Design of Microstrip Rectangular Circular Array Antenna 1x8 at Frequency of 1800 MHz for Increase Power of 4G signal

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Abstract. Technology of 4G is a cellular technology improved from 3G and 2G which provide network with the bandwidth of 75MHz and operated frequency of 1800 MHz. In a process of receiving and sending information signal, 4G system need antenna as the device functioning to send electromagnetic to the air. When information signal is transmitted, there was possibility that the signal weaken which caused by several factors such as air, building wall thickness and weather. Rectangular circular patch array 1x8 microstrip antenna is an antenna functioning as 4G signal strengthens at the frequency of 1800MHz. Antenna was design by using software of CST Studio Suite. From the result of rectangular circular patch array 1x8 microstrip antenna measurement at the frequency of 1800 MHz, it was obtained that the gained was 7.32 dB, VSWR was 1.208, and return loss was -20.3 dB. Performance test of antenna was conducted for 4 Indonesia’s cellular providers namely Telkomsel, Indosat Ooredoo, XL, and 3 in various places. The test result in PNJ telecommunication laboratory showed that the best average value of RSRP from provider of Indosat Ooredoo was-72.9 dBm, the best average value of RSPS from provider of 3 was -70.7 dBm located in Bambon raya, and the best average value of RSPP from provider of XL was -65.2 dBm located in Cibubur.

1. Introduction
In globalization era, information technology role is very prominent and important for society. The development of cellular technology starts from 2G, 3G up to 4G or fourth generation. Technology of 4G is a improvement of cellular phone technology called 3G and 2 G which provide high bandwidth, which was 75 MHz and operated at the frequency of 1800 MHz [3]. The service of 4G initially launched in Indonesia in 2013.

In receiving and sending information signal, 4G system needs antenna as the device functioning to send electromagnetic wave to the air. When the information signal is transmitted there is a possibility that the signal waken due to several factors such as air, building wall thickness and weather. To solve this problem, a device is required to strengthen the signal transmitted by Evolved Node B (eNodeB) in order that the user can receive good signal. eNodeB is a device in cellular telecommunication in a form of tower with transmitter antenna functioning as signal strengthen device. Repeater is one of device for user to strengthen the signal transmitted by eNodeB.

2. Methodology
2.1 Research Method
In this study there were several steps to obtain rectangular circular patch array 1x8 microstrip antenna design. The first step was by calculating the weave length, calculating rectangular microstrip
dimension, calculating circular microstrip dimension, calculating space between patch, calculating transformer length and transmission path width. After calculating, the next step is by simulating antenna in software of CST Studio Suite. The second step is making simulation by designing rectangular circular patch array 1x8 microstrip antenna. The third step was the development of antenna designing. The forth step is testing the antenna whether or not the antenna fit to the specification. The fifth step was testing the application and taking the required data [2].

2.2 Antenna Designing

The first step is antenna designing by determining antenna specification. The specification used in designing rectangular circular patch array 1x8 microstrip antenna is shown on Table 1.

Table 1. Specification of rectangular circular patch array 1x8 microstrip antenna.

| Specification          | Value  |
|------------------------|--------|
| Working frequency      | 1800 MHz |
| VSWR                   | < 2    |
| Radiation pattern      | Unidirectional |
| Gain                   | > 3 dB |
| Substrate              | FR4    |
| Return Loss            | ≤ -10 dB |
| Bandwidth              | 20 MHz |
| Substrate              | FR4    |
| Dielectric constants (εr) | 4.3  |
| Substrate thickness    | 1.6    |
| Conductor thickness    | 0.1 mm |

Antenna designing was started by determining working frequency of 1.8 GHz and the material used was PCB epoxy with the substrate of FR4. The shape of rectangular circular patch array 1x8 microstrip antenna which will be designed is shown on Figure 1.

To determine patch dimension was by calculating the wavelength, rectangular microstrip dimension, circular microstrip dimension, space between patch, transformer and transmission path width. The width and length of patch which will be calculated by using equation 1 [1], [5]-[9].

\[
W = \frac{c}{2f} \left( \frac{\varepsilon_r + 1}{2} \right) = 50.96 \text{ mm} \quad (1)
\]

To determine constant effective dielectric value, equation 2 is used:

\[
\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left( \frac{1}{1 + \frac{2h}{W}} \right) = 2.709 \text{ mm} \quad (2)
\]
Where $\varepsilon_r = 4.3$; $h = 2.5$ mm; and $W = 50.96$ mm, thus it was obtained $\varepsilon_{eff} = 2.709$ mm. Patch element length can be calculated by using equation 3 [5]-[9].

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} = 50.83 \text{ m}$$ (3)

The next was calculating $\Delta L$ by using equation 4.

$$\Delta L = 0.412h \left(\frac{(\varepsilon_{eff}+0.3)(\varepsilon_{eff}+0.624)}{(\varepsilon_{eff}-0.258)^{1/2}+0.8}\right) = 1.232 \text{ mm}$$ (4)

Hence patch length can be calculated by using equation 5.

$$L = L_{eff} - 2\Delta L = 48.37 \text{ mm}$$ (5)

Based on the calculation in designing process, the shape of antenna was obtained as shown on Figure 2.

![Figure 2](image)

Figure 2. Result of rectangular patch microstrip antenna

The size of radius can be calculated by using equation 6.

$$F = \frac{0.792 \times 10^9}{f\sqrt{\varepsilon_r}} = 2.36$$ (6)

After obtaining F value, size of patch radius can be calculated by using equation 7 [6].

$$a = \frac{f}{\left[1+2h\left|\ln\left(\frac{\pi h}{2h}\right)+1.7726\right|\right]^{1/2}} = 23.03 \text{ mm}$$ (7)

Based on the calculation results of the antenna patch radius, the antenna shape is shown as shown in Figure 3.

![Figure 3](image)

Figure 3. Result of circular patch microstrip antenna dimension
The space between patch can be calculated by using equation 8.

\[ d = \frac{\lambda}{2} = \frac{c}{2f} = 83.33 \text{ mm} \quad (8) \]

Based on the result of calculation the shape of antenna was obtained as shown on Figure 4.

Figure 4. Space between patch

The next step is calculating transformer length and transmission path width. To calculate transformer length and transmission path width equation 9, 10, and 11 were used:

\[ W_{zo} = \frac{377}{\sqrt{\varepsilon_r}} \left( \frac{h}{2d} \right) = 4.55 \text{ mm} \quad (9) \]
\[ W_{zl} = \frac{377}{\sqrt{\varepsilon_r}} \left( \frac{h}{2z} \right) = 9.05 \text{ mm} \quad (10) \]
\[ W_{zt} = \frac{377}{\sqrt{\varepsilon_r}} \left( \frac{h}{2t} \right) = 6.36 \text{ mm} \quad (11) \]

The result of rectangular circular patch array 1x8 microstrip antenna design in overall is presented on Figure 5.

Figure 5. Result of rectangular circular patch array 1x8 microstrip antenna designin

After being optimized and the result fit to specification was obtained, the fabrication of design rectangularcircular patch array 1x8 microstrip antenna was conducted as shown on Figure 6.
3. Result and Discussion

After designing and fabricating, the next step was antenna parameter testing. The testing was conducted in Radar Telekomunikasi Indonesia (RTI), Bandung. The measured parameters were return loss, VSWR, polaradiation, and gain [4]. Based on simulation result at the frequency of 1800 GHz the value of return loss was obtained as -37.743 dB and from the testing result the value of return loss was obtained as -20.3 dB. The value from simulation was better than testing result. Several factors can cause the difference of return loss value from simulation result and test result those were fabrication process, there was cutting sticker at PCB, etching process of PCB and less precision connector installation. But the results of the -20.3 dB return loss test are still in accordance with the desired specifications which are <-10 dB.

The VSWR value of the simulation results obtained is 1.0262, while the test results obtained the VSWR value of 1.208. The VSWR value of the simulation results is better than the test results, but the value of the test results can still be said to be good because it is still in accordance with the desired VSWR value which is <2.

For gain testing result, it was obtain the gain value as 7.32 dB and have unidirectional polaradiation.

The next step was antenna testing for application as 4G signal amplifier. The testing was conducted by measuring signal quality or RSRP for 4 cellular operators namely Telkomsel, Indosat Ooredoo, XL, dan Three in 3 different location, those are PNJ Telecommunication Laboratory, Beji Timur Depok, and Cibubur.

1. Testing in telecommunication laboratory, Politeknik Negeri Jakarta

Table 2 shows the testing result at provider of Indosat Ooredoo. The testing was conducted before using repeater, using spiral – indoor omni antenna, microstrip antenna – indoor omni, and microstrip antenna – octaquad.

| No | Without signal amplifier (dBm) | Spiral indoor omni (dBm) | Mikrostrip– indoor omni (dBm) | Mikrostrip– octaquad (dBm) |
|----|-------------------------------|--------------------------|-------------------------------|---------------------------|
| 1  | -92                           | -87                      | -79                           | -76                       |
| 2  | -95                           | -86                      | -82                           | -74                       |
| 3  | -90                           | -86                      | -81                           | -74                       |
| 4  | -89                           | -83                      | -82                           | -73                       |
| 5  | -90                           | -84                      | -81                           | -74                       |
| 6  | -94                           | -86                      | -79                           | -73                       |
| 7  | -90                           | -83                      | -79                           | -72                       |
| 8  | -89                           | -84                      | -82                           | -72                       |
| 9  | -90                           | -82                      | -79                           | -71                       |
| 10 | -90                           | -83                      | -79                           | -70                       |
| Average | -90.9                          | -84.4                    | -80.3                         | -72.9                     |
2. Testing in Beji Timur, Depok.

Table 3 shows the testing result at provider of Three. The testing was conducted before using repeater, using spiral antenna – indoor omni, microstrip antenna – indoor omni, and microstrip antenna – octaquad.

Table 3. Testing at provider of three in Bambon Raya, Beji Timur

| No | Without signal amplifier (dBm) | Spiral indoor omni (dBm) | Mikrostrip– indoor omni (dBm) | Mikrostrip–octaquad (dBm) |
|----|------------------------------|--------------------------|-------------------------------|---------------------------|
| 1  | -105                         | -85                      | -85                           | -70                       |
| 2  | -104                         | -84                      | -83                           | -69                       |
| 3  | -104                         | -84                      | -78                           | -69                       |
| 4  | -104                         | -83                      | -77                           | -68                       |
| 5  | -105                         | -84                      | -77                           | -69                       |
| 6  | -103                         | -89                      | -76                           | -69                       |
| 7  | -103                         | -84                      | -75                           | -71                       |
| 8  | -103                         | -79                      | -78                           | -73                       |
| 9  | -101                         | -77                      | -80                           | -75                       |
| 10 | -105                         | -77                      | -84                           | -74                       |
| Average | -103.7                      | -82.6                    | -79.3                         | -70.7                     |

3. Testing in Cibubur, Jakarta Timur

Table 4 shows the testing result at provider of XL. The testing was conducted before using repeater, using spiral – indoor omni antenna, microstrip antenna – indoor omni, and microstrip antenna – octaquad.

Tabel 4 Testing at provider of XL in Cibubur, Jakarta Timur

| No | Without signal amplifier (dBm) | Spiral– indoor omni (dBm) | Mikrostrip– indoor omni (dBm) | Mikrostrip–octaquad (dBm) |
|----|------------------------------|--------------------------|-------------------------------|---------------------------|
| 1  | -82                          | -76                      | -75                           | -65                       |
| 2  | -87                          | -75                      | -77                           | -64                       |
| 3  | -84                          | -78                      | -70                           | -64                       |
| 4  | -86                          | -76                      | -60                           | -67                       |
| 5  | -86                          | -80                      | -75                           | -66                       |
| 6  | -88                          | -81                      | -76                           | -65                       |
| 7  | -87                          | -80                      | -74                           | -66                       |
| 8  | -85                          | -78                      | -72                           | -65                       |
| 9  | -83                          | -78                      | -72                           | -65                       |
| 10 | -86                          | -77                      | -72                           | -65                       |
| Average | -85.4                         | -78.1                    | -72.3                         | -65.2                     |

4. Conclusion

Based on the result of designing, antenna testing, and analysis it can be concluded that:

1. The result of rectangular circular patch array 1x8 microstrip antenna at working frequency of 1800 GHz it was obtained return loss value as -37.743 dB, VSWR value as 1.0262, gain value as 7.83 dB, and unidirectional radiation pattern. This result is suitable to the expected specification which were return loss of ≤-10 dB, VSWR of < 2, gain of >3dB, and unidirectional radiation pattern.

2. The result of quality testing of signal or RSRP antenna as 4G amplifier was conducted at 4 cellular operator in Indonesia with 3 testing location namely telecommunication laboratory the best value of RSRP was -72.9 dBm at provider of Indosat Ooredoo, in Beji Timur Depok, the
best average value of RSRP was -70.7 dBm at provider of Three, and in Cibubur with average the best value of RSRP was -65.2 dBm at provider of XL.

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