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Performance Analysis of Microstrip Grid Array Antenna on Different Substrates for 5G Mobile Communication

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***Abstract*—This paper investigated the performance and characteristics of microstrip grid array antenna (MGAA) on three different substrates which are Rogers RT5880LZ, Taconic RF-43, and Fr-4. For this work, the proposed MGAA has been designed at 15 GHz for 5G mobile communication application. The proposed microstrip grid array antenna consists of 12 cells block with 19 radiating elements and was feed using the 50 Ω coaxial port from the ground plane. A comprehensive study on the effect of substrate on the performance of MGAA is carried out. S-parameters, gain, and efficiency of MGAA on all those substrates have been used as parameters in determining the performance of proposed antenna in order to fulfill the design criteria for 5G mobile communication application. The design and simulation process of MGAA was done in CST Microwave Studio Software.**

***Index Terms*—Microstrip Grid Array Antenna; 5G; Rogers RT5880LZ; Taconic RF-43; Fr-4.**

I. Introduction

Fourth generation (4G) wireless communication is already at the mature or end stage. Currently there are a lot of research being done towards the fifth generation (5G) wireless communication. As a developing country, Malaysia 5G is expected to be available and realized in the market in the year 2020. This 5G mobile communication system demand the antenna that has high efficiency, wide bandwidth, and has the high directional beamforming characteristic to be used in both base station and mobile devices [1]. Therefore, the proposed MGAA must fulfill the entire requirement so that it can be used in mobile communication networks for the 5G system. However, there is no concrete carrier frequency band decided for the 5G communication system yet. As discussed in [2], the idea is to utilize two frequency bands which are high-SHF band and the EHF that cover above 6GHz and from 30 GHz until 60 GHz respectively. The main reason in using high frequency band is to easily get a wide frequency bandwidth. Besides, as presented in [3] where the frequency range from 3 GHZ until 300 GHZ was suggested for the future mobile broadband applications. In this work, they have analyzed different millimeter-wave frequencies with 1 GHz system bandwidth in order to test its suitability for mobile communication. The suitability of a certain frequency must be analyzed carefully before choosing it as the next wireless communication band as discussed in [4][5][6] . As discussed in [4], the effect of rain in Malaysia on the microwave systems operating at 26 GHz has been done where two types of losses which are due to propagation at 26 GHz and the losses due to wet antenna has been identified. In addition, work in [5] described the technique of deriving path reduction factor at 15 GHz for terrestrial microwave links in Malaysia. From the review, there is a lot of factor that need to be considered. Therefore, deep understanding and research must be done on a certain frequency before choosing it as the frequency for 5G communication system.

Microstrip grid array antenna is one of the good candidates to be used for the 5G mobile communication system because of its ability to operate at high frequency band and has the high gain characteristic. A study in [7] stated that the performance of MGAA is strongly influenced by the choice of substrate. The substrate used is Rogers and Low Temperature-Cofired Ceramic (LTCC). Another work using LTCC as a substrate is as discussed in [8] and [9]. In [7] the proposed antenna was integrated into a grid array package in an LTCC technology. While in [9], the MGAA was designed using Ferro A6M LTCC for antenna in package applications. From the review, most of the work used LTCC and Rogers as a substrate and only some work used the low-cost material such as FR-4 in designing their microstrip grid array antenna such as presented in [10] and [11]. So, in this work MGAA will be designed and simulated using FR-4, Rogers RT5880LZ, and Taconic RF-43. The performance of MGAA will be analyzed in order to determine which substrate gives a good performance. For this work, it is focused and only limited for three types of substrates and there is still a lot of material that can be studied and used as the substrate for this type of antenna. The proposed antenna must be operated at 15 GHz and has frequency bandwidth at least 1 GHz at -10 dB return loss. Besides that, the designed antenna must have high gain and high efficiency to fulfill the characteristics of the future 5G mobile communication application. This paper is organized as follows: Section 2 will describe the proposed antenna configuration, dimensions of the antenna, and location of the coaxial feed line. Section 3 is where the result will be presented and discussed. Finally, section 4 will conclude all the work that has been done.

II. ANTENNA DESIGN

The proposed MGAA was designed on three different substrates which are Rogers RT5880LZ, Taconic RF-43, and FR-4. The detail specification about those three substrates is as shown in the Table 1. It shows that the FR-4 has the highest loss tangent value compared with the other two substrates. The ground and patch for the proposed antenna for all substrate is made up of copper where the thickness is t=0.035 mm and the antenna was feed from the ground plane using 50Ω coaxial feed line. The feed line position is near the center of the antenna which is between the transmission line and radiating element. The pin diameter of the coaxial probe is 1.3 mm and the coaxial probe filled with Teflon with dielectric constant εr = 2.1.

Table 1
Substrates Specification

Parameters	Rogers RT5880LZ	Taconic RF-43	FR-4
Thickness, (h), mm	1.5	1.5	1.5
Dielectric constant (ε_r)	1.96	4.3	4.3
Loss Tangent	0.0019	0.0033	0.025

Figure 1 shows the geometry of the proposed antenna. The antenna consists of 12 rectangular cells where the short side of the single cell operates as both transmission part and radiating part, while the long side of single cell operates as transmission line [7][8][9][10][11]. So there exist 19 radiating elements in that meshes.

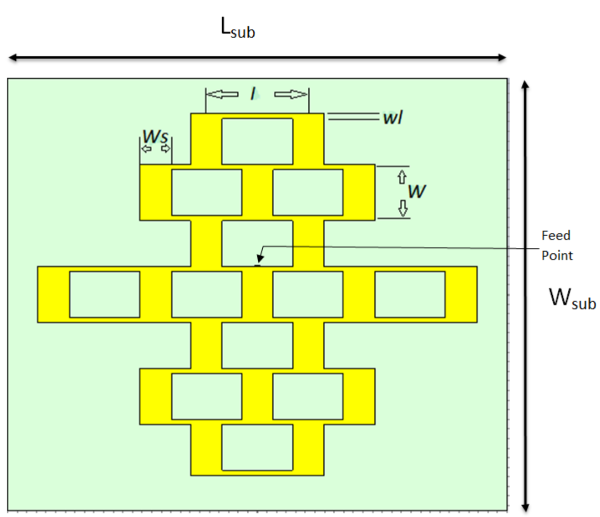

Figure 1: Geometry of the Proposed Antenna

The length (l) and width (W) of the cells are the parameters that determine the operating frequency for the MGAA. Besides, the width of the short side (Ws) and long side (Wl) also important in determining the microstrip grid array antenna performance. It was defined as l ≈ λg and W ≈ λg/2 where λg is the guided wavelength [7][8][9][10][11].

$$l = \lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} = \frac{C}{f_0\sqrt{\varepsilon_{eff}}} \quad (1)$$

The value for *Ws* and *Wl* are obtained from the optimization process in CST Microwave Studio Software. At 15 GHz, the parameters for *l* and *W* is obtained for each substrate by substitute the dielectric constant (ε_r) into the guided wavelength equation. The obtained values of the antenna parameters after some optimization and simulation in CST Microwave Studio are shown in Table.2. From the table, when using Rogers as a substrate, it gives the largest total dimension for the proposed antenna due to small dielectric value. But the total dimension of that antenna is still acceptable because it is not really big.

Table 2
Antenna Parameters

Parameters (mm)	Rogers RT5880LZ	Taconic RF-43	FR-4
l	15	10.6	11.2
W	7.5	5.3	5.6
Ws	4.9	3.3	3.4
Wl	0.55	0.5	1.4
Total Antenna Dimension (mm^3)	75x 65 x1.57	52x45x 1.57	55x48 x 1.57

III. RESULT AND DISCUSSION

The return loss of the proposed MGAA is shown in Figure 2. At -10dB, the bandwidth for Rogers RT5880LZ, Taconic RF-43, and FR-4 are 2.76 GHz (14.06-16.82) GHz, 1.64 GHz (14.39-16.03) GHz, and 1.26 GHz (14.24-15.49) GHz respectively. It shows that Rogers gives a better bandwidth compared to the other substrate. But the overall return loss for all substrates still satisfied the requirement which is greater than 1 GHz for the frequency bandwidth at -10 dB.

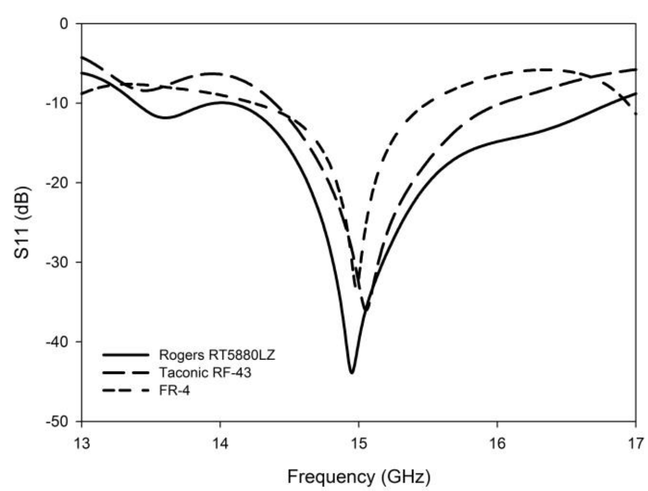

Figure 2: Return losses of the proposed antenna

Figure 3 shows the gain of the proposed MGAA on three different substrates. High gain antenna is crucial in long-range wireless communication. From the figure, the highest gain for the proposed MGAA is when using Rogers RT5880LZ as antenna substrate which is at 16 dB at 15 GHz. While, the antenna gain when using Taconic RF-43 is 12.4 dB at 15 GHz and FR-4 gives the smallest gain value which is 10 dB at 15 GHz. This is due to the loss tangent value of the substrates where the gain will drop when the loss tangent value increase. As shown in table 1, FR-4 has the highest loss tangent value. So this is why the proposed antenna gives the lowest gain value when FR-4 is used as the substrate.

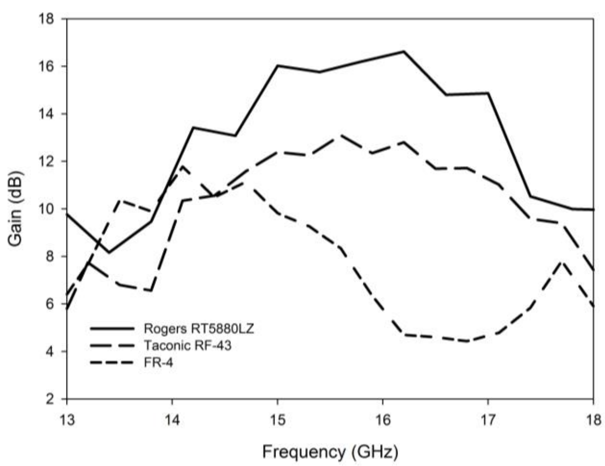

Figure 3: Gain of the proposed antenna

Figure 4 shows the total efficiency of the MGAA on three different substrates. From the figure, at 15 GHz the proposed MGAA has the highest efficiency when using Rogers RT5880LZ as the substrate where the efficiency is equal to 95%. FR-4 gives the lowest total efficiency for the proposed MGAA where the efficiency is only 57% while the Taconic RF-43 has a quite good total efficiency which is equal to 87.5% at 15 GHz.

As stated in section I, the proposed MGAA must have directive radiation pattern characteristic in order to use it for 5G mobile communication applications. Fig. 5 shows the radiation pattern on the YZ-plane and XZ-plane for the proposed antenna. From the figure, it shows that the proposed antenna on all substrates has directional radiation pattern characteristics which pointed in the boresight direction in order to obtain the maximum value of gain. So, the antennas fulfill the requirement for 5G mobile communication application. Other applications besides using this antenna on mobile devices and on base stations, this type of antenna also suitable to be used to connect one building to another building which is known as point to point wireless link application.

Table 3 shows the summary of comparison for three difference substrate. Overall, Rogers give the highest performance compared to Taconic and FR-4. But the performance when using Taconic RF-43 is quite good and the size of the antenna is smaller than Rogers and FR-4. Even FR-4 also gives smaller size than Rogers, but in terms of performance, it is not as good as the Rogers and Taconic RF-43. So, if the system requires an antenna which has wide bandwidth, high gain, and high efficiency Rogers RT5880LZ is a good choice to be used as the antenna substrate and if the system demand low cost material and also smaller size antenna, Taconic RF-43 is a better choice than FR-4 because the performance is better.

Table 2
Summary of Comparison on all substrate

	Rogers	Taconic	FR-4
-10dB S11 BW (GHz)	2.76	1.64	1.26
BW percentage (%)	18.40	10.93	8.40
Gain (dB)	16.00	12.40	10.00
Efficiency (%)	95.00	87.50	57.00
Antenna Dimension (mm^3)	75x65 x1.57	52x45x 1.57	55x48 x1.57

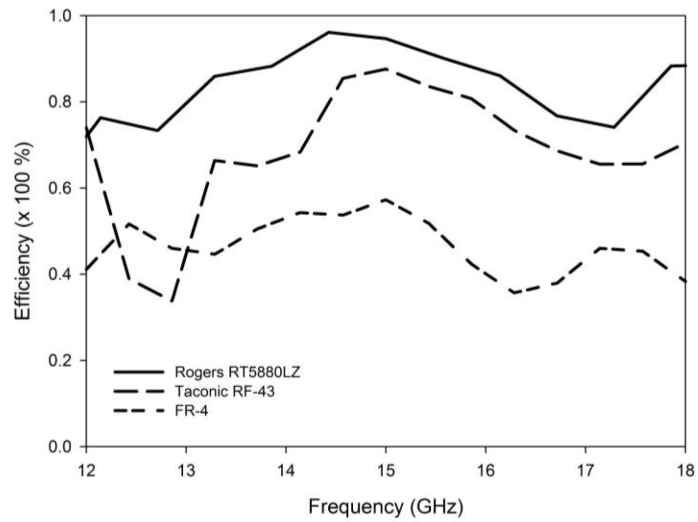

Figure 4: Total Efficiency of the proposed antenna

IV. Conclusion

The microstrip grid array antenna on three different substrates for 5G mobile communication application is presented. The proposed antenna resonated at 15 GHz with directional radiation pattern and was feed using a 50Ω coaxial port. A detailed analysis and comparative studies between performances of proposed antenna on Rogers RT 5880LZ, Taconic RF-43, and FR-4 in term of return loss, efficiency, gain, and radiation pattern were discussed effectively. It shows that the antenna operates at the highest performance when using Rogers RT5880LZ as the substrate and the Taconic RF-43 also can give a quite good performance for the proposed MGAA. While FR-4 has the lowest performance compared with the other two substrates.

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