Obtained the resulting radiation pattern has a beam direction in the direction of 13 degrees with a beam width of 21.3 degrees. The gain obtained is 12.8 dB. Figure 5c) shows beamforming result on the second test, the relative phase difference given for each elemental supply is 45 degrees. Obtained the resulting radiation pattern has a beam direction towards 61 degrees with a beam width of 34.4 degrees. The gain obtained is 16 dB. Figure 5d) shows beamforming result on the third test, the relative phase difference given for each elemental supply is 60 degrees. Obtained the resulting radiation pattern has a beam direction in the direction of 13 degrees with a beam width of 22.2 degrees. The gain obtained is 6.69 dB. Figure 5e) shows simulation result on the fourth test, the relative phase difference given for each elemental supply is 90 degrees. Obtained the resulting radiation pattern has a beam direction toward 64 degrees with a beam width of 35.8 degrees. The gain obtained is 17.1 dB.

4. Conclusion

Testing and analysis of 8x8 array microstrip antenna simulation at a frequency of 28 GHz has been carried out. The 8x8 array antenna simulation results in an average return loss of -40.27 dB with a bandwidth acquisition of 1,698 GHz. In the beamforming simulation results, the provision of relative phase differences between the rocks by 45 degrees and 90 degrees produces the radiation pattern that is most close to the desired characteristics. The characteristic radiation pattern that is produced when the relative phase difference given to each unit by 45 degrees produces a beam that can lead to 61 degrees, with a width of 34.4 degrees. The gain obtained is 16 dB. Meanwhile, giving a relative phase difference for each supply of 90 degrees produces a beam that can lead to 64 degrees with a beam width of 35.8 degrees and a gain obtained of 17.1 dB. Based on the simulation results, it can be concluded that the antenna has the performance according to the desired specifications. In addition, the simulation results show that the antenna designed has the potential to be used in 5G technology, because it meets the recommended standards. The next step, will be carried out the realization of the antenna that has been designed.

5. Acknowledgements

Thanks to friends of 3.5 years in college for giving me the opportunity to find this journal conference, the authors are also grateful for the prayers that have been given to the author in completing this journal. thank you father, mother, and also friends who always give joy to the author.

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