Multi Bands Antenna for Wireless Communication System with Slots

Evizal Abdul Kadir, Eko Supriyanto, Siti Mariyam Shamsuddin,
Tharek Abd Rahman, Sharul Kamal Abdul Rahim and Sri Listia Rosa

***Abstract*—** Rapid growing of user in mobile communication and limited of spectrum created many frequency band used by operator. This letter propose a new antenna design with slots that covered multiple bands common used in mobile communication and long-term evolutions (LTE) system. A single patch antenna operating at 2.6 GHz for LTE band was first designed and then optimization by introducing slots on antenna patch has been done to improve the antenna's bandwidth (BW). As a transmitter antenna requires high gain for effective transmission, air gap and aluminum plate are used as ground element in order to achieve high gain performance. The reflection coefficient of initially designed single patch antenna gives a single band response. However some slots and array elements are introduced into the antenna to obtain multi band response, which covers a few bands. The results obtained from reflection coefficient have shown that the proposed patch antenna is suitable in such telecommunication system applications as GSM, UMTS, LTE, WLAN and WiMAX. The result of simulation reflection coefficient is -34 dB at centre frequency 2.6 GHz and antenna gain is 8.21 dBi..

***Keywords*—** Antenna, Wireless, Microstrip, Slot.

I. Introduction

SINCE introduced of wireless technology a few decades ago, wireless devices are now commonly used in communication systems, medical and industrial applications, games console, to mention a few. In telecommunication systems, wireless technology is commonly used especially in mobile communication. Nowadays a mobile phone is not only used for voice communication but also often used for transferring data, images and videos. Third generation (3G) technology attempts to use a mobile phone for video call and now LTE; while the fourth generation (4G) technology is expected use mobile phone as broadband media, that support high speed data rate. In order to achieve these requirements, several methods have been proposed; and one of such methods is antenna diversity and spatial multiplexing. A new high-gain antenna design for transmitter, operating at LTE band 2.6 GHz, is proposed in this letter.

In most of the previous researches, it was found that the LTE antenna was mostly used for mobile devices, such as installation in laptop, mobile phone and gadget [1-3]. A design of an antenna with spiral technique mentioned in [4] then in this proposed antenna design introduce some slots to obtain multiple bands antenna. LTE antenna techniques especially for transmitter, have been highlighted in [5]; however, the antenna gains are generally low and their radiation pattern is omni directional [6]. Wide band antenna is one of the objectives in this proposed antenna design, several method and technique to achieve wideband reflection coefficient such as mention in [7]. The proposed antenna in this study operates at LTE band and has directional radiation pattern. Directional radiation pattern and multiple bands have been introduced in order to obtain a high gain antenna.

This work was supported by Yayasan Amanah Pelalawan, Indonesia.

Evizal Abdul Kadir is with Sekolah Tinggi Teknologi Pelalawan, Jl.Maharaja Indra No. 379, Pangkalan Kerinci, 28300 Pelalawan Riau Indonesia.

Prof. Dr. Eko Supriyanto is the director of IJN-UTM Cardiovascular Engineering Centre, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia (Correspoing author phone: +6075558551-mail: eko@biomedical.utm.my).

Prof. Siti Mariyam Shamsuddin is Director of UTM Big Data Centre, Faculty of Computing, Universiti Teknologi Malaysia, 81310 Johor Malaysia e-mail : mariyam@utm.my

Prof. Dr. T.A. Rahman is the Director of Wireless Communication Centre, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Johor Malaysia

II. Antenna Design

Typically a transmitter or base station (BS) has multiple antennas for a few sectors of coverage area and high gain antennas are used for efficiency of transceiver. Thus, with the current trends in setting up base transceiver system (BTS), the microstrip antenna technique is usually employed to design a directional antenna [8]. The design of microstrip antenna was started by calculating the basic size of patch. A centre frequency of 2.6 GHz LTE band has been chosen in this design. The material used is FR4 board with following specifications: relative permittivity $\varepsilon_r = 4.7$, height h = 1.6 mm and tan δ = 0.019. The basic equation of microstrip antenna was used to calculate width (W) and length (L) of patch [8]. Figure 1 shows basic design of microstrip antenna with length and width of patch.

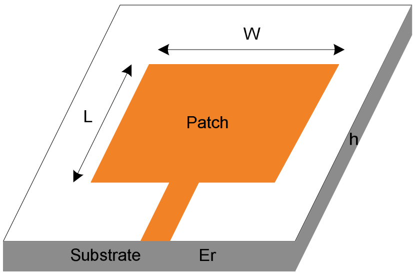


Fig. 1. Basic microstrip antenna.

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{v_0}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}} \sqrt{\mu_0 \varepsilon_0}} - 2\,\Delta L \qquad (2)$$

where:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[1 + 12 \frac{h}{W}\right]^{-1/2} \qquad (3)$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (4)$$

The size of antenna patch has been optimized done to meet reflection coefficient in LTE band 2.6 GHz. Next step is to optimize response in wideband or multiple bands that cover others frequency bands in telecommunication such as GSM, UMTS, WLAN and WiMAX. The single patch antenna design is shown in Figure 2in which slots have been introduced to achieve wideband and multiple frequency response. Note that all dimensions are in millimetre (mm).

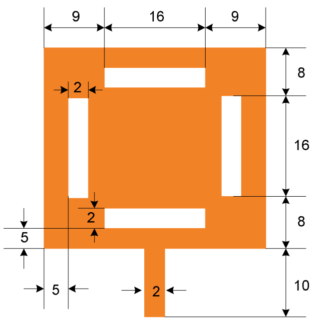


Fig. 2. Single patch antenna design with slots.

As previously mentioned, a BS requires a high gain antenna for efficient transceiver. In this design, an antenna is proposed with array patch to increase gain and which used air gap [9]. The number of patches is 4 x 4; then they are arranged and optimized to achieve optimum reflection coefficient and multiple bands response. Figure 3 shows the complete diagram of proposed antenna with array 4x4. Some transmission lines are introduced as feeding to the port at the back of antenna.

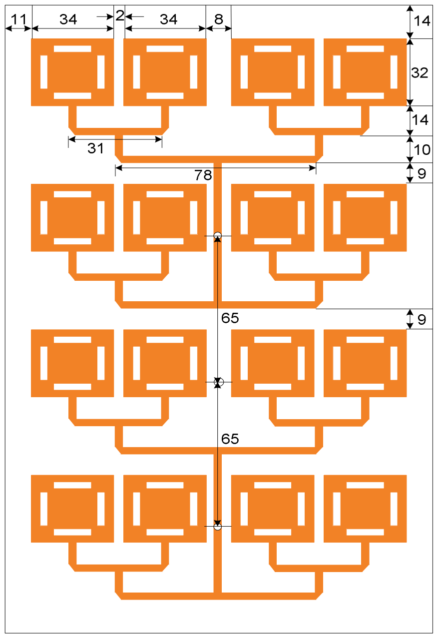
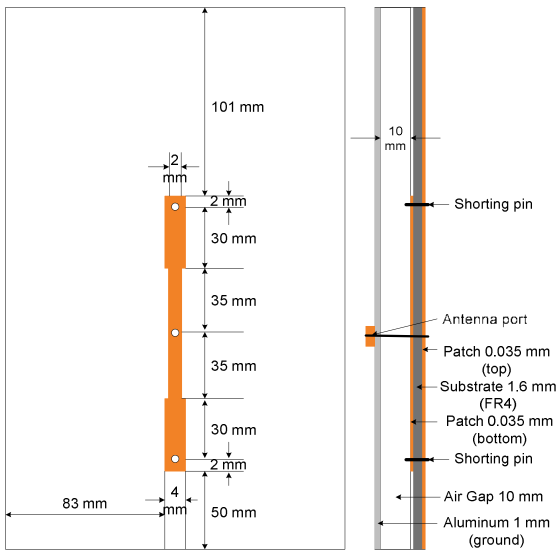


Fig. 3. Proposed high gain array antenna.
(NB: All dimensions are in mm)

The proposed antenna structure is presented in Figure 4, where Figures 4 (a) and (b) represent the feeding line of the patch's bottom layer and the used air gap between ground and antenna patch, respectively. Aluminum of 1 mm thickness was used for antenna ground, while the air gap is 10 mm to the patch antenna. The SMA bulkhead socket of 50 Ohms impedance was used for the antenna port. The typical connector was drawn and simulated by using 3D CST simulation software.

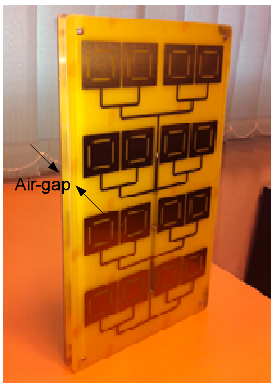


a *b*

Fig. 4. Proposed antenna structure (a) FR4 back view (b) Side view.

III. Measurement Setup

The measurement setup is aimed at testing the antenna E-field and H-field radiation patterns. Graphs are then plotted to analyze the performances. A centre frequency of 2.6 GHz was used for testing the antenna, which complies with the LTE standards. The test results obtained from the measurement would be compared with the standard requirements to ascertain the acceptability of the proposed antenna. The fabricated array antenna is shown in Figure 5 (a), while a SMA connector bulkhead type is shown in Figure 5 (b). As earlier mentioned, the connector is attached at the ground element of antenna for feeding line connection. The radiation patterns of E-field and H-field, as well as antenna gain will be performed in these measurements.



(a)

(b)

Fig. 5. Fabrications of (a) array antenna (b) ground element.

Figure 6 shows a block diagram of measurement setup of test antenna in anechoic chamber, a transmitter antenna used to send radio power to be receiving by test antenna and system will record every signal strength values. In this antenna testing, system able to perform automatically to rotate test antenna as represent angle, record and plot a radiation pattern graph in a computer.

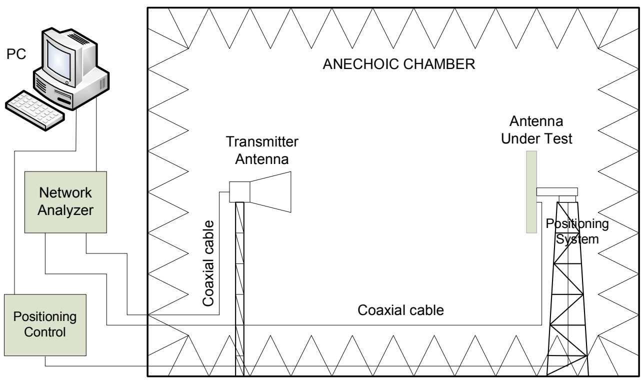


Fig. 6. Block diagram of measurement setup.

Figure 7 shows the test antenna being installed at test gauge in an anechoic chamber room. The test antenna is able to rotate in all directions. Referring to the common measurement setup, a transmitting antenna was used to transmit power to the proposed antenna, and sensitivity of the transmitted signal was recorded by the computer. The antenna performances were measured and tested in terms of both vertical and horizontal radiation patterns. Beside the radiation patterns, other antenna parameters such as gain, efficiency and impedance matching were also measured.

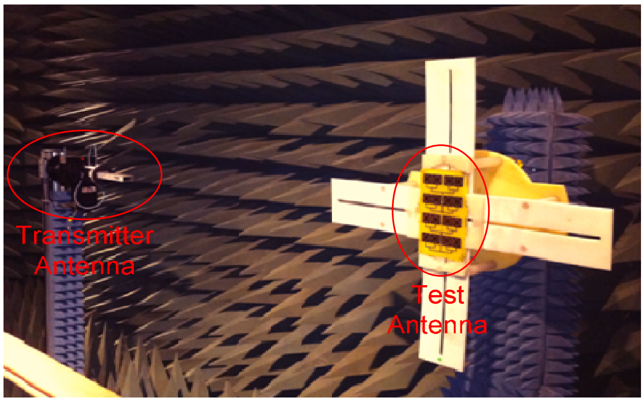


Fig. 7. Test antenna installed at test gauge in anechoic chamber room.

IV. Results and Discussion

Figure 8 shows basic simulation of single patch antenna and the results of minimum reflection coefficient. By introducing slots and air gap, a better response was obtained in terms of reflection coefficient and antenna gain. Besides, multiband response was also obtained. Some optimization exercises were performed to achieve acceptable response in reflection coefficient as required and standardized. The air gap was adjusted from 5 mm to 15 mm. 5 samples were run in the parametric study, and the optimal value of air gap (10 mm) was chosen. The slot dimensions (width and length) were also adjusted, by optimization process, and again the optimal values were obtained (slot size is 2 mm by 16 mm). Arrangement of slots location is crucial, because poor results, as in reflection coefficient and radiation pattern, would be obtained if the slots are misplaced.

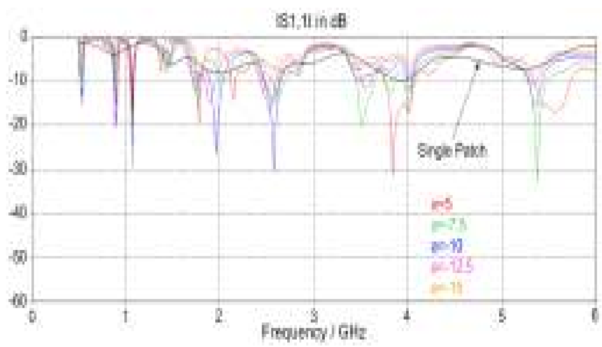


Fig. 8. The antenna array reflection coefficient.

Referring to optimization results presented in Figure 8, slots were introduced in antenna design, and the air gap between patch and ground element was 10 mm. The simulation and measurement results of the final stage of the proposed LTE transmitter antenna are shown in Figure 9. It is observed that both simulated and measured reflection coefficients are in good agreement.

Fig. 9. Proposed array antenna reflection coefficient.

Both the simulation and measurement results have multiple responses, as shown in Figure 9. The most crucial response was observed at 2.6 GHz with maximum reflection coefficient being -34 dB. Other responses are at 900 MHz, 1.7 GHz to 2.7 GHz and 3.5 GHz. The response at 2.0 GHz is wideband, which covers both GSM 1800 and UMTS 2000 bands. The 2.4 GHz band can also be included for Wi-Fi application and the last one, 3.5 GHz covers the WiMAX band and measured results are highlighted in Figure 9. According to the measurement results, the maximum value of reflection coefficient is -26 dB. Note that the main response is also at 2.6 GHz, which is the same as simulation results. Other responses are scattered to some frequencies starting from 900 MHz until 3.5 GHz as shows in Figure 9. Overall, the proposed antenna has a wideband response of reflection coefficient, which makes it suitable for a variety of wireless technology applications.

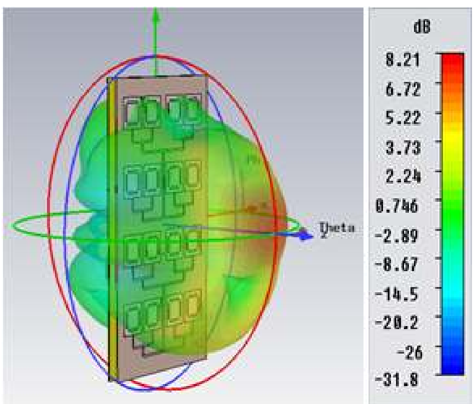
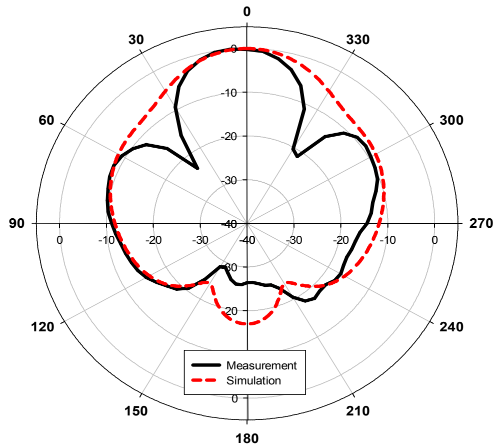


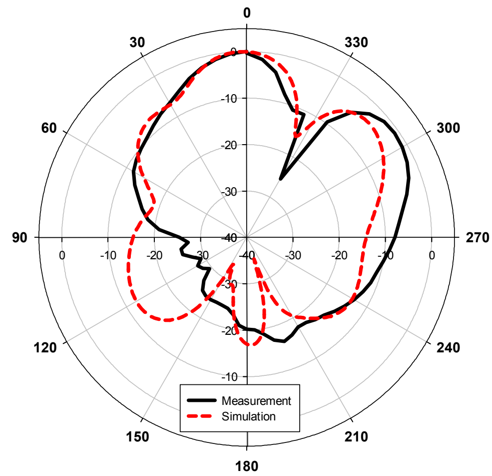
Fig. 10. Array LTE antenna radiation pattern in 3D.

The simulation results of radiation pattern in 3D are shown in Figure 10, where the beamwidth is 44º at -3 dB. The proposed antenna gain, as shown in Figure 10, is 8.21 dBi (maximum); which implies that it is applicable to use in BS due to its narrow beamwidth and high gain.

Measurements of radiation pattern have been done at the center frequency of 2.6 GHz as main response in reflection coefficient. The antenna polar radiation patterns of E-Field and H-Field are shown in Figures 11 (a) and (b) respectively. A directional beam is generated for the E-field at the antenna front, while a minor radiation was generated at the back. Both simulation and measurement results are in good agreement, though with minor shifting in the radiations. The proposed LTE antenna is able to radiate narrow beams forward with narrow beam and minor side lobe on left and right hand sides respectively.



(a)



(b)

Fig. 11. Proposed antenna radiation patterns
(a) E-field (b) H-field.

V. Conclusion

A high gain antenna has been designed and measured in multiple bands for wireless communication system, especially for telecommunication in LTE band. The proposed antenna was simulated and fabricated using the standard FR4 material. The main response was observed at 2.6 GHz LTE band, with the maximum response being -34 dB. Other responses were also observed at GSM, UMTS, WLAN and WiMAX bands. The antenna also gives a wideband response from 1.7 GHz to 2.7 GHz while the reference of reflection coefficient is -6 dB. The antenna's radiation pattern has been measured in anechoic chamber, and both the simulation and measurement results are in good agreement. Overall, the proposed antenna is suitable for a transmitter due to its narrow beamwidth and high gain antenna.

Acknowledgment

Author would like to thank to Yayasan Amanah Pelalawan, Indonesia for the supporting this research.

References

[1] L. Jaejin, *et al.*, "Miniature Long-Term Evolution (LTE) MIMO Ferrite Antenna," *Antennas and Wireless Propagation Letters, IEEE,* vol. 10, pp. 603-606, 2011.

[2] R. Yu-Jiun, "Ceramic Based Small LTE MIMO Handset Antenna," *Antennas and Propagation, IEEE Transactions on,* vol. 61, pp. 934-938, 2013.

[3] C. Yonghun, *et al.*, "Quad-Band Monopole Antenna Including LTE 700 MHz With Magneto-Dielectric Material," *Antennas and Wireless Propagation Letters, IEEE,* vol. 11, pp. 137-140, 2012.

[4] K.-C. H. a. H.-S. K. Han-Byul Kim, "Cavity-backed Two-arm Spiral Antenna with a Ring-shaped Absorber for Partial Discharge Diagnosis," *Journal of Electrical Engineering & Technology,* vol. Vol.8, pp. 856-862, 2013.

[5] Y. Jie-Bang and J. T. Bernhard, "Design of a MIMO Dielectric Resonator Antenna for LTE Femtocell Base Stations," *Antennas and Propagation, IEEE Transactions on,* vol. 60, pp. 438-444, 2012.

[6] M. S. Sharawi, *et al.*, "Four-shaped 2 3 2 multi-standard compact multiple-input-multiple-output antenna system for long-term evolution mobile handsets," *Microwaves, Antennas & Propagation, IET,* vol. 6, pp. 685-696, 2012.

[7] S. J. a. C.-H. Ahn, "Resistive and Inductive Loading Techniques on Microstrip Antenna for Wideband Application," *Journal of Electrical Engineering & Technology,* vol. Vol.6, pp. 693-696, 2011.

[8] C. A. Balanis, *Antenna Theory: Analysis and Design*: John Wiley & Sons, 2005.

[9] M. I. Sabran, *et al.*, "A Dual-Band Diamond-Shaped Antenna for RFID Application," *Antennas and Wireless Propagation Letters, IEEE,* vol. 10, pp. 979-982, 2011.

Evizal received his PhD degree from Universiti Teknologi Malaysia, Malaysia in 2014. He is currently a Post Doctoral at Universiti Teknologi Malaysia. He have been worked in several companies that provide system solution in telecommunication and radio frequency identification, currently is continuing his research activity related to the wireless communication, radio frequency identification and wireless sensor network. His research interest is in the field of Wireless and Mobile Communication, Antenna, Sattelitte Communicaton, RFID and Wireless Sensor.

Eko Supriyanto is a Professor and the Director of IJN-UTM Cardiovascular Engineering Centre, Universiti Teknologi Malaysia. He obtained his PhD in electronics engineering from University of Federal Armed Forces Germany, Hamburg. He worked as an academic staff at this university and a product development manager in a private company in Duesseldorf, Germany, before moved to Malaysia. He is a visiting professor at Ilmenau University of Technology, Germany and guest professor at Department of Radiology, Padjajaran University, Indonesia. His involvement in the computer application in medicine has been started since 1996 for the dialysis machine safety monitoring system. He has 15 patents in the area of biomedical and computer based products. He also obtained more than 24 awards for his achievement from international institutions. He has more than 120 publications in international journals and proceeding and author of few international books. He has been also active in WSEAS conferences since 2009 as an invited speaker, speaker for more than 36 papers and session chairman.

Siti Mariyam Shamsuddin completed her degree and master's in Applied Mathematics both at Dickinson University, New Jersey. She continued her PhD in Artificial Intelligence at Universiti Kebangsaan Malaysia. She has taught both undergraduate and postgraduate level in the subjects related to Artificial Intelligence, Discreet Mathematics for Computer Science, Programming, Numerical Analysis & Optimisation and Geometric Modelling & Fundamental Computer Graphics. Her research interests include areas of Soft Computing and Bio-Inspired Techniques & Algorithm, Feature Extraction & Pattern Recognition and Geometric Modelling & Animation.

Tharek Abd Rahman is a Professor at Faculty of Electrical Engineering (FKE), Universiti Teknologi Malaysia (UTM). He obtained his B.Sc. in Electrical & Electronic Engineering from University of Strathclyde, U.K. in 1979, M.Sc. in Communication Engineering from UMIST Manchester, U.K. and PhD in Mobile Radio Communication Engineering from University of Bristol, U.K. in 1988. He is currently the Director of Wireless Communication Centre (WCC), FKE UTM. His research interests are radio propagation, antenna and RF design and indoor and outdoor wireless communication. HE also conducted various short courses related to mobile and satellite communication to the telecommunication industry and government body since 1990. He has teaching experience in the area of mobile radio, wireless communication system and satellite communication. He has published more than 120 papers related to wireless communication in national/international journal and conference.

Sharul Kamal Abdul Rahim obtained his first degree in Electrical Engineering in 1996 from University of Tennessee, U.S.A., M.Sc. in Engineering (Communication Engineering) from Universiti Teknologi Malaysia (UTM) in 2001 and PhD in Wireless Communication System from University of Birmingham, U.K. in 2007. Currently, Dr. Sharul is an Associate Professor at Faculty of Electrical Engineering, UTM and an academic staff member of Wireless Communication Centre (WCC). His research interest is smart antenna on communication system. He is also a member of IEEE Malaysia section (MIEEE), member Board of Engineer Malaysia (MBEM), member of Institute of Engineer Malaysia (MIEM) and Eta Kappa Nu Chapter (International Electrical Engineering Honour Society, University of Tennessee). He has published a number of technical papers including journals and international conferences on rain attenuation and smart antennas.