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Multiband Microstrip Patch Antenna for LTE Application

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ABSTRACT

This paper presents a multiband patch antenna for LTE application. Conventional single band antenna only operates at one specific frequency and will require multiple single band antenna to support multiband application. Consequently, the antennas will consume more space in the microwave circuitry. The propose antenna is designed to operate at multiple LTE frequencies, which are 1.8 GHz, 2.1 GHz, and 2.6 GHz. The simulation will be done using Computer Simulation Technology (CST) Microwave Studio software and will be fabricated for further development. The simulated reflection coefficient (S11) results for the proposed design are -14 dB, -23 dB and -18 dB while the measurement results are -13 dB, -16 dB and -16 dB. Both results are simulated and measured at 1.8 GHz, 2.1 GHz, and 2.6 GHz respectively.

Keywords: Antenna, LTE, Microstrip, Multiband, Patch

1. INTRODUCTION

The advancement in communication technologies and higher demand from customers for a better and faster mobile technology has bring a huge challenge for engineers and researchers to rapidly enhance and upgrade the mobile technology in order to fullfill the demand to be fully utilised by the customers. The Fourth Generation (4G), also known as Long Term Evolution (LTE) has successfully used worldwide since the second quarter of 2015 where it covers 744 million subscriptions [1]. During this year, there are several Malaysia'a major mobile operators already started to invest into the LTE. Maxis Berhad was the earliest mobile operator that has introduced LTE service as early as January 2013. This step has triggered its competitors such as Celcom Axiata Berhad and Digi Telecommunications Sdn. Bhd. to introduce LTE in April and July respectively in the same year. Others followed afterwards such as YES-YTL and Unifi, formerly known as Packet One (P1)[2].

As a consequence, prior to the advancement, some electronic communication components such as Base Station (BS) require major upgrade to be compatible with the frequency of LTE service. Antenna is one of the most important components in transmitting and receiving the signal and used in either in BS or in mobile devices. Commonly, a compact antenna is designed to be integrated with smaller mobile or any handheld telecommunication devices for supporting the latest wireless technology such as LTE [3]. This requires antenna engineers to design multiband antenna that are much more compact than the conventional antenna and at the same time is able to operate at multiple LTE frequency bands [4]. Malaysia has introduced 3 frequencies for LTE such as 0.8 GHz, 1.8 GHz, and 2.6 GHz [2].

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Moreover, current communication devices are getting smaller and compact in size. Hence, antenna needs to be smaller and able to operate in multi bands frequency so that the mobile device can handle more than one LTE frequency when they move from micro cell to the small cell or vice versa. This requires a multiband antenna that can fit and place inside a smartphone device and can perform well using multiple LTE band. Microstrip patch antenna is one type of antennas that easy to fabricate, low profile, lightweight, cheap, and smaller in size [5]-[6]. Current research studies show that there are lot of works on smaller antenna design for multiband frequency. Several techniques or methods can be applied on the radiator metal part of the antenna since this part contribute to the surface current of the antenna and produce electromagnetic radiation.

One of the solutions is to use microstrip antenna since it has widely used for many wireless application [7]. With microstrip technology, multiband can be made possible in a small dimension with ease for fabrication [8]. Hence, this paper investigates and design compact multiband antenna to be used in LTE frequency band in Malaysia. Other than that, several considerations are added such as size of microwave circuitry, cost, and ease for usability as the technologies are moving towards smaller electrical component [5]

2. ANTENNA STRUCTURE

The design of the structure starts with the shape of a quarter-wavelength radiator antenna which then connected to the transmission line as shown in Figure 1 where it shows the front radiator part of the antenna. The white region and yellow region represent the FR4 substrate and the radiating element, respectively.

Radiator dimension is calculated according to the operating frequency wavelength and type of the substrate used based from theory. Theoretically, the antenna size is directly associated to the wavelength of the required frequency and material.

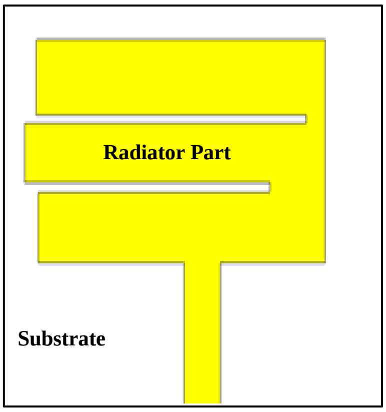
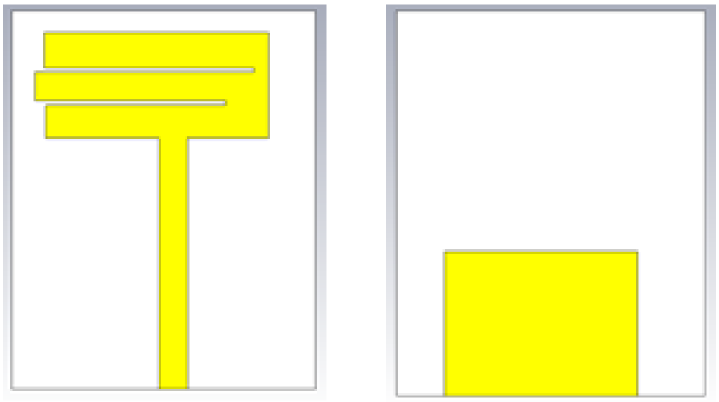


Figure 1. Front radiator

Figure 2(a) shows the front view of the antenna consists of the substrate, feedline, and radiator while in Figure 2(b) shows the rear view of the antenna showing substrate and ground structure.



(a) Front View (b) Back View

Figure 2. (a)Front and (b) back view of the simulated antenna

The formulas such as length, width, dielectric effective value, and effective length for the microstrip patch antenna are based in [9]-[10]. The dimension of microstrip patch antenna can be calculated using the following equations.

Calculation of the width (W) of the microstrip patch antenna is as Equation 2.1:

$$W = \frac{c}{f_o\left(\sqrt{\frac{\varepsilon_r + 1}{2}}\right)} \tag{2.1}$$

where, c is the speed of light which is $3 \times 10^8 \mathrm{ms}^{-1}$, f_o is the resonant frequency and ε_r is the dielectric constant. The effective dielectric value, ε_{eff} is calculated as in Equation 2.2:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 2}{2}\left(1 + \frac{1}{\sqrt{1 + 12\frac{h}{w}}}\right) \tag{2.2}$$

where h is the thickness of the antenna substrate, and in this paper, the thickness is equivalent to the thickness of FR4. The extension of patch length, ΔL and the length of the radiator, L are calculated using Equation 2.3 and 2.4:

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\left(\frac{w}{h}\right) + 0.8\right)}\right] \tag{2.3}$$

$$L = L_{eff} - 2\Delta L \tag{2.4}$$

Lastly, the length, L_g and the width, W_g for the ground plane dimension are calculated. The ground plane length and width dimensions are more than the patch length, L and width, W in that order by six times thickness or height of the patch. These can be calculated by using Equation 2.5 and 2.6:

$$L_g = L + 6h \tag{2.5}$$

$$W_g = w + 6h \tag{2.6}$$

The proposed antenna is designed using FR4 substrate with the dielectric constant, ε_r = 4.3, thickness of 1.6 mm and loss tangent of 0.025. Figure 3 and 4 show the proposed dimension according to the desired frequency which are 1.8 GHz, 2.1 GHz and 2.6 GHz. The dimensions are further tabulated in Table 1. Two common materials in antenna simulation and fabrication were used in this design, which are copper and FR4.

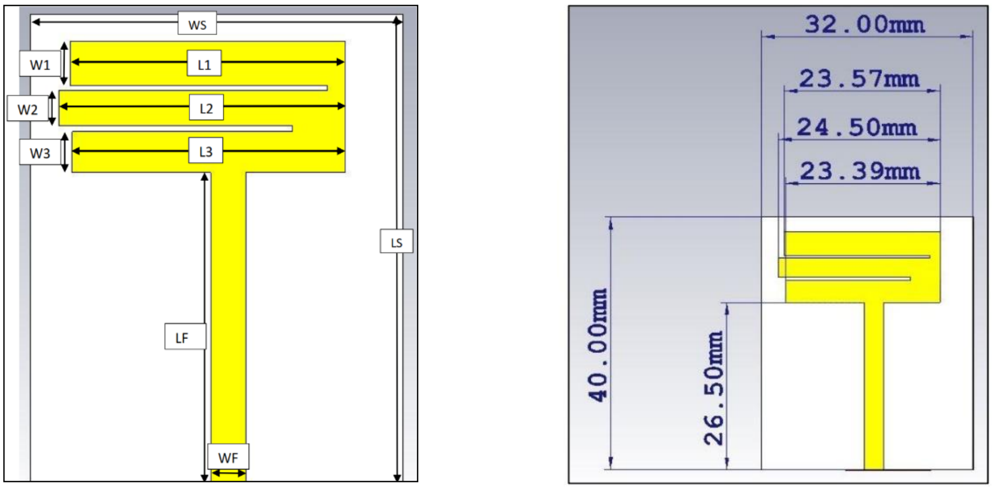


Figure 3. Dimension of front view elements

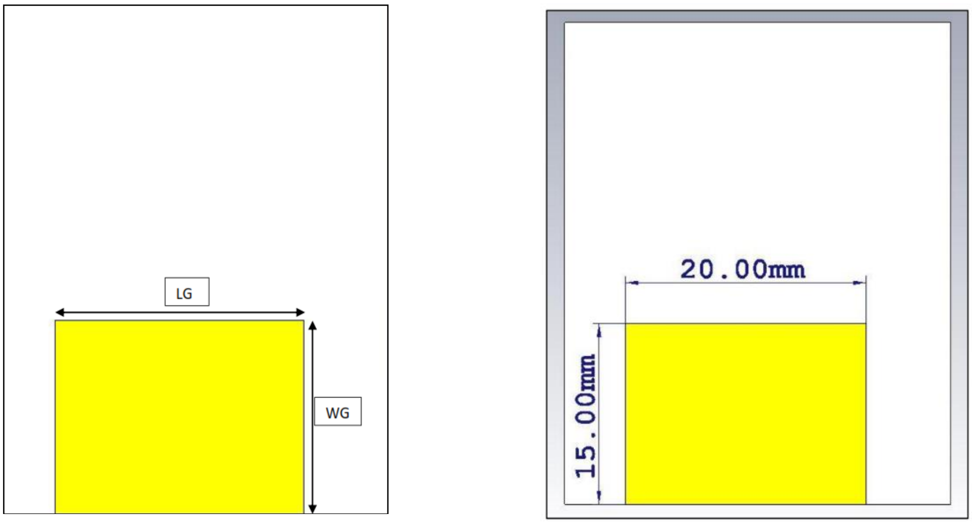


Figure 4. Dimension of back view element

Table 1 Antenna Dimension

Parameter	Value (mm)
WS	32.00
LS	40.00
W1	3.80
W2	3.00
W3	3.50
L1	23.57
L2	24.50
L3	23.39
LF	26.50
WF	3.00
LG	20.00
WG	15.00

3. SIMULATION, PROTOTYPE FABRICATION AND MEASUREMENT

3.1 Antenna Simulation

The simulated reflection coefficient S11 as in Figure 5 at resonant frequencies of 1.8, 2.1 and 2.6 GHz are -14 dB, -23 dB and -18 dB respectively, and it shows a good S11 magnitude value. The resonant frequency meets the requirement of the design which that the reflection coefficient need to be equal, or better, less than -10 dB. The simulation bandwidth also meets the bandwidth requirement for the frequency which is 40 MHz. The bandwidth that is more than 40 MHz is enough to cover the multi frequency range of the LTE specified. Figure 6 shows the impedance matching and Voltage Standing Wave Ratio (VSWR) at the respective resonant frequency. The impedance at resonant is between 49 to 50 Ω at resonant frequency 1.7 GHz, 2.1 GHz and 2.6 GHz respectively. To get the good impedance matching, the value should close to 50 Ω in an ideal case where the maximum power will be transferred [11]. The VSWR for the desired resonant frequencies are 1.5, 1.0 and 1.3, where these values are in the range of a good VSWR in antenna design which is below 2.

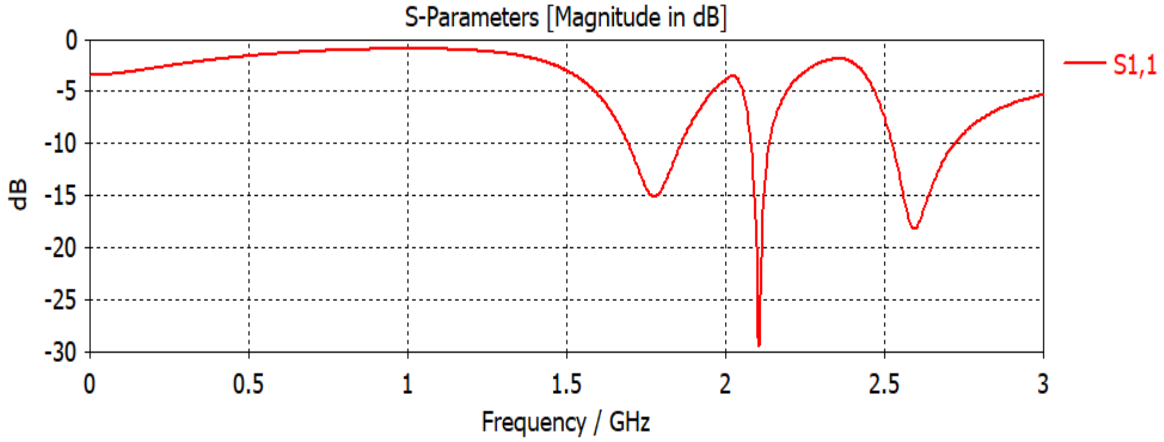
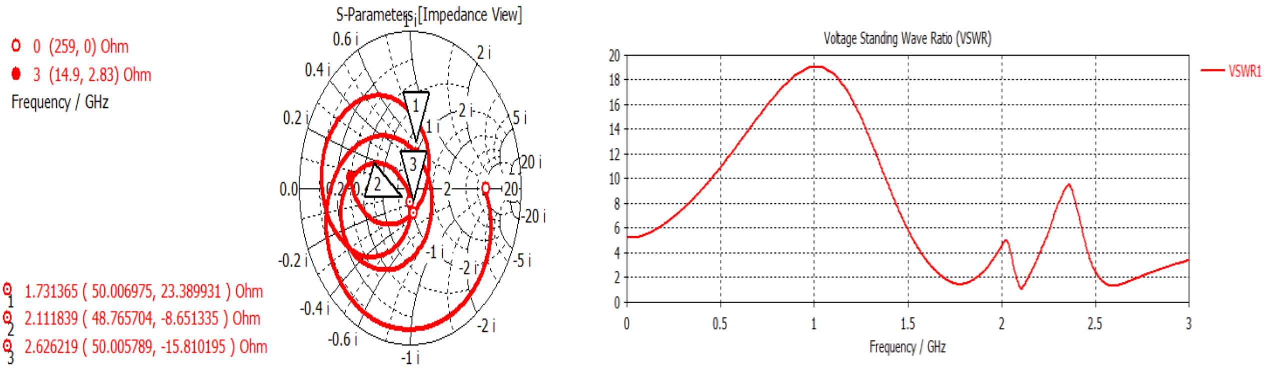


Figure 5. S11 simulation result



(a) Smith Chart (b) VSWR

Figure 6. Smith Chart impedance and VSWR from simulation

Figure 7, 8 and 9 show the simulated E-Field and H-Field radiation pattern for the frequency of 1.8 GHz, 2.1 GHz and 2.6 GHz respectively. From the radiation pattern, we can see that both antenna fields are omnidirectional.

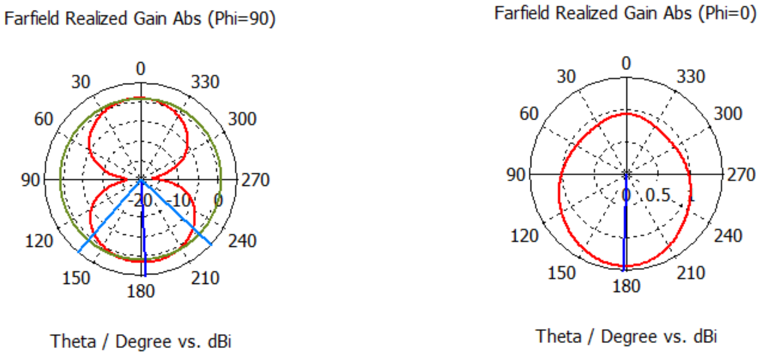


Figure 7. E-Field and H-Field Radiation pattern for 1.8GHz

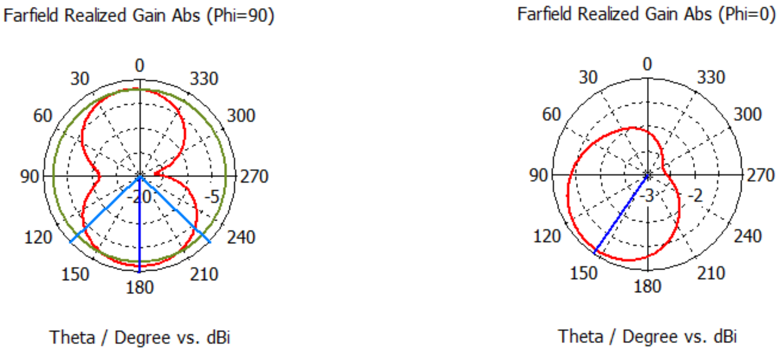


Figure 8. E-Field and H-Field Radiation pattern for 2.1 GHz

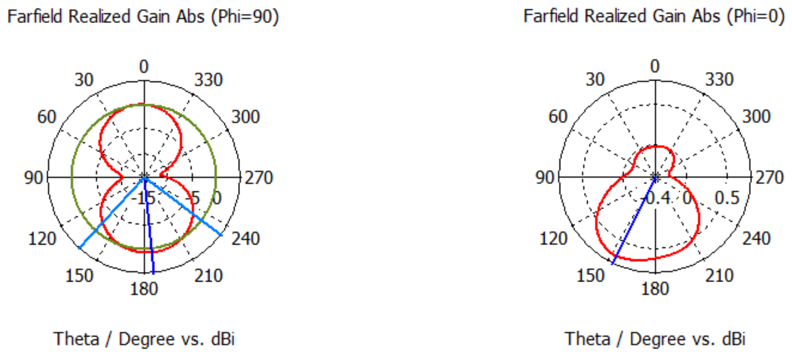
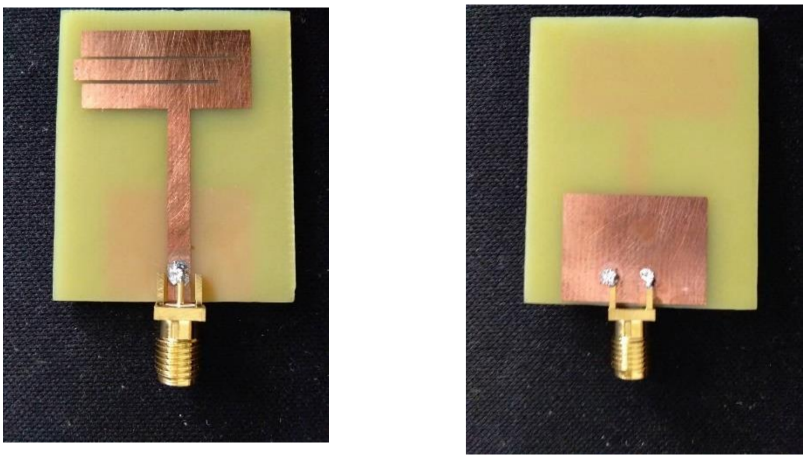


Figure 9. E-Field and H-Field Radiation pattern for 2.6 GHz

3.2 Fabrication, Measurement Process and Result

There are three main stages in the fabrication process. The stages consist of UV exposure, developing and etching process. The process involves machinery and skills to be completed. Figure 10 shows the front and back view of the fabricated prototype. After the fabrication process, the antenna is measured using Vector Network Analyzer (VNA) to validate and to confirm its functioning as desired. Figure 11 shows the S11 comparison between the simulation and the prototype measurement.



(a) Front view (b) Back view

Figure 10. (a) Front view and (b) back view of the fabricated antenna

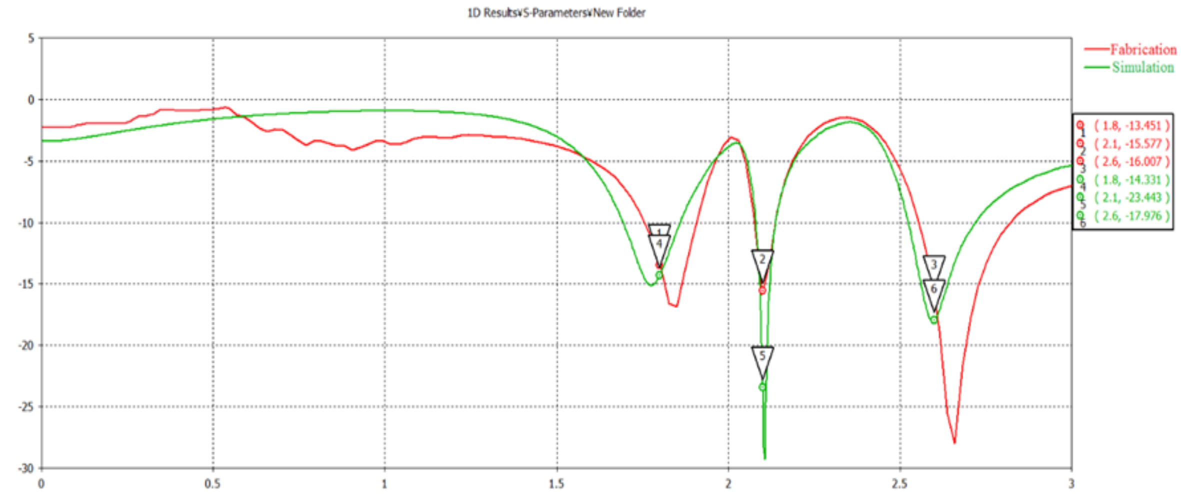


Figure 11. Comparison between simulation and measurement result

Based on the results in Table 2, the readings between simulation and measurement results were slightly inconsistent. In addition, the difference between the results may contributed from several factors such as the in-lab fabrication process, difference in FR4 dielectric constant value, poor soldering and SMA quality that contribute to the mismatch between the connector and feeding line and also the external noise or interference from existing communication devices during the measurement. However, the measurement results show a low discrepancy with the simulation results. Hence, the designed multiband antenna is shown can operate at 1.8 GHz, 2.1 GHz, and 2.6 GHz.

Table 2 The S11, Bandwidth and VSWR of the antenna

Resonant Frequency	Simulation S11 (dB)	Bandwidth (MHz)	VSWR	Measurement S11(dB)
1.8 GHz	-14	170.3	1.5	-13
2.1 GHz	-23	58.2	1.0	-16
2.6 GHz	-18	196.1	1.3	-16

The measured E-Field and H-Field radiation pattern of the antenna shows the omnidirectional shapes for three different resonant frequencies as in Figure 12 and 13 respectively.

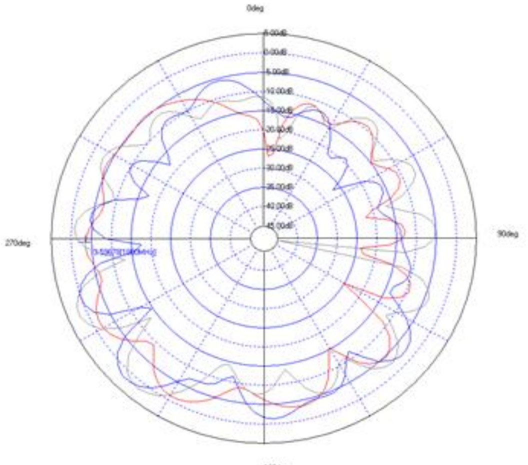


Figure 12. E-Field Radiation pattern measurement for 1.8 GHz (Red), 2.1 GHz (Green) and 2.6 GHz (Blue).

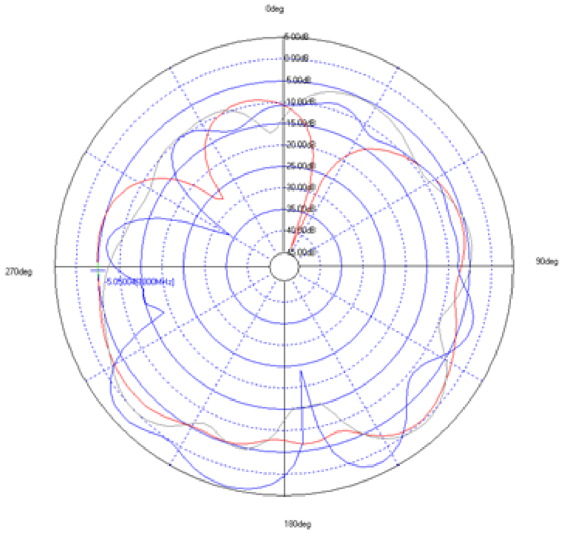


Figure 13. H-Field Radiation pattern measurement for 1.8 GHz (Red), 2.1 GHz (Green) and 2.6 GHz (Blue).

4 DISCUSSION

Subsequently, the comparison and analysis between simulation and measurement results for the microstrip patch antenna, shows that a multiband antenna can be realized with cheaper cost and can be easily fabricated using FR4 as the insulating dielectric substrate. Several microstrip patch antenna advantages also proven as the antenna was easy and cheap fabrication process, and lightweight and smaller. Several multiband antennas for LTE have been proposed by researchers using several methods such as Multiple Input Multiple Output (MIMO) [12], reconfigurable [13] and Inverted-F antenna. However, some of the methods need to consider other parameters such as isolation between ports and complicated design. Thus, the proposed design is suitable to be used since it is not a complicated design and only used 1 input port. So, there is no other external parameters need to be considered, yet this proposed antenna can perform well according to the antenna design requirements proven by the simulation and prototype measurement.

The LTE technology has made the industry to focus on their research in making the device that compatible with LTE standard and current communication technology. Moreover, the multiband frequency will solve the coverage problem where user can be directed to another carrier frequency. It is because most of the user's experiencing very bad coverage especially when they are inside a building. This multiband antenna will improve the performance of handheld devices. Telecommunication service providers only need to adopt LTE network into their main infrastructures and can offer many LTE services such as Voice Over LTE (VoLTE) and small cell Node B by using LTE frequency band of 1.8 GHz, 2.1 GHz and 2.6 GHz. The results from both simulation and measurement proved that the multiband antenna can be designed to operate in multi LTE frequencies band according to its standard.

5 CONCLUSION

Triple band antenna has been designed, simulated, and fabricated using FR4 substrate. This design can be used for LTE application that operates in 1.8 GHz, 2.1 GHz, and 2.6 GHz bands. The antenna operated at three operating frequencies of 1.8 GHz, 2.1 GHz and 2.6 GHz for simulation and the corresponding S11 simulation are -14 dB, -23 dB, -18 dB and the measurement results counterpart are -13 dB, -16 dB and -16 dB respectively. The VSWR and bandwidth are in acceptable range and radiation pattern is almost omnidirectional where this type of pattern is suitable to be used in mobile devices.

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