A Study on Different Slot Position for Designing Dual Band Microstrip Antenna for 5G Wireless Communication

N A M Nasir¹, H Ja’afar¹,²*, H Baba¹, N H A Aziz¹

¹Antenna Research Center (ARC), Faculty of Electrical Engineering, Universiti Teknologi MARA, Selangor, Malaysia.
²Faculty of Electrical Engineering, Universiti Teknologi MARA, Terengganu Branch, 23000 Dungun, Terengganu, Malaysia.

*Corresponding author: hajar_3112@yahoo.com.my

Abstract. In this paper, four antenna designs with different slot positions for dual band frequencies are analysed. A reference antenna operating at 8 GHz is used at a dimension of 30 mm² using Rogers RT58880 as the substrate with a dielectric constant of 2.2. Two slots are etched in order to produce a dual band. The antenna resonates at 8 GHz and 15 GHz. Return loss at 8 GHz and 15 GHz are -17.03 dB and -21.37 dB with gain at 7.39 dB at 8 GHz. By using CST Microwave Software, the simulated results are obtained. The slotted antenna produces a dual band antenna that is a suitable candidate for 5G wireless communication tool.

1. Introduction

As 4G has been globally implemented alongside the growth of world population, the need for better quality of life through upgraded and enhanced technology has created a demand that 5G is capable of exceeding. With new emerging ideas of improving people’s life, scientists are struggling with the new era challenges that push people to move towards the beyond. With rapid technological progress, the global market has invented a strong desire for businesses to create scientific breakthroughs in nanotechnology that can be utilized in everyday life as well as modern infrastructure usage [1].

Among all antenna types, this research uses microstrip antennas for its advantages and it is widely used for wireless communication because of its uncomplicated design and affordable in terms of the materials used. The basic microstrip patch antenna (MPA) consists of a radiating patch usually made out of copper, a substrate, a ground and its impedance matching are matched at 50 Ω.

Dual band antennas are preferred to wideband antenna for its higher efficiency. Various techniques have been applied to achieve dual band antennas such as coplanar waveguide [2], metamaterials [3] and multi-layered [4] structures but these techniques require a lot of time and is complex to design, hence creating slots on the radiating patch is preferable because its low-complexity in design [5].

In this research, slot positions are studied to determine which position produces suitable results. Double slots are etched in order to produce dual band frequency [6]. Based from R. Parikh findings, arranging the slots into different positions are studied in order to produce multiband frequencies [7]. The antenna is made out of copper as the radiating patch with thickness of 0.035 mm. The area of the antenna is W×L=30 mm² by using Rogers RT58880 with a dielectric constant of 2.2 with thickness of 1.575 mm². The antenna is designed to work at 8 GHz and 15 GHz suitable for 5G wireless technology.
2. Methodology

The antenna is designed to produce 8 GHz and 15 GHz. The following formulas are used to determine the antenna’s dimension.

\[ W_p = \frac{v_0}{2f_r} \sqrt{\frac{2}{\varepsilon + 1}} \]  

(1)

The length of the patch is calculated

\[ L = L_{eff} - 2\Delta L \]  

(2)

The effective length, \( L_{eff} \) calculated by using this formula

\[ L_{eff} = \frac{v_0}{2f_r\sqrt{\varepsilon_{eff}}} \]  

(3)

\[ \Delta L = 0.412h \left( \frac{(\varepsilon_{eff} + 0.3)(W/h + 0.264)}{(\varepsilon_{eff} - 0.258)(W/h + 0.8)} \right) \]  

(4)

To calculate the effective dielectric constant \( \varepsilon_{eff} \)

\[ \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \]  

(5)

Calculations are made and is optimised. The results are tabulated in table 1 as a reference.

| Parameter                              | Value (mm) |
|----------------------------------------|------------|
| Length of patch, \( W_p \)            | 15.5       |
| Width of patch, \( L_p \)             | 11.6       |
| Length of substrate, \( W_s \)        | 30.0       |
| Width of substrate, \( L_s \)         | 30.0       |
| Length of feed line, \( l_f \)        | 6.25       |
| Width of feed line, \( w_f \)         | 4.60       |
| Width of half quarter wave port, \( w_q \) | 0.47   |
| Length of half quarter wave port, \( l_q \) | 1.59 |
| Length of slot                         | 6.5        |
| Width of slot                          | 0.4        |

The proposed antenna is designed and simulated using Computer Simulation Technology (CST) Microwave Software. The dimension of the antenna is \( W_p \times L_p = 30 \text{ mm}^2 \) by using Rogers RT58880 with a dielectric constant of 2.2 with thickness of 1.575 mm\(^2\). The ground dimension is the same as the substrate of 30 x 30 mm using copper with thickness of 0.035 mm. The width of feedline, \( w_f \) and length of feedline, \( l_f \) are 4.6 mm x 6.25 mm respectively. 50 Ω matching is achieved by using quarter waveguide feedline with a dimension of \( w_q \) and \( l_q \) of 0.468 mm x 1.59 mm. Figure 1 show the antenna reference without slot.
3. Results and Discussions
Four antennas are designed and simulated using Computer Simulation Technology (CST) Microwave Software. All four designs, slots are etched on different positions to study the relationship between the slot positions on the radiating patch. The slot dimension is determined by optimization with width and length, 6.5 mm x 0.4 mm. Two slots are etched in order to create dual-band frequency. The designs of the antennas are shown below.
3.1. Antenna Performances

As shown on the graph above, Design [a] and [d] resonates at 8 GHz and 15 GHz with return losses both below -10 dB. For Design [b] and [c], both designs do not produce dual band frequencies, hence they are not preferred unlike Design [a] and [d].

| Simulated Antenna | Frequency (GHz) | Return loss (dB) | Bandwidth (MHz) |
|-------------------|----------------|-----------------|-----------------|
| Design [a]        | 8              | -17.03          | 366             |
|                   | 15             | -21.37          | 546             |
| Design [b]        | 8              | -24             | 380             |
| Design [c]        | 8              | -25             | 394             |
| Design [d]        | 8              | -10.0           | 192             |
|                   | 15             | -11.0           | 517             |

3.2. Surface current and gain

Further study on the antenna’s surface current and gain to determine which design has better results in terms of slot positions.
Table 3. Surface current density and gain at 8 GHz of simulated results

| Simulated antenna | Surface current distribution at 8 GHz | Gain at 8 GHz (dB) |
|-------------------|-------------------------------------|-------------------|
| [a]               | ![Image]                           | 7.39              |
| [b]               | ![Image]                           | 7.58              |
| [c]               | ![Image]                           | 7.46              |
| [d]               | ![Image]                           | 7.57              |

The results show that the slot shows that the current is more concentrated on the sides of the antenna patch compared to the other edge of the antenna. With the presence of the slots etched on the radiating patch, it helps to control the current distribution. Design [a] has the lowest gain at 8 GHz compared to order designs. Improving the gain by adding stubs will help to increase the gain.

4. Conclusion
An antenna that operates at 8 GHz and 15 GHz is achieved by etching slots on the radiating patch. Different slot positions give out different results that determines whether it is best suited for better performances. Positioning the slots at the antenna sides will allow current to concentrate at the edge of the antenna for better current distribution. Design a is preferred for its return loss both at 8 GHz and 15 GHz (-17.03, -21.37) dB respectively, as well for its gain at 8 GHz at 7.39 dB. Further investigation will be appreciated in order to improve the antenna performances in terms of return loss and gain. The antenna is suitable for 5G telecommunication applications.
ACKNOWLEDGEMENTS
The authors would like to express their gratitude to University Teknologi MARA for funding this research and to the utmost thanks to the members of Antenna Research Centre (ARC), Faculty of Electrical Engineering, Universiti Teknologi MARA for their shared knowledge and guidance.

References
[1] J. G. Andrews et al. 2020 What Will 5G Be? 32(6) 1065-1082
[2] T. Hariyadi 2013 A Coplanar Waveguide (CPW) Wideband Octagonal Microstrip Antenna Int. Conf. of Inf. and Comm. Techn. (Indonesia) 340-343.
[3] S. Al Nahiyan, A. R. Salehin, G. M. H. Shuvho, S. M. Liaqat, and H. Sagor 2017 Dual Band Operation with Dual Radiation Pattern for Rectangular Microstrip Patch Antenna Loaded with Metamaterial IEEE Region 10 Humanitarian Technol. Conf. (R10-HTC) 21-23.
[4] H. Yon, A. H. Awang, M. T. Ali, S. Subahir, and S. N. Kamaruddin 2017 Comparative Analysis for Multilayer Stacked Substrates Microstrip Patch Antenna IEEE Asia-Pacific Conf. on App. Electromagn. (APACE) 34-37.
[5] M. Kumar 2018 Introducing Multiband and Wideband Microstrip Patch Antennas Using Fractal Geometries : Development in Last Decade Wirel. Pers. Commun. 98(2) 2079-2105.
[6] D. Lodhi, M. M. Sharma, and R. P. Yadav 2017 Analysis of Dual Band Double Slot Loaded Microstrip Patch Antenna Inter. Conf. on Comput., Commun and Elect. 286-288.
[7] Rina Parikh, Bharati Singh 2018 Effects of Slots On Resonant Frequencies of a Microstrip Patch Antenna Inter. Conf. on Comput. Commun. Contr. and Automat. (ICCUBEA).