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# Dual-band Rectangular Microstrip Patch Antenna for LTE and BWA Application

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**Abstract**. This paper proposes a design of rectangular patch antenna used for Long Term Evolution (LTE) networks communication and Broadband Wireless Access (BWA). The antenna can operate in dual-band at the frequency of 2.3 and 3.5 GHz. The proposed antenna dimension has a patch size of 39.6 mm x 29.8 mm, a feedline length of 19 mm, and a 1.4 mm channel width. Some parameters are used for the antenna in terms of bandwidth, VSWR, return loss, impedance, and gain. This antenna has a directional radiation pattern. At 2.3 GHz frequency obtained a gain of 3.612 dB, VSWR 1.07, bandwidth of 60 MHz, return loss of -20.00 dB, and an input impedance of 48.651 + j2.561Ω. While at the frequency of 3.5 GHz obtained a gain of 1.00 dB, VSWR of 1.33, bandwidth of 66 MHz, return loss of -16.90, and an input impedance of 46.258 + j4.897 Ω. Adjusting the antenna dimensions, either the patch dimension, and the feeder line dimension, can generate the desired working frequency as well as generating predefined ideal parameters.

## 1. Introduction

High performance, solid size, and low cost are often the strict requirements of modern microwave communications systems. In the field of telecommunications, microstrip antenna is one of technology that allows small sized antennas to perform well. Microstrip antenna size is small and light weight that makes this type of antenna is simple and easy to integrate and widely applied to various mobile devices, such as WiFi, RFID, WiMax and the like. Microstrip is generally used because it is easier in the factory and the losses are relatively smaller when compared to the lumped circuit [1].

Microstrip antenna is one antenna that can be used in Long Term Evolution (LTE) application and Broadband Wireless Access (BWA) [2]. Various research and development of dual-band antennas has been widely done with the aim of antenna efficiency, because if one antenna only covers one frequency band, the amount becomes inefficient. The dual-band antenna is discussed on [3] that is able to work on frequency 2.4 and 5.2 GHz. The antenna consists of two T-shaped monopoles stacked in different sizes. The shape of dual-band patch antenna is developed differently, that is a double L-shaped [4]. Modified shapes and techniques can also be done to obtain dual-band antennas capable of working on L-band and

K band for satellite communications. On this antenna, the dual-band behavior is obtained by inserting a small X-band microstrip patch antenna into a large L-band one. Both patches are printed on the same substrate [5].

A more compact dual-band antenna shape is also developed to achieve more optimal performance [6–9]. The dual-band antenna design can also be enhanced with the addition of Defected Ground Structure (DGS) to achieve more optimal results [10, 11].

In this paper, it is proposed a dual-band rectangular microstrip patch antenna for LTE and BWA application. The method is quite simple, by modifying patch dimension and dimension of feeder channel to get optimum result. The microstrip antenna with this rectangular patch facilitates the modification process to produce the desired impedance, radiation pattern, and working frequency.

## 2. Material and design

This study proposes a microstrip antenna for Long Term Evolution (LTE) and BWA application in Indonesia. The proposed antenna is capable of working at frequencies 2.3 GHz (LTE) and 3.5 GHz (BWA), bandwidth ≥ 60 MHz, VSWR ≤ 2, radiation pattern is in the form of directional, and impedance 50 **Ω**. Antenna is a microstrip antenna with rectangular patch -shaped. The antenna is realized with FR4 epoxy substrate, with relative dielectric constant ($\varepsilon_r$) = 4.4, dielectric loss tangent (*tan δ*) = 0.02, and thickness ($h$) =1.6 mm.

The development of the antenna is done by referring to the flow shown in Figure 1.

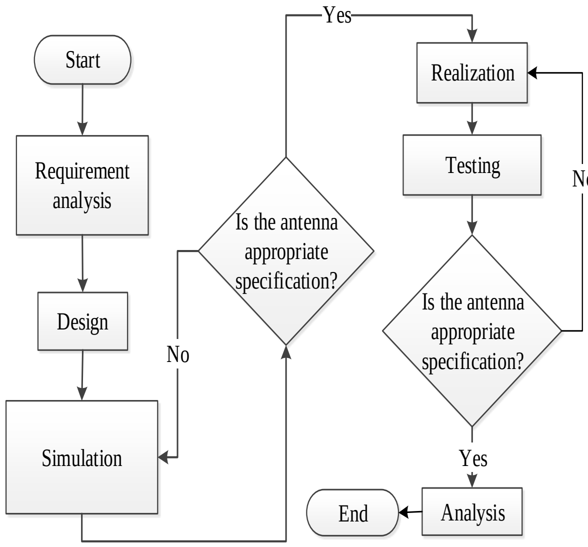


**Figure 1.** Flow chart of antenna development.

## 3. Design of microstrip antenna

### *3.1. Patch design*

Before performing the simulation, the patch size for the 2.3 GHz frequency is determined first, by using equations (1) and (2) below [12].

$$\lambda_o = \frac{c}{f}, \tag{1}$$

$$W = \frac{\lambda_o}{2}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2}, \tag{2}$$

Where c is the speed of light (3x10$^8$ m/s), $f$ is the working frequency of the antenna, $W$ is the optimum patch width, and $\varepsilon_r$ is the dielectric constant/relative permittivity (4.4).

The physical length of the microstrip antenna can be determined by the equation (3), (4), and (5).

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}, \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{\frac{1}{1+12\frac{h}{W}}}, \quad (4)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L, \quad (5)$$

Where $\Delta L$ is the length increase of L due to fringing effect, $h$ is the thickness of the substrate, and $\varepsilon_{reff}$ is $\varepsilon_r$ effective. By using equations (1) through (5) above, obtaining the antenna patch dimension for the initial frequency 2.3 GHz and 3.5 GHz is 40 mm x 30 mm.

### *3.2. Feeder line design*

The feeder line used in this design is expected to have an input impedance of 50 Ω. The dimension of the feeder line is calculated using the equation (6) – (9).

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}}, \quad (6)$$

$$w = \frac{2h}{\pi}\left\{B - 1 - ln(2B-1) + \frac{\varepsilon_r-1}{2\varepsilon_r}\left(ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right)\right\}, \quad (7)$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon eff}}, \quad (8)$$

$$l = \frac{\lambda_g}{4}, \quad (9)$$

Where $Z_o$ is the input impedance (50 Ω), $\varepsilon_r = 4.4$, $h$ is the thickness of the substrate (1.6 mm), $w$ is the width of the feeder, and $l$ is the length of the feeder. With the set parameter values, obtained the initial size of feeder line is initial 3 mm x 16.24 mm.

### *3.3. Dimension of groundplane*

The minimum dimension of the required groundplane of the microscope antenna is obtained by equations (10).

$$W_g = 6h + a, \quad (10)$$

Where $W_g$ is width groundplane, $h$ is the substrate thickness, and a is the length of the feeder line plus the width of the patch dimension. With the value of existing parameters, getting the dimension of groundplane is 60 mm x 60 mm.

## 4. Simulation and realization of antenna

Based on existing parameters and measurements that have been calculated.

### *4.1. Simulation results*

*4.1.1. Antenna dimension.* Simulation and optimization is done to generate the working frequency 3.5 GHz besides 2.3 GHz as well as to obtain the value of the specified parameter. Through several simulations, the targeted parameters are reached for the frequency 2.3 GHz and 3.5 GHz with antenna dimensions as shown in Figure 2.

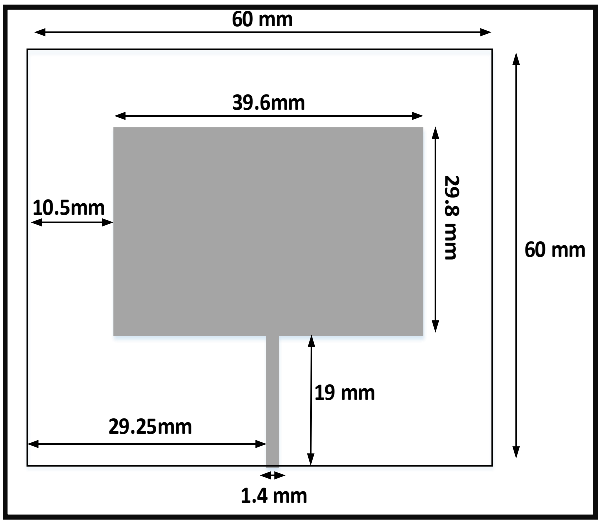


**Figure 2.** Dual-band rectangular microstrip patch antenna.

*4.1.2. Return loss.* The return loss graph and the resonant frequency of the rectangular microstrip antenna are shown in Figure 3.

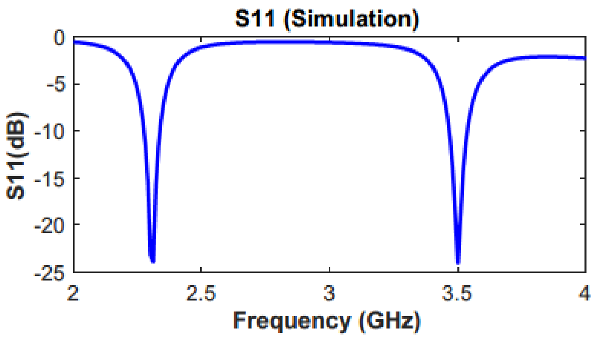


**Figure 3.** The return loss graph (simulation results).

The return loss graph in Figure 3 shows that the resonance frequency or working frequency obtained meet the desired working frequency, that is at the frequency 2.3 GHz (LTE) and 3.5 GHz (BWA). Based on simulation, at frequency 2.3 GHz obtained return loss of -23.1025 dB, and bandwidth of 60 MHz. while at frequency 3.5 GHz, obtained return loss of -24.0074 dB, and bandwidth of 70 MHz.

*4.1.3. Voltage Standing Wave Ratio (VSWR).* Patch dimension and feeder line is matching if VSWR ≤ 2. Figure 4 shows the VSWR graphs from the simulation.

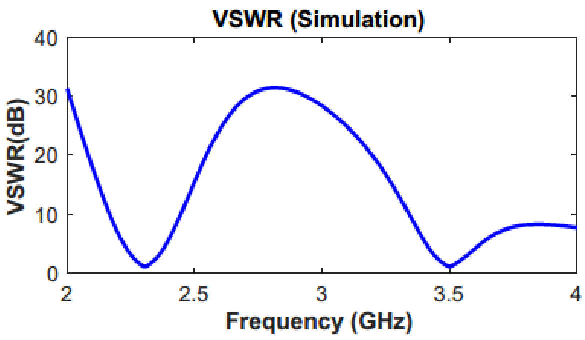


**Figure 4.** VSWR (simulation results).

Simulation results show that at the frequency 2.3 GHz obtained VSWR of 1.15046, and at the frequency 3.5 GHz obtained VSWR of 1.13457. With the achievement of these values, the antenna can be said already matching.

*4.1.4. Gain.* After several simulations and optimizations, gain is obtained at the frequency 2.3 GHz and 3.5 GHz which reaches the set target. Figure 5 and Figure 6 show the 3D radiation pattern and the gain for frequency 2.3 GHz and frequency 3.5 GHz.

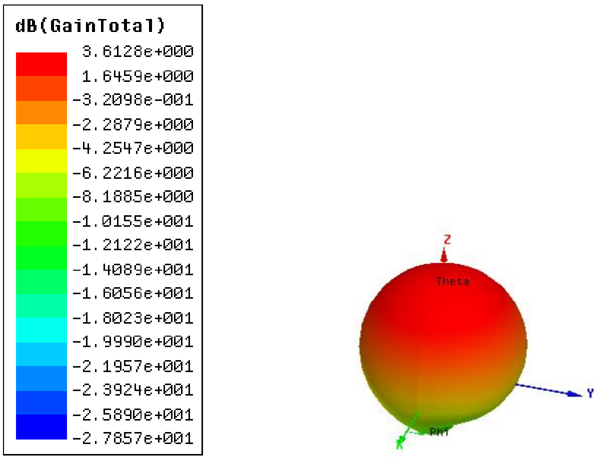


**Figure 5.** 3D radiation pattern and gain value at frequency of 2.3 GHz.

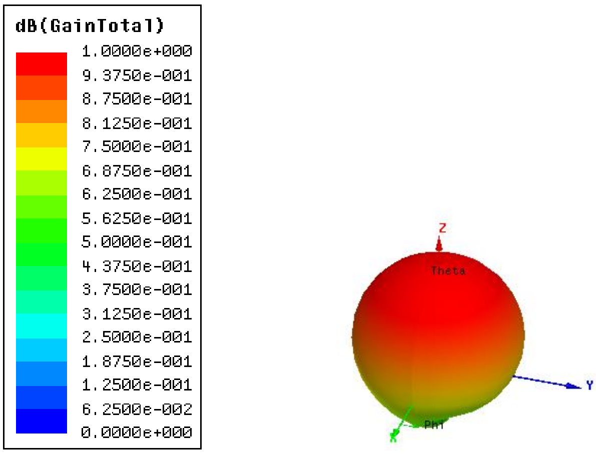


**Figure 6.** 3D radiation pattern and gain value at frequency of 3.5 GHz.

The desired gain in this study is the optimum gain on a single patch microstrip antenna using rectangular patch. Based on the graphic plot of the results of simulation, obtained a gain that is 3.612 dB at frequency of 2.3 GHz and 1.00 dB at the frequency of 3.5 GHz.

*4.1.5. Radiation pattern and impedance.* The desired radiation pattern is directional, as shown in Figure 5 and Figure 6. The result of impedance simulation can be seen in Figure 7.

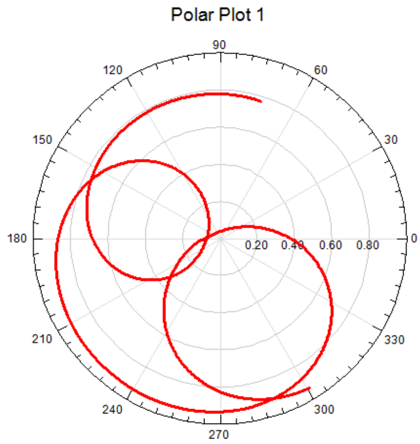


**Figure 7.** Impedance (simulation results).

### *4.2. Realization of antenna*

The antenna is printed using an FR4 epoxy substrate with a thickness of 1.6 mm and a dielectric permittivity of 4.4. The connectors used are SMA female with impedance of 50 ohm. Results of antenna realization can be seen in Figure 8.

**Figure 8.** The antenna realization looked ahead (patch) and looked back (ground plane).

## 5. Testing and analysis

Testing is done using Vector Network Analyzer. The main parameters measured are VSWR, return loss (S11), Impedance, and Gain. VSWR, Return Loss, and input impedance are parameter that indicates the suitability of an antenna to its transmission line so that it affects the received power.

### *5.1. VSWR (Realization)*

VSWR measurements are performed in the frequency range 2-4 GHz. The result of VSWR measurement of realized antenna is shown in Figure 9.

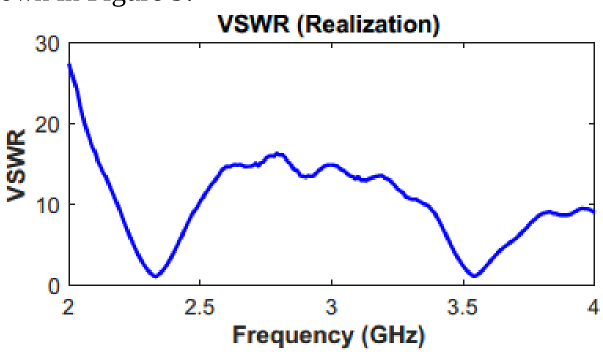


**Figure 9.** VSWR (realization).

Based on the measurement it can be seen that the VSWR value for the 2.3 GHz frequency is 1.07 and for the 3.5 GHz frequency is 1.33. VSWR value is close to 1 which is the ideal value, because at that moment the power received by the antenna reaches maximum power. The occurrence of VSWR differences in any frequency range that can be caused by several things, among others, the interference of reflected free waves in the air.

### *5.2. Return loss*

The return loss graph (S11) and the resonant frequency of the dual-band rectangular microstrip patch antenna are shown in Figure 10.

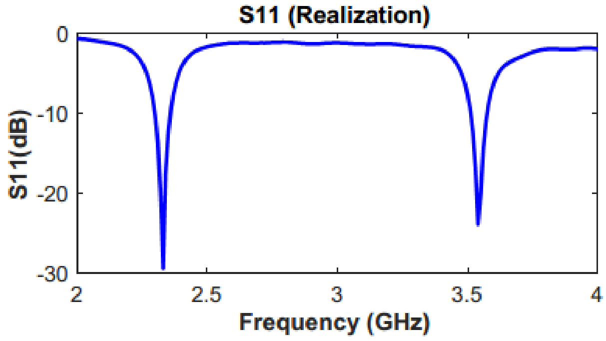


**Figure 10.** Return loss (realization).

Return loss at 2.3 GHz frequency is -20.00 dB and at a 3.5 GHz frequency is -16.90 dB. This result is already qualified return loss with value ≤-10 dB. The change in return loss is strongly influenced by the change in VSWR value. The smaller the VSWR value leads to the decrease of the reflective point on the return loss. In other words, if the value of VSWR is ideal, it will cause an ideal return loss as well.

### *5.3. Impedance*

The data reading in smith-chart mode can be seen from the measurement of input impedance in the frequency range between 2 - 4 GHz as shown in Figure 11.

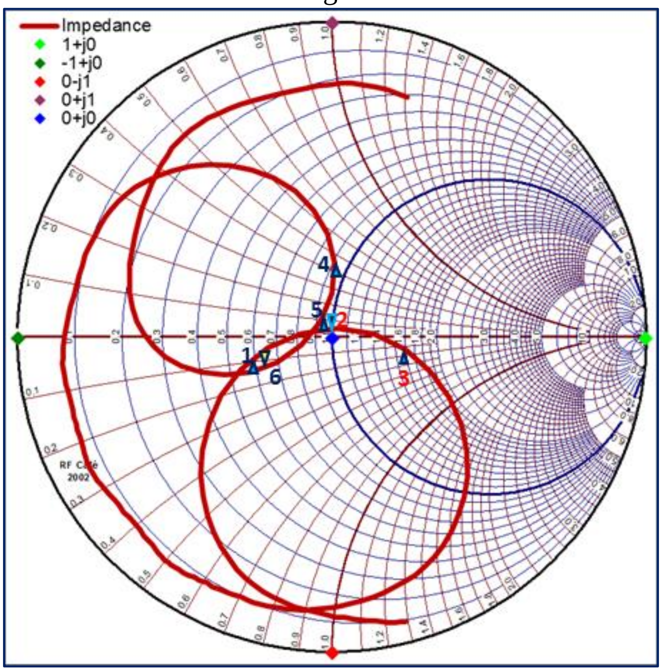


**Figure 11.** The Impedance (realization results).

| | | | | |
|---|---|---|---|---|
| MKR01 | 2.302 GHz | 28.463 Ω | -5.044 Ω | 13.702 pF |
| MKR02 | 2.327 GHz | 48.651 Ω | 2.561 Ω | 175.189 pH |
| MKR03 | 2.353 GHz | 85.175 Ω | -11.733 Ω | 5.762 pF |
| MKR04 | 3.517 GHz | 43.803 Ω | 24.662 Ω | 1.11 nH |
| MKR05 | 3.540 GHz | 46.258 Ω | 4.897 Ω | 220.204 pH |
| MKR06 | 3.567 GHz | 30.228 Ω | -6.531 Ω | 6.830 pF |

**Figure 11.** Cont.

The antenna input impedance is expressed in complex forms, there are real parts and imaginary parts. The real part is an input resistance that states the power radiated by an antenna in a far fields. While the imaginary part is an input reactance that states the power stored in the near fields of the antenna.

The result of the smith chart above shows that the dual-band rectangular microstrip patch antenna at 2.3 GHz frequency has an input impedance of 48,651+ j2.561Ω and at 3.5 GHz frequency is 46.258 + j4.897Ω. The impedance is close to 50Ω. As a result, the input impedance has an effect on the VSWR value. This is because if the microstrip antenna is connected to a transmission line having a characteristic impedance of 50Ω, so it will generate a reflected wave.

### *5.4. Comparative analysis*

If we compare parameter values of VSWR and S11 between simulation and realization there are differences in values of these parameters.

The values of VSWR on the measurement is better than the simulation results and the return loss value while the simulation results are better than the measurement results, this is due to several things as follows:

- Radiation of emitted signals is very sensitive to the surrounding environment, because the signal will be attenuated in the free space and reflected or absorbed by objects in the room. In addition, the materials used also affect the transmission power.
- Reflecting waves which are large enough, as a result of objects around the measurement site.
- There is a possibility that the dielectric constants value is less precise.

The simulation results show a better impedance than the measurement result. This is because the large input impedance is affected by the value of VSWR.

## 6. Conclusions

Proper settings of antenna dimensions, both patch dimensions and feeder line dimensions, can generate the desired working frequency, and generate ideal parameters, albeit a simple antenna shape. The proposed antenna has achieved an ideal parameter value with a patch size of 39.6 mm x 29.8 mm, the size of the feeder line is 19 mm x 1.4 mm, and the size of the groundplane is 60 mm x 60 mm. With these measures, obtained value VSWR at frequency 2.3 GHz is 1.07 and at frequency 3.5 GHz is 1.33, return loss at frequency 2.3 GHz is 20.00 dB and at frequency 3.5 GHz is -16.90 dB with directional radiation pattern.

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