International Journal of Electrical and Computer Engineering (IJECE)
Vol. 3, No. 5, October 2013, pp. 612~617
ISSN: 2088-8708

Impedance Matching Improvement of Half-Cut Broadband Printed Monopole Antenna with Microstrip Feeding

Teguh Prakoso[1,2], Mochammad Facta[1], Razali Ngah[2], Tharek A. Rahman[2]
[1]Department of Electrical Engineering, Universitas Diponegoro
[2]Wireless Communication Centre, Universiti Teknologi Malaysia

Article Info

Article history:

Received Jun 2, 2013
Revised Jul 21, 2013
Accepted Aug 2, 2013

Keyword:

Broadband antenna
Half-cut technique
Impedance improvement
Microstrip transformer
Printed monopole

ABSTRACT

The requirement of wireless access networks and user equipments to support coexistence of many communication standards and frequency bands poses challenge on antenna to be broadband and small. The application of half-cut technique to broadband printed monopole with microstrip feeding worsens the resulted antenna's impedance. To improve the half-cut antenna impedance matching, two methods were investigated in this paper: (1) monopole and ground extension, (2) the application of microstrip line transformer and ground extension. The first approach only produces limited improvement, whereas method #2 can enhance the return loss significantly. The second approach potentially produces antenna pair that has low mutual coupling, good return loss, and small size. Considering its radiation pattern, the antenna is suitable for diversity and MIMO. Its application in broadband microwave-photonic access point need special arrangement due to radiation null at 5 GHz band at right side.

Corresponding Author:

Teguh Prakoso,
Departement of Electrical Engineering, Faculty of Engineering,
Universitas Diponegoro,
Jl. Prof. Soedharto, Tembalang, Semarang, Jawa Tengah, Indonesia.
Email: tprakoso@fkegraduate.utm.my

1. INTRODUCTION

Current and future wireless access network and user equipment are required to support the coexistence of many communication standards and operating frequencies (bands). More functionalities and hardwares should be packed in the limited space. In the antenna context, these requirements pose challenges on producing antenna that covers very wide range of frequency and at the same time only takes small space.

In this respect, broadband printed monopole antenna which is aimed to cover 1.7 – 6.0 GHz has been proposed and miniaturized [1] using half-cut technique. This miniaturization method has been used successfully in various types of antennas [2-6] in which impedance bandwidth and radiation pattern of original antennas commonly can be retained. However, the application of the technique in [1] raises two problems: (a) the microtrip line impedance is changed from 50 Ohm to 90 Ohm hence the antenna's return loss characteristic worsen, (b) the radiation pattern is deformed especially at 5 GHz band.

This paper is intended to improve the impedance characteristics of half-cut printed rectangular monopole antenna with microstrip feed line [1]. Two approaches are investigated, i.e. (1) the use of monopole and/or ground extension, (2) the utilization of line transformer between the miniaturized monopole and the port. The half-cut technique is applied to bandwidth-enhanced printed rectangular monopole [7] which is constructed on 1.6mm-thick FR4 (ε_r = 4.4), width of 48 mm and length of 69 mm.

The rest of this paper is organized as the following. Section 2 describes the research method involved in the investigation. The results of the investigations are presented and discussed in Section 3. Finally, Section 4 concludes this paper.

2. RESEARCH METHOD

Actually, [1] has tried to rectify the impedance mathing problem by extending its ground 3 mm. Although the return loss characteristics can be improved, the $|S_{11}|$ values are still quite close to -10 dB at quite large portion of the antenna's intended frequency range, i.e. from 2.3GHz to 4.7 GHz. Provided that the half-cutting line affects the impedance, the extension of monopole and ground need to be investigated further to find optimum extension configuration.

Another insight from impedance characteristics of half-cut antenna (without ground extension) in [1] is that its |S11| graph is very good if calculated with reference impedance of 90.5 Ohm. This inspires the possibility of using microstrip line impedance transformer between the monopole which is round 90.5 Ohm the the port which is required to be 50 Ohm.

The investigations of the two approaches are conducted by employing electromagnetic simulation software, CST Microwave Studio (CST-MWS). Time domain solver is employed with accuracy is set to -50 dB. Moreover, all of $|S_{11}|$ calculations are normalized to 50 Ohm; if not set like this, CST MWS reports $|S_{11}|$ values which are normalized to the antenna's port impedance that sometimes are not 50 Ohm.

The following two sub-sections explain the details.

2.1. Monopole and Ground Extension

Variables being investigated are described in Figure 1. Half-cut line divides the original antenna exactly into two halves, right-half and left-half. Only left-half is presented in Figure 1. Extending the ground of left-half antenna means adding its ground-width to right-direction along W_{ext} or W_{eg} mm. Similarly, monopole extension of the left-half is adding the width of the monopoleand the feedline to right-direction along M_{ext} mm. Combination of ground and monopole extensions are also investigated.

2.1. Microstrip Line Impedance Transformer

Figure 2 describe the impedance transformer. The width of half-cut monopole's feeding line is 1.6 mm, whereas the original antenna's feed line width is 3.2 mm to produce characteristic impedance of 50 Ohm. In this arrangement, the antenna port is specified having impedance of 50 Ohm with length of 3 mm. The variable is the length the transformer line (L_{trafo}) started from the edge of the 50 Ohm microstrip transmission line. L_{trafo} determines rate of change of impedance. Smoother the impedance changes, better is the impedance matching.

3. RESULTS AND ANALYSIS

Results from two types of investigations are presented in the following sub-sections. Then, one design which produces the best $|S_{11}|$ is chosen to show its radiation pattern characteristics.

3.1. Monopole and Ground Extension

Variation of $|S_{11}|$ as effect of varied M_{ext} values at a fixed W_{ext} is presented in Figure 3. Figure 4 shows the effect of varying W_{ext} at a fixed value of M_{ext} to the antenna's $|S_{11}|$ values. It is clear that extending the width of monopole and feedline only worsen the antenna's $|S_{11}|$ as proved by Figure 3. Improvement on the return loss characteristics is demonstrated by Figure 4 in which W_{ext} up to 2 mm produces significant decrease of return loss. However, the effect of increasing W_{ext} larger than 3 mm only improves $|S_{11}|$ slightly.

In general, both M_{ext} and W_{ext} affect return loss. M_{ext} is stronger than W_{ext}. Unfortunately M_{ext} cannot create return-loss enhancement. On other side W_{ext} influence is only limited to 3 mm.

3.2. Microstrip Line Impedance Transformer

Antenna configuration depicted in Figure 2 is investigated in term of its transformer length and ground extension. As shown in Figure 5, |S11| is improved with the increase of L_{trafo}; the more gradual the impedance changes, the better is the impedance matches. The maximum improvement is at L_{trafo} = 26.67 mm. At traformer length of 30 mm, the return loss is slightly worse than 26.67 mm; maybe the EM field configuration at the lower part of the monopole is disturbed by the transformer upper end.

It can be observed that $|S_{11}|$ curves in Figure 5 are very similar. This similarity is determined by at W_{eg}; the reflection coefficient curves of the same W_{eg} but different L_{trafo} follow similar shape; the curves of the same L_{trafo} but different W_{eg} follow quite different trends, see Figure 6. Therefore, W_{eg} determines the curve shape and L_{trafo} scale the magnitude of S_{11}.

Nonetheless, it does not mean that we should choose W_{eg} and then adjust L_{trafo} to get the optimum result. In the contrary, it has been known from these simulations, see Figure 5, that L_{trafo} = 26.67 mm produces the lowest $|S_{11}|$ at W_{eg} values being simulated. Therefore, the optimization process is actually choosing W_{eg} values of L_{trafo} = 26.67 mm that results the optimum $|S_{11}|$ curve shape. As an example, Figure 6 offers trade off between 2 – 3 GHz or 3.5 GHz band. If 3.5 GHz band is considered more important than 2 – 3 GHz, then W_{eg} = 0.8 mm should be chosen. However, in case of 2 – 3 GHz band is more critical, higher value of W_{eg} can be chosen; if 5 GHz band is also considered, W_{eg} = 1.85 or 2.9 mm may give better performance.

3.3. Discussion

Section 3.1 describes that playing monopole and/or ground extension only provides limited space in improving return loss of the half-cut antenna. Fortunately, the second method investigated in this paper produce much better $|S_{11}|$ enhancement. The success of the characteristic impedance transformation technique confirms that the application of half-cut method to the printed monopole double the impedance of the antenna, i.e. 50 Ohm (original antenna) to 90.5 Ohm (half-cut antenna). It also implies that the half-cut antenna's impedance is quite stable (or homogeneous) along the (half-cut) transmission line hence the microstrip transformer works well from 10 mm to 30 mm (simulation results of L_{trafo} below 20mm are not presented in this paper, but they follow similar trend).

Investigation on left-right half-cut antenna pair compared to original antenna pair in [8] shows that original pair is preferred due to its better return loss characteristics although left-right pair produces better mutual coupling. The application of microstrip transformer may produce better antenna pair for broadband microwave-photonic access point (BMwPhAP), diversity, or MIMO due to its lower mutual coupling while retaining potentially good return loss.

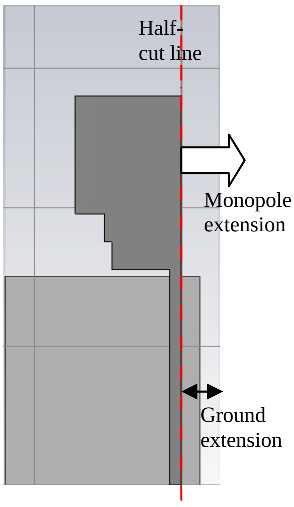


Figure 1. Description of monopole and ground extensions effect on the half-cut antenna's $|S_{11}|$

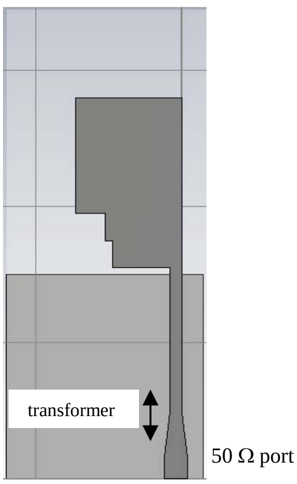


Figure 2. Arrangement of microstrip 50 Ohm port, transformer, ground extension, and half-cut antenna

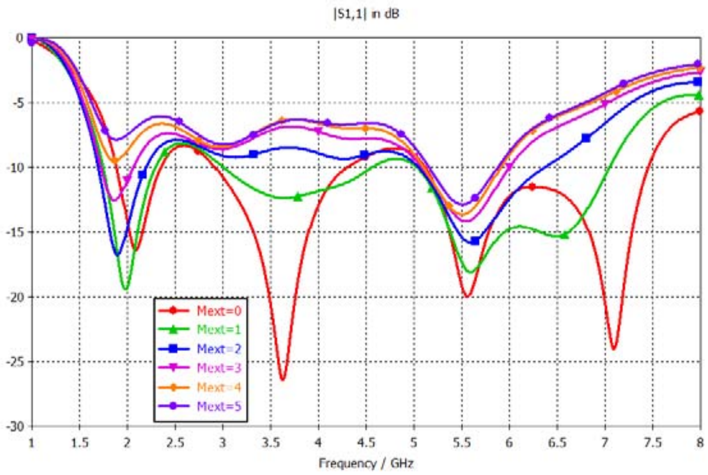


Figure 3. $|S_{11}|$ at W_{ext} = 3 mm, with monopole and feedline width is extended from 0 to 5 mm.

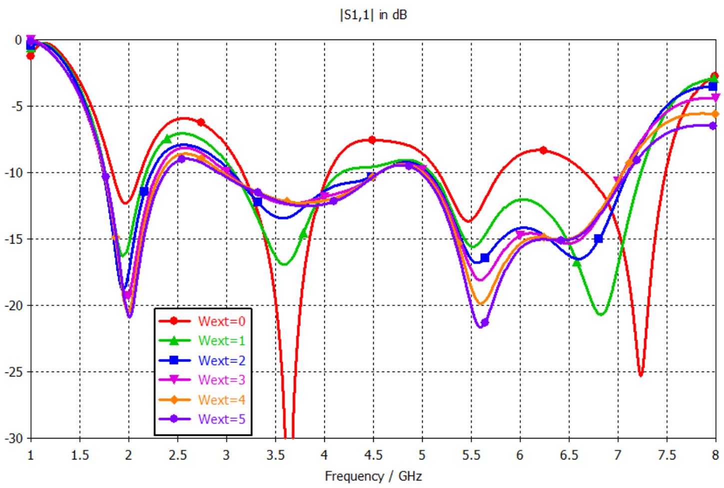


Figure 4. $|S_{11}|$ at M_{ext} = 1 mm, with ground width is extended from 0 to 5 mm.

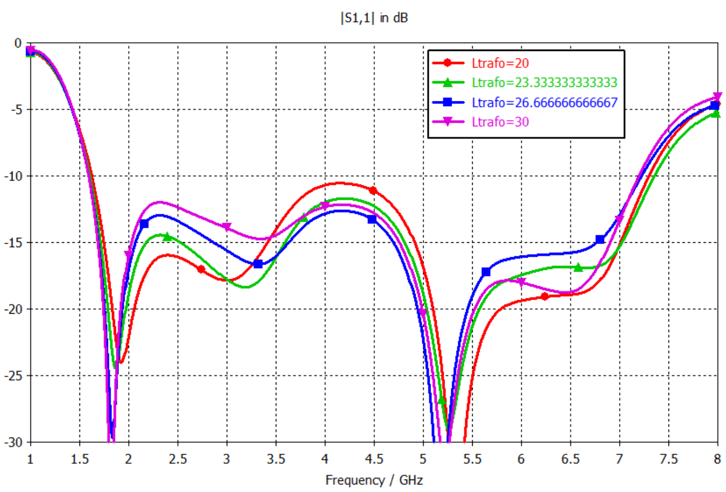


Figure 5. $|S_{11}|$ at W_{eg} = 0.8 mm, with ground width is extended from 20 mm to 30 mm.

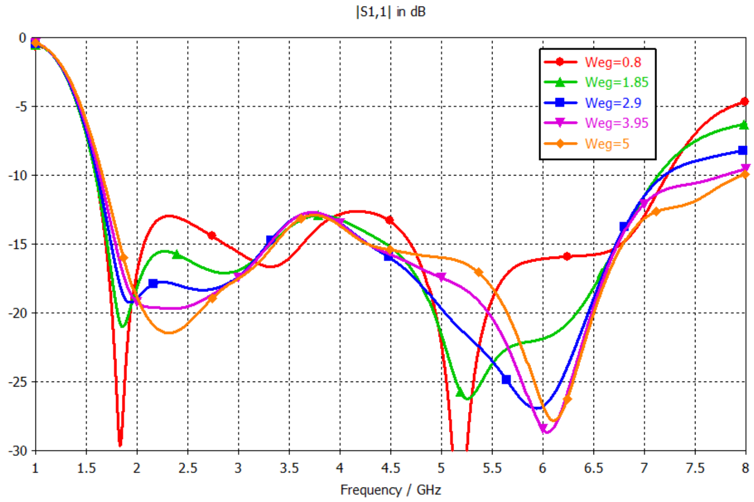
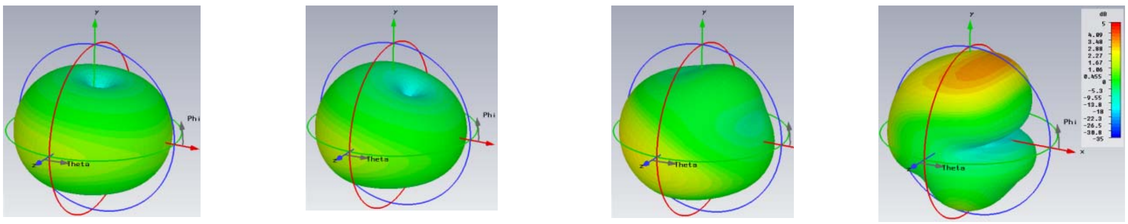


Figure 6. $|S_{11}|$ at L_{trafo} = 26.67 mm, with ground width is extended from 0.8 mm to 5 mm.

Considering that 2 – 3 GHz and 5 GHz bands as priority, left half-cut antenna with W_{eg} = 2.9 mm and L_{trafo} = 26.67 mm is chosen as the best candidate. This simulated antenna radiation pattern is depicted in Figure 7. Up to 3.5 GHz, the radiation pattern is nearly omnidirectional. Nonetheless, the antenna has null at right side. While its return loss is good at 1.7 – 6.0 GHz, the antenna needs special arrangement if used at 5.8 GHz due to it null in radiation pattern at that band. With this radiation pattern characteristics, this antenna is suitable for diversity and MIMO.



f_c = 1.8 GHz f_c = 2.4 GHz f_c = 3.5 GHz f_c = 5.8 GHz

Figure 7. 3D realized gain pattern of left-half antenna with L_{trafo} = 26.67 mm and W_{eg} = 2.9 mm.

4. CONCLUSION

Half-cut technique can miniaturize symmetrical printed antenna into 50% of original size. However, its application to microstrip-fed printed monopole antenna worsens the antenna impedance hence matching enhancement method is needed. This paper has investigated two approaches: (1) monopole and ground extension, (2) microstrip line transformer and ground extension. Method #1 only produces limited improvent to return loss characteristic of half-cut antenna. Method #2 can enhance the impedance matching significantly. The length of the line transformer the major factor in reducing $|S_{11}|$, whereas the the ground extension plays tradeoff among frequency band being optimized. This result potentially implemented in left-right half-cut antenna pair to used in broadband microwave photonic access point, diversity, or MIMO which not only provide good isolation between antenna in pair but also has good return loss characteristics. The antenna’s radiation pattern is nearly omnidirectional at frequency up to 3.5 GHz but exhibit nulls at 5 GHz band. Hence, it is suitable for diversity and MIMO but needs additional arrangement if it is used in access point.

ACKNOWLEDGEMENTS

This research is supported in part by Faculty of Engineering, Universitas Diponegoro.

REFERENCES

[1] T Prakoso, et al. "An evaluation of half-cut technique for microwave-photonic access-point antenna miniaturization". in *2011 IEEE International RF and Microwave Conference (RFM 2011)*. Seremban, Malaysia. 2011: 384-388.

[2] WJ Liu and QX Chu. "Half-Cut Disc UWB Antenna with Tapered CPW Structure for USB Application". *Microwave and Optical Technology Letters*. 2010; 52: 1380-1384.

[3] M Sun, et al. "Miniaturization of Planar Monopole Antenna for Ultrawideband Radios". *IEEE Transactions on Antennas and Propagation*. 2010; 58: 2420-2425.

[4] WX Wu and YP Zhang. "Analysis of Ultra-Wideband Printed Planar Quasi-Monopole Antennas Using the Theory of Characteristic Modes". *IEEE Antennas and Propagation Magazine*. 2010; 52: 67-77.

[5] W Jiang, et al. "Novel Ultrawideband Monopole Antenna with Miniaturized Size". *Microwave and Optical Technology Letters*. 2011; 53: 1176-1178.

[6] G Guo-Ping, et al. "Design of a Miniaturization Printed Circular-Slot UWB Antenna by the Half-Cutting Method". *Antennas and Wireless Propagation Letters, IEEE*. 2013; 12: 567-570.

[7] T Prakoso, et al. "A broadband antenna for microwave photonic access point". in *7th Jordanian International Electrical and Electronics Engineering Conference (JIEEEC 2011)*. Amman, Jordan. 2011.

[8] T Prakoso, et al. "Isolation Enhancement and Size Reduction of Printed-Antenna Pairs for Broadband Microwave-Photonic Access-Point". in *IEEE 20th International Conference on Telecommunications (ICT 2013)*. Casablanca, Marocco. 2013.

BIOGRAPHIES OF AUTHORS

Teguh Prakoso obtained his Bachelor and Master in Electrical Engineering from Institut Teknologi Bandung, Indonesia in 2002 and 2006, respectively. Currently he is PhD student at Wireless Communication Centre, Faculty of Electrical Engineering, UTM, Johor Bahru and lecturer at Universitas Diponegoro, Semarang, Indonesia. From 2002 to 2006 he involved in the development of upper air instrumentation system, namely digital radiosonde; in that project he was responsible on the transmitter system. From 2007 to now, he has been developing radio over fiber (RoF) link, pre-/post amplifier for RoF link, broadband antenna for microwave-photonic access point, and also a method to include broadband frequency characteristics of antenna in system simulation.

Mochammad Facta (M'07 IEEE) received his full bachelor degree in electrical power engineering from University of Hasanuddin, Ujung Pandang, Indonesia, his master degree with cum laude in Electrical Power System from Institute of Technology 10 Nopember Surabaya, Indonesia, in 1996 and 1999 respectively. Since 1999, he has been a lecturer and researcher in Electrical Engineeering Department of Universitas Diponegoro, Semarang Indonesia. He obtained PhD degree in Energy Conversion Department, Universiti Teknologi Malaysia (UTM), Johor, Malaysia in 2012. His research interests are in electrical power system, electrical machines, power electronics, and converters for plasma generations, as well as communication engineering. Email: facta@ieee.org or facta@elektro.ft.undip.ac.id

Assoc. Prof. Dr. Razali Ngah obtained his Bachelor in Electrical Engineering (Communication) from Universiti Teknologi Malaysia, Skudai in 1989, MSc in RF Communication Engineering from University of Bradford, UK in 1996 and PhD in Photonics from University of Northumbria, UK in 2005. Currently, he is an Associate Professor at Wireless Communication Centre (WCC), Faculty of Electrical Engineering, UTM Skudai. His research interests are Mobile Radio Propagation, Antenna and RF design, Photonics Network, Wireless Communication Systems and Radio over Fibre (RoF). Dr. Razali had published more than 50 technical papers for journal and international conferences. His current focus is on his research activity, internal audit committee of university and supervising Postgraduate and Undergraduate students.

Prof. Dr. Tharek Abd Rahman is a Professor at Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM). He obtained his BSc. in Electrical & Electronic Engineering from University of Strathclyde UK in 1979, MSc in Communication Engineering from UMIST Manchester UK and PhD in Mobile Radio Communication Engineering from University of Bristol, UK in 1988. He is the Director of Wireless Communication Centre (WCC), UTM. His research interests are radio propagation, antenna and RF design and indoors and outdoors wireless communication. He has also conducted various short courses related to mobile and satellite communication to the Telecommunication Industry and Government body since 1990. He has a 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.